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Relative impact of different ERP forms on manufacturing organisations: an exploratory analysis of a global manufacturing survey

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There are many types of enterprise resource planning (ERP) systems, ranging from very large and very functional vendor products such as those provided by SAP and Oracle, through in-house systems, and smaller vendor products. Thus, there is a substantial range of enterprise computing support available for manufacturing organisations and their manufacturing planning and control. The Global Manufacturing Research Group (GMRG) has collected a systematic survey of manufacturing organisations around the world, providing a picture of manufacturing operations. We have taken GMRG data and organised it around seven levels of ERP functionality, and analysed these data to determine effectiveness in terms of how ERP systems are used in global manufacturing firms, their role in accomplishing manufacturing planning and control, the relationship between ERP forms and data-management practices, the satisfaction firms have across ERP forms, and finally, relative perceived benefits and costs across ERP forms.

Keywords: enterprise resource planning systems; global manufacturing organisations and practices; manufacturing production and control; GMRG data; supply chains; impact of ERP

1. Introduction

Enterprise resource planning (ERP) is a concept that supports the need of enterprise-level planning and control of resources in businesses (Jacobs and Bendoly 2003). This evolving concept, rooted in such previous concepts as manufacturing resource planning and material requirement planning, has significantly changed the landscapes of business and information technology in many organisations and industries (Jacobs and Weston Jr 2007). For manufacturing firms and industries, this ERP concept has been adopted extensively in connection with firms' manufacturing planning and control (MPC) (Vollman *et al*. 2005) and is important for firms' competitiveness (Wacker and Sheu 2006).

In connection with this ERP concept for MPC, information systems with various labels have been implemented in manufacturing firms for the past decades. These systems, which have evolved over the years, range from simple spreadsheet-like systems and legacy systems to enterprise applications (Rondeau 2001, Chan and Burns 2002). To manufacturing firms, ERP systems are information systems designed to support various MPC practices, including inventory control, labour and cost planning, material planning, and sales and operations planning. MPC is the core of ERP systems (Vollman *et al*. 2005).

An ERP system is not a homogenous system. Instead, in practice there are various optional forms implemented to support diverse MPC practices. For example, there was a time when 'ERP system' meant one of the BOPSE (BAAN, Oracle, PeopleSoft, JD Edward) systems, or even specifically SAP. However, the twenty-first century has seen the emergence of other forms of ERP, to include: (1) Microsoft's Dynamics suite targeted at a market with less budget than the large organisations that purchased most ERP systems in the 1990s; and (2) an expanded number of smaller systems such as Lawson and Sage, and open source systems. In practice, owing to mergers and acquisitions and other factors, there are many legacy systems, to include in-house ERP. Furthermore, smaller organisations still have to do their computing even if they do not have the budget to obtain a major commercial software system. Thus, many organisations use various spreadsheet software products as the basis of their computing systems and these are used for MPC practices. Finally, many organisations do not claim to have an ERP system (Kale *et al*. 2010).

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In practice, these various forms of ERP (and ERP-like) systems are being used to support MPC practices. For simplicity, our study labels these systems for MPC as ERP systems or various optional forms of ERP systems.

Thus, our study is interested in reporting the status of various forms of these ERP systems for MPC practices in global manufacturing firms, and how such systems are perceived by those firms in supporting MPC practices and in creating operational values. There is a rich body of literature on ERP systems, particularly the reasons for and the cost of system implementation, critical success factors, and the benefits (Irani *et al*. 2007, Moon 2007, Raymond and Uwizeyemungu 2007, Yang *et al*. 2007, Kim 2009, Schlichter and Kraemmergaard 2010). The usage of such various systems (e.g. legacy systems, in-house ERP, BOPSE, SAP) in global manufacturing firms, and their relationships with MPC practices is not well understood. To our knowledge, this is the first study explicitly taking into account different ERP forms and studying them with MPC activities.

For example, how are different forms of ERP systems used for manufacturing firms' strategic planning? Is there any association between different ERP system forms and the communication practices (e.g. communication frequency, communication method) of manufacturing department with other departments? How are major MPC activities (e.g. MRP, shop-floor control) accomplished in connection with different ERP system forms? What are the satisfaction levels for different ERP forms? Are there any advantages perceived by companies over different ERP forms? These questions are important since they shed light on the usage and satisfaction of various forms of ERP systems in global manufacturing contexts and their association with major MPC activities. In seeking to answer these questions, we have applied the GMRG database (Whybark *et al*. 2009), the result of a systematic effort of collecting survey results from manufacturing firms around the globe. The statistical results show the status of ERP system usage and MPC practices and their relationship, as perceived by global manufacturing firms.

The following section first describes the spectrum of ERP and ERP-like systems and briefly summarises a literature on ERP systems relevant to our research questions. Then, Section 3 summarises our research questions and objectives and Section 4 describes the survey data set from the Global Manufacturing Research Group (GMRG) and basic descriptive statistics organised about the data set. Section 5 presents the results of our statistical analyses of various survey questions regarding our research questions. The results describe the status of using various ERP forms and how these systems are perceived by global manufacturing firms in the contexts of diverse manufacturing planning and control practices. Finally, Section 6 offers the discussion of and implications for those results for research and practice.

2. ERP optional forms

ERP, as a relatively new concept, has changed the traditional understanding of manufacturing planning and control (MPC) from a narrow list of independent activities owned by a firm's manufacturing department alone, to a set of interdependent activities conducted by multiple departments in an integrated manner. IT support for these MPC activities has been of great interest in both academics and industry. The latest innovation successfully renamed by IT vendors and consulting service providers is ERP systems, and is often referring to SAP or similar products on the market. However, in practice, there are various forms of ERP systems, not merely one off-the-shelf product, supporting MPC activities in manufacturing firms.

While the adoption of SAP-like ERP systems has been seen as a major trend in many firms, industries, and countries, firms are also strategic (Scott 2008) in that they consider the costs and risks associated with large IT investment and their internal factors such as company size and resources. Therefore, the results are the existence of various optional forms of ERP systems in practice. For example, according to Kale *et al*. (2010), a large number (around 50 per cent) of Indian small-to-medium enterprises (SMEs) rely on in-house systems and still 10 per cent of those use little IT for MPC related activities. Only 15 per cent have adopted large-scale ERP systems.

There could be several reasons for this, including high costs and risks associated with SAP-like ERP systems and firms' uniqueness (e.g. firm size, unique business practices, IT competences, internal resources). For example, several studies have pointed out that there is risk involved in large ERP system implementation, especially for SMEs (Poba-Nzaou *et al*. 2008, Kirytopoulos *et al*. 2009). Premkumar (2003) noted that SMEs usually lack resources and have few of the knowledge skills required to implement such systems. This has increased the number of options, beyond top-of-the-line vendor systems such as SAP and Oracle, to include products from more moderately priced vendors such as Microsoft and Lawson (Olson and Kesharwani 2010) and in-house developed ERP systems. Olsen and Saetre (2007a) reported that in-house developed ERP was feasible and cost effective owing to the availability of modern development tools. For niche companies, standardised ERP may not be a good option. Instead, in-house

developed ERP systems offer numerous benefits, especially flexibility, and thus can be a strategic alternative to standardised ERP systems (Olsen and Saetre 2007b).

In addition, in specific countries, such as China (Wei *et al*. 2005, Xu *et al*. 2005) and Brazil (De Carvalho 2009), and elsewhere (Baki and Caki 2005), there are additional local forms of ERP. Overall, when selecting an ERP option there is a general trade-off between functionality and cost. Total cost of ownership (TCO) is a complex matter that defies accurate calculation (Kabassi and Virvou 2006). Firms' choices of ERP form are sometimes influenced by other firms, such as industry leaders and competitors. Firms also determine the solutions for their unique environments. As a result, different forms of ERP systems emerge in practice.

3. Research questions

Our study focuses on the extant practices of manufacturing planning and control (MPC) by global manufacturing firms and the usage of various ERP system options for MPC practices. MPC is of most interest to operations management/SCM researchers and practitioners (Vollman *et al*. 2005, Wacker and Sheu 2006, Jacobs and Weston Jr 2007). Extant surveys of ERP system usage in different countries (e.g. US, Sweden, Korea) show that MPC is the single most popular area of ERP system application (Mabert *et al*. 2000, Olhager and Selldin 2003, Katerattanakul *et al*. 2006).

The previous section describes different optional forms of ERP systems. The primary purpose is to investigate the status of MPC activities being practised in global manufacturing firms, and the relationships between ERP forms and those MPC practices. We are particularly interested in studying such questions as:

(1) What optional forms of ERP systems are being used by global manufacturing firms?
(2) How are major MPC activities, such as material planning, inventory control and communication with other departments, being performed? And what are the relationships between these MPC activities and ERP forms by global manufacturing firms?
(3) Given that managing manufacturing-related data are critical for effective MPC, are there any relationships between ERP forms and data-management practices (e.g. method of recording manufacturing data, frequency of manufacturing data revision)?
(4) To what extent are the firms being satisfied with their MPC practices, and are there any relationships between the level of satisfaction and ERP forms?
(5) How are the benefits and costs of different ERP forms perceived by the firms?

There have been survey-based studies of ERP adoption in single countries (Olhager and Selldin 2003, Katerattanakul *et al*. 2006, Kale *et al*. 2010, Annamalai and Ramayah 2011, Hasan *et al*. 2011). Question 1 can help us understand the status of ERP system adoption in global manufacturing contexts. Given that MPC is the primary area of ERP system application, Question 2 can reveal some potential relationships between the usage of different ERP forms and various MPC activities (e.g. material planning). MPC extensively relies on data (Gustavsson and Wanstrom 2009): firms use ERP systems to organise and use data for MPC. Thus, Question 3 closes up ERP forms in the light of manufacturing-data-management practices. Finally, Questions 4 and 5 show us how firms perceive different ERP forms. Overall, these are important questions that have not been investigated in the literature.

4. Research methodology: GMRG survey database

The data were gathered by the Global Manufacturing Research Group (GMRG). GMRG is a multinational community of researchers studying the improvement of manufacturing practices worldwide (www.gmrg.org). Since 1985, the GMRG has conducted four rounds of worldwide surveys that have been utilised in many OM studies (Narasimhan and Jayaram 1998, Schmenner and Vastag 2006). This study used data from the GMRG 4.0 with samples from 17 countries. Data were compiled from surveys administered between 2007 and 2010. Coding was conducted to assure consistent formats and to minimise missing entries. The version used included respondents from 17 countries, including a grand total of 964 responses. Of these, 228 did not respond to the question concerning the ERP system used, leaving 736 responses for use in this study. Survey questions are listed in Table 1.

We used these GRMG questions to answer the five questions proposed in the previous section. The relationship between our research questions and the GMRG survey questions is indicated in Table 1.

Table 1. MPCS section of the GMRG survey.

Survey question	Scales	Research questions
Tools used for MPC (e.g. SAP, JD Edwards, BPCS, in-house-developed, etc., or none)		#1
Degree of customisation	1–7; 1: not at all; 7: highly customised	
Years of use	Years	
Months of current system	Months	
Software used for strategic planning	1–7; 1: not at all; 7: always	#2
Communication frequency:		#2
Engineering	1: not at all	
Marketing	2: annually	
Accounting	3: monthly	
Finance	4: weekly	
Personnel	5: several times a week	
Customers	6: daily	
Suppliers	7: several times a day	
Communication method		#2
Engineering	1: don't	
Marketing	2: discussion	
Accounting	3: memo	
Finance	4: phone	
Personnel	5: e-mail	
Customers	6: inter/extranet	
Suppliers	7: EDI	
Perform material planning	0: no formal method	#2
Perform inventory control	1: manual	
Perform labour planning	2: desktop	
Perform shop-floor control	3: custom software	
Perform cost planning	4: commercial software	
	5: modified software	
How manufacturing data recorded	1: manual	#3
	2: typed into computer	
	3: bar code	
	4: automatic data capture	
How often manufacturing BOM revised	1: less than annually	#3
How often routings revised	2: annualluy	
How often batch revised	3: monthly	
How often safety mechs revised	4: weekly	
How often lead times revised	5: every order	
Determine data – batch sizes	1: experience	#3
Lead times, routings	2: statistical methods	
Safety stocks, lead times	3: mathematical optimisation	
Satisfaction with material planning	1–7; 1: dissatisfied; 7: very satisfied	#4
Satisfaction with inventory control		
Satisfaction with labour planning		
Satisfaction with shop-floor control		
Satisfaction with cost planning		
Operations benefits	1: decrease > 30%	#5
Operations costs	2: decrease 16–30%	
	3: decrease 1–15%	
	4: no change	
	5: increase 1–15%	
	6: increase 16–30%	
	7: increase > 30%	

Table 2. Systems by country.

	None	Spread	In-house	Small	MSD	BOPE	SAP	Total
Albania			8				3	11
Australia	4		9	17		8	12	50
Austria	1			6	1		6	14
Croatia		1	3	55		1	6	66
China	1		29	8		3	12	53
Finland	6	10	10	90	3	6	8	133
Germany				2			2	4
Hungary	9	2	13	16		2	8	50
Ireland	3		4	15		1	8	31
Italy	8		5	24	1	1	2	41
Korea	3	2	19	7		1	16	48
Macedonia	2							2
Mexico		8		39		2	8	57
Sweden			2	22	2	2	2	30
Switzerland			6	11	1	2	6	26
Taiwan			31	4		5	5	45
USA	5	2	13	45		2	6	50
	42 (6%)	25 (3%)	152 (21%)	361 (49%)	8 (1%)	38 (5%)	110 (15%)	736

5. Results

In Section 3, we presented five research questions about ERP forms and MPC practices, and the perception of global manufacturing firms. The results of analysing GMRG data are described regarding those five questions.

5.1 *What optional forms of ERP systems are being used by global manufacturing firms?*

This first question is important, since the answer can offer a broad view of ERP system usages by global manufacturing firms. The 736 responses came from firms using a variety of systems. We have separated these data into seven categories of ERP systems, eliminating those respondents that left the question blank. None reflects those who consider themselves not to have an ERP system. Some respondents indicated that they were functioning using spreadsheets to plan and coordinate manufacturing activities. Many respondents indicated having legacy systems or in-house systems, or simply stated that they had their own system. There were four groups of commercial ERP products categorised. Microsoft Dynamics was separately tabulated because it is an important new entrant into the ERP market. BAAN, Oracle, PeopleSoft, and JD Edwards systems were grouped together, isolating SAP. Between in-house systems and Microsoft Dynamics, 361 other software products, categorised as small systems, were gathered. There are many examples, including Fourth Shift ERP, Visual ERP, etc. Table 2 shows the distribution of systems across survey sources.

5.2 *How are major MPC activities being performed? And what are the relationships between these MPC activities and ERP forms by global manufacturing firms?*

The second question covers the three categories of activities for firms' MPC: strategic planning, communicating with other departments, and operational planning. Strategic planning is defined in the survey as more than one year into the future. MPC is performed in a broad environment and intra-organisational communication is recognised as a key element. For an increasing number of organisations, Sales and Operations Planning (S&OP) serves as the platform for strategic planning and intra-organisational communication (Oliva and Watson 2011). The operational planning includes traditional MPC functions such as material planning, inventory control, and shop-floor control (Vollman *et al*. 2005).

Table 3. *P*-values for one-tailed *t*-test comparing responses to 'Software used for Strategic Planning'.

Category	Average	Spread	In-house	Small	MSD	BOPE	SAP
None	1.27	0.011**	0.000***	0.001**	0.124	0.000***	0.000***
Spread	2.76		0.005**	0.393	0.355 (–)	0.028**	0.001**
In-house	3.77			0.000*** (–)	0.037** (–)	0.435 (–)	0.193
Small	2.86				0.288 (–)	0.013**	0.000***
MSD	2.50					0.053*	0.020**
BOPE	3.71						0.238
SAP	4.08						

Note: *Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.

Table 4. Communication differences across system categories by frequency.

	None	Spread	In-house	Small	MSD	BOPE	SAP
Engineering	2.60	4.68	4.03	4.35	3.75	4.32	4.44
Marketing	3.12	4.52	4.31	4.21	4.13	4.58	4.19
Accounting	4.19	3.84	4.09	4.35	3.88	4.45	4.48
Finance	3.88	4.24	4.04	4.29	4.14	4.42	4.23
Personnel	3.80	4.16	3.84	3.96	3.50	4.08	3.77
Customers	3.93	4.04	3.78	3.94	3.13	3.63	3.99
Suppliers	3.19	4.48	3.66	4.16	3.75	3.68	4.24
Average	3.53	4.28	3.96	4.18	3.75	4.20	4.19

Note: 1: not at all; 2: annually; 3: monthly; 4: weekly; 5: several times a week; 6: daily; 7: several times a day.

5.2.1 *ERP forms and strategic planning*

Table 3 shows the probability levels and significant differences for strategic planning across the seven systems we are examining.

On the matter ERP systems use to aid strategic planning, SAP was significantly stronger for any system except in-house or other BOPSE systems. SAP had the highest survey average response. In-house systems were slightly higher than other BOPSE systems, but both were used significantly more often for strategic planning than smaller systems. The key message seems to be that larger systems support strategic planning better than smaller systems.

5.2.2 *ERP forms and communication with other departments*

Intra-organisational communication is another essential component of MPC (Vollman *et al.* 2005, Gattiker 2007). Two aspects of communication were investigated: communication frequency and methods of communication between manufacturing and other departments. Table 4 shows results addressing communication frequency and method across seven different departments within organisations:

Table 4 indicates that those using spreadsheet systems (which we interpret as simpler systems) actually communicate more, on average, than larger systems. The second most frequent on average are BOPSE (including SAP) users, with users of small commercial systems very close behind. The reason for spreadsheet frequency could be that spreadsheets are inherently easy to send through e-mail and to share with colleagues. Table 5 shows survey results for methods of communication between manufacturing and other organisational elements. The more complete BOPE and SAP systems have larger average ratings.

On this spectrum of reliance upon technology, BOPSE users have higher reliance on electronic technology. In-house system users are nearly as high, with the others relying more on older methods of communication. This would seem to be expected, as the more large-scale ERP systems almost force users to rely upon electronic technology.

Table 5. Communication methods across system categories by media.

	None	Spread	In-house	Small	MSD	BOPE	SAP
Engineering	2.55	3.04	3.75	3.32	2.33	3.80	4.48
Marketing	2.97	3.68	4.10	3.42	3.43	4.29	4.58
Accounting	3.03	3.92	3.96	3.79	4.50	4.49	4.89
Finance	3.03	3.56	4.13	3.82	4.50	4.51	4.84
Personnel	2.80	3.42	3.73	3.12	3.43	3.92	4.05
Customers	3.53	3.84	4.00	3.87	3.75	4.00	4.49
Suppliers	3.73	4.00	3.97	4.06	4.38	4.19	4.56
Average	3.09	3.64	3.95	3.63	3.76	4.20	4.56

Note: 1: don't; 2: personal; 3: memo; 4: phone; 5: e-mail; 6: intranet/extranet; 7: EDI.

Table 6. Methods used to accomplish major planning and control activities.

Category	MRP	Inventory control	Labour planning	Shop-floor control	Cost planning
None	1.87	2.13	1.63	1.63	2.00
Spreadsheet	2.33	2.71	2.70	2.63	2.83
In-house	3.02	3.16	2.62	2.67	2.94
Small	3.55	3.41	3.06	3.17	3.28
MSD	4.14	4.00	3.50	4.00	4.00
BOPE	4.17	3.95	3.18	3.25	3.91
SAP	3.88	3.89	3.07	3.38	3.72

Note: 1: manual; 2: desktop software; 3: custom software; 4: commercial software; 5: modified commercial software.

Table 7. Proportion of use for methods to record manufacturing-operations data.

Category	Manual	Typed into computer	Bar codes	Automatic data capture
None	0.51	0.39	0.06	0.03
Spreadsheet	0.04	0.83	0.04	0.08
In-house	0.04	0.67	0.20	0.09
Small	0.09	0.65	0.19	0.07
MSD	0	0.75	0.25	0
BOPE	0.05	0.62	0.27	0.05
SAP	0.02	0.52	0.31	0.15

5.2.3 *ERP forms and other planning and control activities*

The relationships between ERP forms and other MPC activities (e.g. inventory control) were analysed. Table 6 displays the results. These results show a clear trend for more sophisticated software for MRP, inventory control, shop-floor control, and cost planning on the part of commercial ERP system users. There also is a similar trend for labour planning, but not to the same degree. Users of smaller systems and users of in-house systems have notably less reliance, but more than spreadsheet system users or those who claim no ERP support.

5.3 *Given that managing manufacturing-related data are critical for effective MPC, are there any relationships between ERP forms and data-management practices?*

Given the importance of data management for MPC and ERP systems (Gattiker and Goodhue 2005, Gustavsson and Wanstrom 2009), the survey asked how manufacturing operations data, such as inventory transactions or production order status, were recorded. Table 7 displays the results, showing the relationship between the methods of recording manufacturing data and ERP forms.

Those without ERP systems are the only ones that rely heavily on manual methods. Those relying upon spreadsheet-like systems emphasise typing data into a computer (such as a spreadsheet). Other systems also have high proportions of entering data into computer systems, but there is more reliance on bar coding or automatic data capture with the more advanced systems. SAP systems have the highest proportions for reliance on these technological means to enter manufacturing data.

The survey looked at another dimension of data-management practices: frequency of data revision. Table 8 displays averages by category for five different types of data:

Table 8 shows that those without ERP systems have less frequent revision of all types of data. Those using spreadsheet systems seem to update data more than other categories, with the exception of batch size updates. BOPSE users (including SAP) do not seem to update as much as in-house system users on average.

Table 8. Average frequencies of data revision.

Category	Manufacturing BOM	Routings	Batch sizes	Safety mechanisms	Lead times
None	2.77	2.41	2.94	2.75	2.78
Spreadsheet	3.35	3.38	3.18	2.76	3.13
In-house	3.12	2.94	3.37	2.88	3.20
Small	3.09	2.96	3.33	2.85	2.99
MSD	2.43	2.38	3.13	2.63	2.29
BOPE	2.92	2.44	2.95	2.81	2.84
SAP	3.13	2.95	3.29	2.94	2.93

Note: 1: over one year; 2: annually; 3: monthly; 4: weekly; 5: every order.

Table 9. Proportions reporting reliance on each method for determining manufacturing data.

	None	Spread	In-house	Small	MSD	BOPE	SAP
Batch size-experience	0.72	0.60	0.42	0.51	0.37	0.45	0.24
Batch size-statistics	0.19	0.16	0.43	0.30	0.37	0.32	0.48
Batch size-optimisation	0.08	0.24	0.14	0.19	0.25	0.23	0.29
Lead time & routing-experience	0.79	0.56	0.44	0.51	0.37	0.39	0.23
Lead time & routing-statistics	0.18	0.24	0.42	0.35	0.25	0.47	0.51
Lead time & routing-optimisation	0.03	0.20	0.14	0.14	0.37	0.13	0.25
Safety stock & lead-experience	0.80	0.62	0.44	0.47	0.37	0.32	0.31
Safety stock & lead-statistics	0.14	0.17	0.44	0.38	0.12	0.43	0.43
Safety stock & lead-optimisation	0.06	0.21	0.12	0.15	0.50	0.24	0.25

Table 9 displays results as to how manufacturing data were determined. More advanced optimisation methods are more commonly used in more advanced systems, as expected. Those who claim no ERP system have a heavy reliance on experience, and little use of optimisation tools. Those using smaller systems see more reliance on statistics, but not as much as those using BOPSE systems.

5.4 *To what extent are the firms being satisfied with their MPC practices and are there any relationships between the level of satisfaction and ERP forms?*

Given that ERP forms are extensively used for various MPC activities, knowing the level of satisfaction with their MPC by global manufacturing firms can reveal potential effects of ERP forms on firms' operational performance. The survey asked 'To what extent are you satisfied with the current MPC?' Table 10 shows the degree of satisfaction with current manufacturing planning and control systems in the contexts of different ERP forms.

There is a clearly higher satisfaction rating on the part of larger systems (BOPSE, including SAP). The strongest ratings are for inventory control. The highest satisfaction score average was for SAP systems, with the other major vendor systems a close second. There was not a significant difference in satisfaction with MRP functionality between SAP and other BOPE systems. SAP was significantly better than all other systems, except Spreadsheet systems (owing to small sample size for the spreadsheet option). BOPE sample size was also small, explaining its lack of significance over other systems other than None and MSD. MSD had the second lowest satisfaction average, and was significantly worse to some degree than any other system except for None (the difference was not significant between MSD and None).

Additional significance tests were conducted for each MPC activity. The results are as indicated below. Table 11 presents significant advantages for MRP satisfaction based upon Table A1 in the appendix.

Table 12 shows significant advantages with respect to satisfaction with inventory control functionality, based on Table A2.

Table 10. Satisfaction with manufacturing planning and control systems on a 1–7 scale.

Category	MRP	Inventory control	Labour planning	Shop-floor control	Cost planning
None	3.56	3.82	3.52	3.41	3.82
Spreadsheet	4.58	4.50	4.43	4.13	4.35
In-house	4.55	4.71	4.44	4.48	4.71
Small	4.61	4.57	4.30	4.35	4.27
MSD	3.75	4.29	4.13	4.63	3.75
BOPE	4.84	5.14	4.84	4.63	4.82
SAP	4.99	5.05	4.50	4.74	4.93

Note: 1: dissatisfied; 7: very satisfied.

Table 11. Significant advantages in MRP satisfaction.

Higher average				
SAP >	In-house***	Small***	MSD**	None***
BOPE >			MSD**	None***
Small >			MSD*	None***
Spreadsheet >			MSD*	None**
In-house			MSD*	None***

Note: *Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.

Table 12. Significant advantages in inventory control satisfaction.

Higher average					
BOPE >	Spreadsheet*	In-house*	MSD**	Small**	None***
SAP >	Spreadsheet*	MSD**	In-house**	Small***	None***
In-house >					None**
Small >					None**

Note: *Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.

Table 12 displays strong advantages of BOPSE systems over other systems with respect to satisfaction in inventory control. In-house and small systems have weaker advantages over those surveyed who claimed no ERP. Otherwise, there were no significant differences, indicating a feature that large vendors can provide but smaller competitors do not.

Table 13 shows significant advantages, with respect to satisfaction with labour planning, based on Table A3. With respect to labour planning, fewer significant differences were detected. SAP was not rated as highly as other BOPSE vendors on this function. MSD was rated high enough so that the small sample size resulted in no significant differences (either positive or negative).

Table 14 shows significant advantages with respect to satisfaction with shop-floor control, based on Table A4. SAP appears to have a stronger relative advantage with respect to shop-floor control. The difference between ratings for SAP and BOPE, as well as MSD, was not significant.

Table 15 shows significant advantages with respect to satisfaction with cost planning, based on Table A5. Table 15 indicates another advantage for SAP, with other BOPSE vendors close behind. In-house systems perform relatively well on cost planning, as do spreadsheet systems. Overall conclusions are that more satisfaction is obtained from more expensive systems. SAP systems seem the strongest, except on the function of labour planning, where they are second. In-house systems do relatively well on cost planning and labour planning, with high ratings on all functions. Small systems seem to do better at MRP and inventory control, with satisfaction ratings dropping off slightly for other functions. Spreadsheet models did quite well considering their simplicity. Microsoft Dynamics received lower ratings. Significance is low, however, owing to small sample size. The overall benefit of an ERP is indicated primarily by the consistently low ratings for those respondents reporting no ERP system.

5.5 *How are the benefits and costs of different ERP forms perceived by the firms?*

Another important question was related to the impact of ERP systems on overall benefits and costs. Table 16 displays the results.

Table 16 shows a slight increase in benefits. Costs were reported to be slightly lower by four system categories, slightly higher for those without ERP system, those using spreadsheet models, and SAP users. Table A6 indicates few significant differences in perceived benefits and Table A7 for cost improvement. Table 17 shows these.

Table 13. Significant advantages in labour planning.

Higher average			
BOPE >	In-house*	Small**	None***
SAP >			None**
In-house >			None**
Spreadsheet >			None**
Small >			None**

Note: *Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.

Table 14. Significant advantages in shop-floor control.

Higher average				
SAP >	In-house*	Spreadsheet**	Small***	None***
BOPE >				None**
MSD >				None**
In-house >				None***
Small >				None**

Note: *Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.

Table 15. Significant advantages in cost planning.

Higher average				
SAP >	Spreadsheet**	MSD**	None***	Small***
BOPE >		MSD**	None***	Small**
In-house >		MSD**	None***	Small***

Note: *Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.

Table 16. Perceived impact on manufacturing-information-system benefits and costs.

Category	Benefits	Costs
None	4.17	4.07
Spreadsheet	4.50	4.13
In-house	4.49	3.90
Small	4.66	3.72
MSD	4.75	3.88
BOPE	4.37	3.82
SAP	4.53	4.13

Note: 1: decrease > 30%; 2: decrease 16–30%; 3: decrease 1–15%; 4: no change; 5: increase 1–15%; 6: increase 16–30%; 7: increase > 30%

Table 17. Significant advantages in perceived system benefits.

Higher average		
In-house >	Small*	None**
Small >		None***
SAP >		None***
MSD		None*
Spreadsheet		None*

Note: *Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.

Table 18. Significant advantages in perceived system costs.

Higher average			
SAP >	BOPE*	In-house**	Small***
None			Small***
Spreadsheet			Small***
In-house			Small**

Note: *Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.

With respect to costs, Table 18 shows significant perceived advantages with respect to system costs. Perceived cost advantages were indicated as significant for SAP over some systems. Small systems received the worst ratings.

6. Discussion and implications

Manufacturing firms are provided with many choices of ERP systems, ranging from simple spreadsheet-like to large SAP-like, for their manufacturing planning and control systems. This research has attempted to address five broad questions covering the presence of ERP forms in global manufacturing firms, the ways MPC activities are being conducted, the relationships between ERP forms and those MPC activities, and firms' perception of ERP forms in terms of benefits and costs. The MPCS section of GMRG survey was used to answer these questions.

Of the 964 manufacturing organisations surveyed, 736 responded to the question about their manufacturing planning and control system. We organised these responses into seven groups, ranging from reporting no use of ERP to use of SAP. A small ERP (49%) is the largest group in the survey results. This strong presence of a small ERP is found in most countries. In-house developed ERP is the second largest group (21%), followed by SAP (15%), None (6%), and BOPE (5%). MSD represents only 1% of the surveyed firms. This indicates a large

spectrum of ERP forms for the MPC activities of global manufacturing firms. These results differ from some previous studies. For example, Kale *et al*. (2010) surveyed 130 SMEs in India. Seventy-two per cent of surveyed firms reported None ERP system and small and large ERP represent only 11% of those surveyed. It is noted that India is not included in the GMRG survey. Olsen and Saetre (2007a,b) have argued for In-house ERP. Our results show that there is high usage of such systems for MPC in global manufacturing firms. In three countries (Turkey, Czech, and Korea), in-house ERP represents the largest group among ERP forms.

Our study has looked at some detailed MPC practices in global manufacturing firms, focusing on strategic planning, communication with other departments, and traditional MPC activities. There were significant differences in the use of software for strategic planning. The more sophisticated SAP and BOPE systems were significantly stronger on this dimension than the simpler systems. SAP and BOPE systems were not used significantly more than in-house systems. This indicates to us that strategic planning requires large ERP software support. Strategic planning, unlike operational planning and scheduling, develops long-term-focused business plans and thus relies on a larger firm-wide data and process integration. Large ERP systems are likely to be in a stronger position than other ERP forms, including small ERP systems, since they are promised to deliver data and process integration (Gattiker and Goodhue 2005, Park and Kusiak 2005, Kim 2009), as well as other benefits, such as decision support benefits (Holsapple and Sena 2005).

We also analysed the firms' use of systems to communicate across departments. There was slightly more frequent communication by those with ERP systems of some type and those organisations that did not report use of ERP systems. However, the size of the ERP system did not seem to matter, as those organisations relying on simple spreadsheet systems had the highest reported frequency of communication. SAP and BOPE users had the highest reliance on electronic technology, while those user-simpler or smaller systems relied on more traditional means of communication, such as personal contact, memos, and telephone. The inference we draw is that more sophisticated ERP systems enhance communication across organisational elements.

MPC systems do appear to increase communication across functional departments, as shown in Table 4. As was discussed in Section 5, simpler systems such as spreadsheet ERP forms can do quite well at this. We also inferred that large ERP systems (BOPE and SAP) enhance communication across organisational elements, and as shown in Table 5, users of these systems seem to place higher reliance on electronic technology.

Management of manufacturing and other related data is critical for MPC (Gattiker and Goodhue 2005, Gustavsson and Wanstrom 2009). Thus, our study shows that there is a notable increase in the use of advanced data entry such as bar codes and automatic data capture on the part of users of SAP and BOPE systems. Those reporting the use of no ERP relied heavily on manual data entry. Those without ERP systems reported less data updating. Users of advanced systems (SAP and BOPE) appear not to have to update data as often. Users of more sophisticated systems used the software to accomplish planning and control to a greater degree than users of simple systems, or no system. The final series of questions related to the basis for determining manufacturing data. More advanced system users (SAP, BOPE, and even Microsoft Dynamics) reported the highest reliance on optimisation methods. In-house users reported a greater reliance on statistics. Smaller system users (or those reporting no ERP) relied more on experience.

The satisfaction with MPC has been a key question in previous studies (Wacker and Sheu 2006). We analysed the link between MPC's satisfaction and ERP forms. Users of advanced systems reported greater satisfaction with respect to manufacturing planning and control. Specifically, SAP users were significantly more satisfied than users of other ERP forms other than those using spreadsheets or other BOPE vendors. BOPE users had significant advantages in satisfaction reported versus only those not using ERP systems and for Microsoft Dynamics users. SAP and BOPE users were significantly more satisfied than users of all other ERP forms with respect to inventory control. With respect to labour planning, BOPE users had the highest reported satisfaction, although differences were significant only with respect to in-house system users, users of small ERP systems, or those reporting no ERP system. Similar results were true of shop-floor control satisfaction, except here SAP users were the most satisfied. With respect to cost planning, SAP, BOPE, and in-house users reported significantly greater satisfaction than other users.

Tables 10 and 11 demonstrate significantly higher satisfaction with MRP and inventory control functions on the part of SAP users. However, this significance varies by function. With respect to labour planning, BOPE users had the highest ratings, but significance was lower than with other functions. With respect to shop-floor control, SAP users had a similar advantage over systems other than BOPE and MSD. Both SAP and BOPE systems were strong in terms of cost planning. There were few significant advantages apparent in Table 18 with respect to system

benefits, other than that most ERP-based MPC systems (not BOPE) were rated significantly better than no system. SAP had significant perceived system cost advantages over three of the other systems (Table 18).

The benefits and costs of ERP systems have received much interest from many previous ERP studies (Olhager and Selldin 2003, Hasan *et al*. 2011). The most important bottom-line impact is reported with respect to impact on ERP system benefits and costs. The greatest benefits were reported by Microsoft Dynamics users, although this difference was significant only with respect to those reporting no ERP. In-house system users had a significant advantage in perceived benefits with respect to users of small ERP systems. Thus, we can conclude no real advantage other than the inference that the ERP system users see benefits over those without ERP systems. With respect to system cost advantages, we were actually surprised to see SAP users reporting significant perceived benefits over BOPE, in-house, and small ERP system users. Those without ERP systems perceived greater cost benefits than those using small ERP systems. Thus, we infer that while SAP users spend a lot, they seem to perceive cost reductions to compensate.

The results of our study do not establish any 'best' system. That would depend entirely upon context. A small company would be much better served with a more affordable small system than with a more powerful SAP system that would bankrupt them. Even large firms, such as Samsung, feel they have the ability to develop their own internal systems, that they feel are superior to any vendor system (to include SAP).

Overall, this study has shed light on the presence of various forms of ERP systems used in global manufacturing firms and the current business practice of MPC activities by those firms in the light of ERP forms. The study has taken advantage of the data from the GRMG survey, a systematic survey conducted with manufacturing firms from 17 countries. The results presented in this study can help researchers and practitioners understand the current status of ERP forms and MPC practice, in national and global contexts, and the relationships between them.

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Appendix 1. *t*-tests of significant differences in satisfaction ratings (one-tailed, assuming unequal variance)

Table A1. Probability of no difference in satisfaction with MRP function.

	Spreadsheet	In-house	Small	MSD	BOPE	SAP
None	0.031**	0.008***	0.004***	0.435	0.005***	0.000***
Spreadsheet		0.453	0.467	0.072*	0.257	0.103
In-house			0.325	0.063*	0.156	0.005***
Small				0.052*	0.205	0.007***
MSD					0.030**	0.015**
BOPE						0.310

Note: *Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.

Table A2. Probability of no difference in satisfaction with inventory-control function.

	Spreadsheet	In-house	Small	MSD	BOPE	SAP
None	0.160	0.014**	0.040**	0.325	0.002***	0.001***
Spreadsheet		0.273	0.424	0.333	0.065*	0.069*
In-house			0.151	0.147	0.062*	0.033**
Small				0.237	0.017**	0.002***
MSD					0.037**	0.042**
BOPE						0.377

Note: *Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.

Table A3. Probability of no difference in satisfaction with labour-planning function.

	Spreadsheet	In-house	Small	MSD	BOPE	SAP
None	0.082*	0.036**	0.082*	0.356	0.008***	0.029**
Spreadsheet		0.493	0.322	0.311	0.140	0.415
In-house			0.162	0.294	0.081*	0.369
Small				0.378	0.029**	0.121
MSD					0.133	0.264
BOPE						0.129

Note: *Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.

Table A4. Probability of no difference in satisfaction with shop-floor control function.

	Spreadsheet	In-house	Small	MSD	BOPE	SAP
None	0.167	0.007***	0.016**	0.034**	0.012**	0.001***
Spreadsheet		0.155	0.245	0.164	0.125	0.043**
In-house			0.191	0.360	0.312	0.058*
Small				0.256	0.186	0.007***
MSD					0.495	0.380
BOPE						0.355

Note: *Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.

Table A5. Probability of no difference in satisfaction with cost-planning function.

	Spreadsheet	In-house	Small	MSD	BOPE	SAP
None	0.324	0.033**	0.356	0.239	0.038**	0.007***
Spreadsheet		0.129	0.400	0.159	0.114	0.044**
In-house			0.001***	0.046**	0.349	0.107
Small				0.166	0.019**	0.000***
MSD					0.039**	0.025**
BOPE						0.346

Note: *Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.

Table A6. Probability of no difference in perceived benefits.

	Spreadsheet	In-house	Small	MSD	BOPE	SAP
None	0.073*	0.015**	0.000***	0.058*	0.226	0.010***
Spreadsheet		0.474	0.227	0.254	0.332	0.456
In-house			0.060*	0.220	0.319	0.386
Small				0.383	0.124	0.131
MSD					0.172	0.255
BOPE						0.271

Note: *Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.

Table A7. Probability of no difference in costs.

	Spreadsheet	In-house	Small	MSD	BOPE	SAP
None	0.405	0.123	0.004***	0.277	0.139	0.337
Spreadsheet		0.162	0.034**	0.248	0.142	0.486
In-house			0.045**	0.464	0.346	0.049**
Small				0.314	0.332	0.000***
MSD					0.435	0.216
BOPE						0.085*

Note: *Significant at 0.1 level; **significant at 0.05 level; ***significant at 0.001 level.