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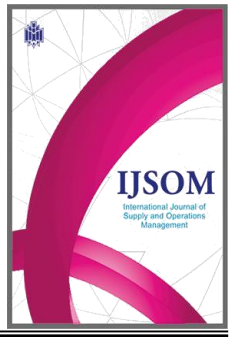

Exploring the Effects of Enterprise Resource Planning Systems on Direct Procurement: An Upstream Asset-intensive Industry Perspective

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Abstract
The past two decades have experienced an unprecedented rise in enterprise resource planning (ERP) systems implementation among asset-intensive organizations. Typical asset-intensive industries such as oil and gas, energy, and mining, rely heavily on the performance of their asset investments to stay competitive. Recently, several ERP vendors have developed solutions with diverse functionalities to address different business processes within such organizations. However, challenges unique to asset-intensive industries such as multiplex global supply chains, geographically dispersed sites, and sporadic climatic conditions add to existing impediments. This paper explores the effects of ERP systems on direct procurement with a focus on upstream asset-intensive industries. The study examines existing functionalities within ERP to determine benefits and constraints and builds on a framework with which to address potential gaps and opportunities. A quantitative research method was used to address five constructs related to ERP systems functionality to support inventory levels, delivery lead-times, procure-to-pay process, engineering change management, and ERP usability. The findings reveal statistically significant relationships between ERP systems effectiveness and all mentioned constructs, except the procure-to-pay process and ERP usability. The study informs on future improvements and feasible developments in procurement management and extends the scope of ERP systems knowledge in asset intensive industries.

Keywords: ERP Systems; Asset-intensive industries; Direct procurement

1. Introduction

The adoption of ERP systems in asset-intensive industries (AIIs) is on the rise. According to Mishra and Mishra (2011), the upstream segment of the oil and gas industry realized more opportunities for IT integrators specialized in energy. Typical AIIs include oil and gas, energy, and mining, where high-value and complex assets lock up significant capital investments. Nonetheless, these industries depend highly on the reliability and productivity of their assets to succeed. Furthermore, costs savings incurred from proper maintenance of assets translate to increased profitability. As the maintenance and supply chain domains in such industries gain more visibility, they become perceived as significant contributors to performance and profitability. The assurance of quality spare parts and operating supplies in the right quantities and at the right time is crucial to supporting upstream maintenance activities. Hence, the procurement function is of strategic importance. The effects of ERP are limited to direct procurement, which in theory refers to the acquisition of raw materials and services to produce finished goods. Since goods are not produced, which reflect raw material purchases, categorizing procurement as direct or indirect is debatable. Direct procurement in the context of this study refers to the acquisition of components, spare parts, and supplies to maintain assets within upstream AIIs.

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Contemporarily, many big companies have taken advantage of the advances in supply chain management (SCM) practices using special software to manage production and inventory (Cooke, 2014). ERP vendors such as JD Edwards, Oracle, and SAP have developed integrated packages that include SCM and maintenance modules. These are critical modules within the ERP framework to drive these business objectives.

2. Problem statement

The evidence of discontent in recent case studies with regard to ERP implementations from a procurement standpoint in AIIs has ignited the curiosity of this investigation. The problems presented in this research are as follows:

- The extent to which ERP systems have impacted direct procurement in upstream AIIs.
- Existing gaps in ERP systems usability in support of direct procurement in upstream AIIs.

3. Literature review

The study derives its body of knowledge from major areas of information systems, operations and SCM. It is centred on maintenance and inventory control. Figure 1.0 clearly shows the positioning.

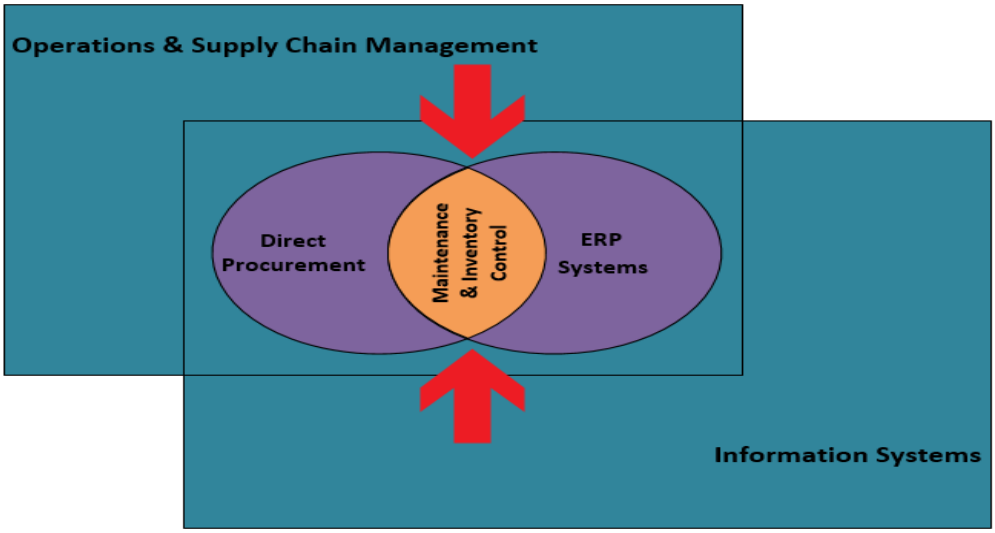

Figure 1. Theoretical framework

ERP is an evolution of an earlier material requirement planning (MRP) concept, which was predominantly production and inventory management. The entire ERP idea was built initially to adapt well with manufacturing industries because ERP systems originated to serve information needs of manufacturing companies (Mishra and Mishra, 2011). Manufacturing industries include procurement, production and supply chains in their ERP strategies. Conversely, AIIs consider asset management as the key driver. Halim (2014) contended that even though the functional aspects of both industries look similar, operational distinctions exist between the two in which AIIs focus on maintaining equipment. Traditionally, a bill of material (BOM) would contain the total of all components necessary for the production of an end product or assembly, such as sub-assemblies, individual parts and raw materials (Dickersbach et al., 2007). However, in the maintenance arena, an equipment bill of material (EBOM) lists all the components of an asset including its assemblies and sub-assemblies (Wallace, 2008). Dhillon (2002) asserted that profitable operations will be the ones that have employed modern thinking to evolve an equipment management strategy that takes effective advantage of new information, technology and methods. Magal and Word (2012) contended that ERP systems focus primarily on intra-company processes (i.e., the operations performed within an organization) and they integrate functional and cross-functional processes.

Absoft (2014) reported business challenges consistently faced by operators, as well as drilling and oil service companies. The challenges include the following:

- Steady increases in inventory costs;
- Many ‘stockout’ occurrences related to high priority work;
- Stock in a warehouse not reflected in an SAP system and vice-versa;
- Difficulties in differentiating stock types;
- Difficulties in synchronizing replenishment parameters with fluctuating material demand.

Pierce et al. (2012) maintained that an industry philosophy exists whereby having excess material is preferred rather than risking delays in projects or the start of production. This philosophy is certainly understandable, because materials and components for oil and gas production usually have long lead times and often need to reach remote areas (Pierce et al., 2012). Wen-sheng and Zhi-chao (2013) argued that ERP planning management is still the same as that of the MRPII modelled in the 1980s. MRPII plans demand by master production scheduling (MPS) and MRP, which are most suitable in manufacturing environments where the BOM process is more stable. Genpact (2014) uncovered business challenges faced by the AIIs as listed below:

- Non-standardized engineering and sourcing processes led to incorrect parts procurement, inventory pile up and high maintenance cycle time;
- A high number of field assets (more than 250, globally) without engineering BOMs;
- Historical and technical data of most assets distributed in multiple, disparate IT systems.

Kumar et al. (2015) contended that although ERP systems are sophisticated databases that automate cross-functional business processes, an ERP user often encounters challenges using complex ERP interfaces. ERP system usability issues are relatively minimal in some industries. Nonetheless, such industries usually present high-quality users, but finding such users in upstream AIIs is challenging due to their remoteness. Shipcom Wireless (2012) reported a case study on ENSCO, a renowned global offshore oil and gas drilling contractor, in which ERP usability was mentioned as a critical issue within the industry. Shipcom maintained that the ongoing data management of inventory and spare parts on rigs was a challenge primarily due to the complex presentation of operational data ENSCO was facing in its Corporate ERP (PeopleSoft). With rigs moving around constantly, the issue contributed to the need for solutions to problems caused by delayed data entry, exhaustive paperwork and the complexity of PeopleSoft transactions for ENSCO's "EDGE" workers (Shipcom, 2012).

According to Jabareen (2009), a conceptual framework represents a network of interconnected concepts from which a complete understanding of a phenomenon is derived. Figure 2 shows the conceptual framework of this study.

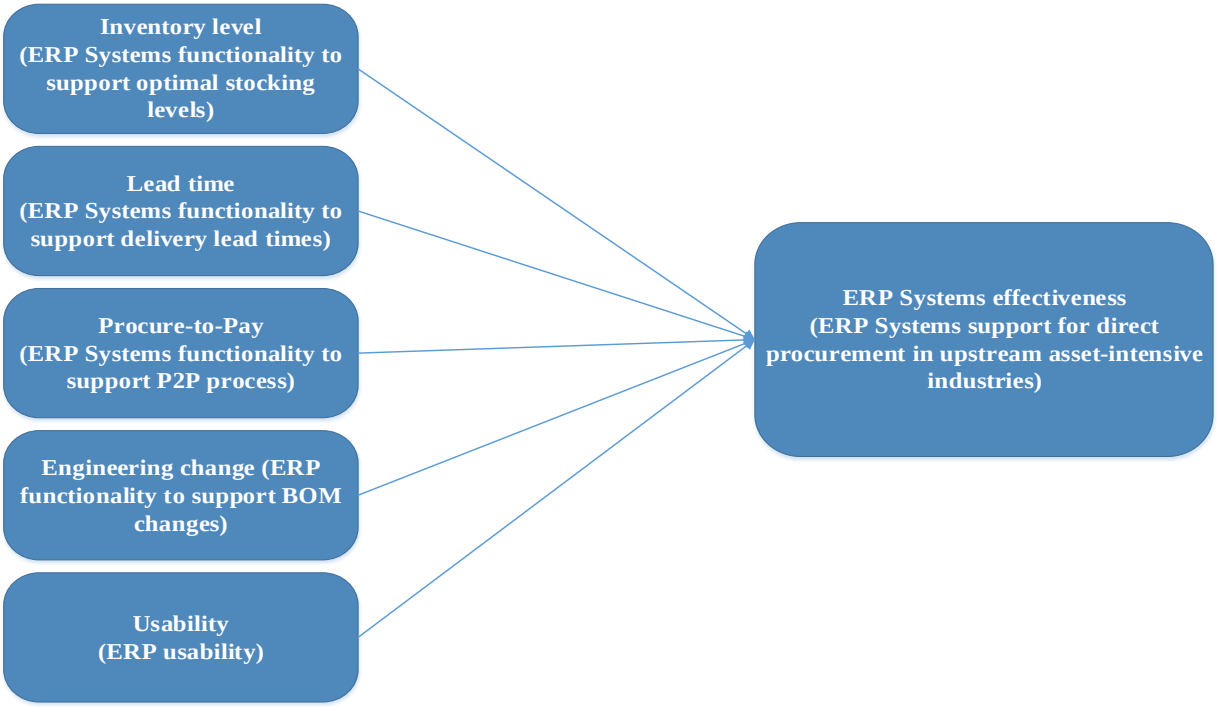

Figure 2. Conceptual framework

4. Research questions and hypotheses

The research questions below were formulated based on the research problems:

- RQ1: Do ERP systems support optimal stocking levels for direct materials in upstream AIIs?
- RQ2: Do ERP systems support lead times on maintenance supplies in upstream AIIs?
- RQ3: Do ERP systems adequately support the procure-to-pay process for direct materials in upstream AIIs?

- RQ4: To what extent do ERP systems effectively handle engineering changes for maintenance BOMs in upstream AIIs?
- RQ5: How do business users rate the usability of ERP systems in support of direct procurement processes in upstream AIIs?

The following hypotheses were derived:

- H1: ERP systems support optimal stocking levels for direct materials in upstream AIIs;
- H2: ERP systems support lead times on maintenance supplies in upstream AIIs;
- H3: ERP systems support the procure-to-pay process for direct materials in upstream AIIs;
- H4: ERP systems effectively handle engineering changes for maintenance BOMs in upstream AIIs;
- H5: Business users favourably rate the usability of ERP systems in support of direct procurement processes in upstream AIIs.

5. Methodology and study population

A quantitative research method was adopted. According to Leedy and Ormrod (2013), quantitative research design involves either identifying the characteristics of an observed phenomenon or exploring possible associations among two or more phenomena. A survey instrument was deployed to collect data. The intended population of study was professionals working in the field of procurement and maintenance management who used ERP systems within upstream AIIs. Given the isomorphism that exists within these industries, respondents were drawn randomly from different segments including mining, oil and gas and energy industries. The survey questionnaire was developed and delivered using Survey Monkey web tools. Out of the 314 questionnaires sent out, a total of 109 responses were returned, thereby amounting to a 35% response rate. However, during data cleansing, 29 responses were found incomplete. They were eliminated, and 80 responses were analysed.

6. Instrument validity and reliability

After several iterations of revisions, the final questionnaire addressed the research questions meaningfully. Internal consistency reliability tests using Cronbach's alpha were carried out on the questionnaire. The statements utilized 7-point Likert scale, which ranged from 1 (*strongly disagree*) to 7 (*strongly agree*). Statements were also clustered based on each construct. The results revealed an alpha greater than 0.70 for all grouped construct variables, which suggested an acceptable level of internal consistency. Table 1 summarizes the survey questionnaire.

Table 1. A summary of the survey questionnaire

Section 1:	Welcome Statement
Section 2:	General information about the respondent, organization and ERP systems: 1: Industry Type 2: Department Type 3: Job Role 4: ERP Longevity 5: ERP Type 6: ERP Modules 7: Stock out based Plant Shutdown 8: P2P Third-party Tools 9: RFQ Usage 10: Single/Multi-Plant Location 11: BOM Usage 12: ERP Requirement Participation
Section 3:	ERP Systems Functionalities: 13: ERP Systems Support 14: Inventory Level - ERP Systems 15: Inventory Level – Master Data Maintenance 16: Stockout – Order Control Accuracy 17: Lead times – ERP Systems 18: Stockout – Lead times 19: P2P Automation 20: ERP ECM - BOM Management 21: Delays – ECM BOM Errors
Section 4:	User Experience: 22: ERP Training 23: ERP User Features 24: ERP Usability

7. Study results:

Tables 2 and 3 below summarize the results of the analysis.

Table 2. Summary of ERP functionalities evaluation

ERP systems functionalities	Minimum	Maximum	Mean	Standard Deviation
ERP systems provide adequate functionalities to support direct procurement	4	7	5.87	0.682
Inventory levels for direct materials are usually at optimum due to the effectiveness of ERP systems	3	7	5.06	1.071
Inventory levels for direct materials are usually at optimum due to accurate master data maintenance	2	7	4.96	1.335
Minimal stock-outs on direct materials due to accurate order controls	1	6	4.88	1.426
ERP systems automatically calculate and resets lead-time for maintenance supplies based on past delivery records	1	6	3.84	1.479
Minimal stock-outs on maintenance supplies due to effective ERP systems support for delivery lead times	1	6	4.44	1.431
The procure-to-pay process within the enterprise systems is automated	1	7	4.30	1.554
ERP systems change management tool in managing bill of material (BOM) changes	1	7	4.53	1.492
Delays in maintenance work-orders caused by wrong parts supply generated from (MRP) is minimal	1	7	4.81	1.284
Training received using ERP systems to perform my current tasks was effective	1	7	4.29	1.708
ERP systems provide adequate user-friendly features to support direct procurement efficiently	1	7	4.49	1.475
Overall experience performing my functions within the ERP systems is positive	1	7	5.29	1.127

Table 3. Summary of average mean and standard deviation for ERP functionalities

Research Questions on ERP Functionalities	Min	Max	Average Mean	Average Standard Deviation
RQ1: Do ERP systems support optimal stocking levels for direct materials in upstream AII?	2.33	6.33	4.97	1.107
RQ2: Do ERP systems support lead-times on maintenance supplies in upstream AII?	1.5	6.0	4.14	1.297
RQ3: Do ERP systems adequately support the procure-to-pay process for direct materials in upstream AII?	1	7	4.30	1.554
RQ4: To what extent do ERP systems effectively handle engineering changes for maintenance BOMs in upstream AII?	1	6.5	4.67	1.255
RQ5: How do business users rate the usability of ERP systems in support of direct procurement processes in upstream AII?	1	7	4.69	1.267

The study determined the relationships between paired variables using correlation analysis. Based on the identified constructs, each aggregate rating for the research questions represented an independent variable. Meanwhile, ERP systems support rating represented the sole dependent variable. Standard assumptions were considered and tested. First, the ordinal nature of the variables suggested a non-parametric Spearman's correlation analysis should be performed. The Shapiro–Wilk normality tests carried out on each paired variable indicated statistically significant outcomes ($p < 0.05$) in all cases. Furthermore, scatter plots for each paired variable were constructed to assess linearity and test for monotonicity.

Table 4. Summary of Spearman's rho correlation analysis results

		Correlation	ERP support ratings	Inventory optimality ratings	Lead time functionality ratings	P2P ratings	BOM Change management ratings	ERP usability ratings
Spearman's rho	**ERP support ratings**	Correlation Coefficient	1	.369**	.442**	-.062	.300**	.102
		Sig. (2-tailed)	.	0.001	0	0.582	0.007	0.368
		N	80	80	80	80	80	80
	Inventory optimality ratings	Correlation Coefficient	.369**	1	.648**	.333**	.727**	.665**
		Sig. (2-tailed)	0.001	.	0	0.003	0	0
		N	80	80	80	80	80	80
	Lead time functionality ratings	Correlation Coefficient	.442**	.648**	1	.483**	.680**	.459**
		Sig. (2-tailed)	0	0	.	0	0	0
		N	80	80	80	80	80	80
	P2P ratings	Correlation Coefficient	-.062	.333**	.483**	1	0.275*	0.295**
		Sig. (2-tailed)	0.582	0.003	0	.	0.14	0.008
		N	80	80	80	80	80	80
	BOM Change management ratings	Correlation Coefficient	.300**	.727**	.680**	0.275*	1	.632**
		Sig. (2-tailed)	0.007	0	0	0.14	.	0
		N	80	80	80	80	80	80
	ERP usability ratings	Correlation Coefficient	.102	.665**	.459**	0.295**	.632**	1
		Sig. (2-tailed)	0.368	0	0	0.008	0	.
		N	80	80	80	80	80	80

Note. *Correlation significant at 0.05 level (2-tailed). **Correlation significant at 0.01 level (2-tailed).

RQ1: Alternate hypothesis H1 supported
RQ2: Alternate hypothesis H2 supported
RQ3: Alternate hypothesis H3 **not** supported
RQ4: Alternate hypothesis H4 supported
RQ5: Alternate hypothesis H5 **not** supported

8. Concluding remarks:

Holism is required to derive a good understanding of the implications of new technology in information systems and SCM. ERP systems have been embraced contemporarily by most industries, although its tenets stemmed from the manufacturing sector. This study defined constructs related to ERP system functionalities to support inventory levels, delivery lead times, procure-to-pay process, engineering change management and ERP usability. Statistical techniques were used to draw inferences on each construct with respect to ERP system effectiveness in AIIs. The study found statistically significant relationships between ERP system effectiveness and all mentioned constructs except for the procure-to-pay process and ERP system usability. This information among other deductions informs academic and practice communities on future improvements and feasible developments within this industry niche. Further research endeavours can extend the findings. A case study conducted on a few organizations in AIIs to complement the results of this study is suggested. The findings of this research also revealed a desperate need to inquire further into how to bridge gaps in procure-to-pay integration. Future studies in this area must employ a holistic approach by examining organizational business strategies, analysing business process alignments and establishing a framework that will guide technological advancement in procure-to-pay integration. Finally, it is also suggested that industry leaders consider improvements in usability, which entails implementing intervention strategies that will improve ease of use of ERP systems.

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