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Energy Management in Manufacturing:
A Knowledge Management Perspective

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ABSTRACT

In order to reduce the growing negative impact of CO_2 emissions, manufacturing firms have begun to refocus efforts on energy management. Several studies have focused on drivers and inhibitors of energy management but few regarding manufacturing energy management maturity. This study investigates both drivers and the role of knowledge management on manufacturing energy management maturity. Using multivariate analyses, questionnaire data from manufacturing personnel throughout the United States is utilized to assess these relationships. The results provide the support that economic followed by organizational and corporate social responsibility (CSR) positively impact knowledge management practices within organizations. Additionally, this study provides support that knowledge management practices within U.S. manufacturing organizations have a positive association with environmental management maturity. Findings contribute to theory and practical knowledge by highlighting the configurational effects of knowledge management and energy management maturity.

KEYWORDS

Energy Management, Environmental Management Maturity Model, Knowledge/Organizational/Economic/External Drivers and Inhibitors

1. INTRODUCTION

Manufacturing accounted for nearly 23.1 percent of U.S. CO2 emissions in 2019 (Vasdev, 2020). Understanding the ways in which to effectively manage energy consumption has become not only paramount for social and environmental sustainability but also an organization's economic sustainability. The capability of energy efficiency is defined by the difference between optimal and actual energy end-use in several categories (Backlund et al., 2012). The energy-efficiency gap for energy-intensive industries has been estimated as being 11%, where 5% could be decreased through more energy-efficient technologies and 6% through proactive energy management (EM) practices (Backlund et al., 2012) including knowledge management (KM).

Although relatively in-depth, KM has become vital for organizations in both their growth financially and environmentally. Defined in this paper as corporate specific practices including

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but not limited to adoption and utilization of environmental management systems, generation, and dissemination of energy efficiency knowledge, KM practices have the capability to preserve and analyze the increasing amount of data all the while improving and managing costs in manufacturing.

Previous research elucidates the various drivers of energy efficiency within organizations. Specifically, Lawrence et al. (2018) analyzed the pulp and paper industry and drivers of EM. Their study indicated a nearly 5.5-19.4% cost reduction annually simply through EM efficiency practices. Inspired by this study, this paper conducts a survey of U.S. manufacturing organizations and analyzes the relationships between external, economic, organizational drivers on KM practices within organizations and KM on the Environmental Management Maturity Model (EnMMM).

Bridging insights from both absorptive capacity (AC) and knowledge-based view (KBV) of the firm, this study deviates from Lawrence et al. (2019) by suggesting KM as the primary driver of EnMMM. And instead, external, economic, and organizational drivers work to promote KM practices within the organization. This in return enhances EnMMM within manufacturing organizations. Added to this is an organization's current CSR initiative, indicating that experience CSR promotes further knowledge enhancing EnMMM over time. This model is applied to the U.S. manufacturing industry, a large consumer of the oil and gas industry.

The paper is organized as follows: first, an overview of each research model construct is presented. This includes EnMMM, drivers, knowledge practices as well as bridging theoretical insights from AC and KBV. Following this, the paper presents the methodology including the data collection and analyzing method. Finally, results, as well as contributions, are presented.

2. BACKGROUND

The procedure with which the industrial companies aim to improve energy efficiency is referred to as EM (Lawrence, 2019). Several studies have examined various aspects of energy management. Schulze et al. (2016, P. 3692-3704) define industrial EM as:

"… the systematic activities, procedures and routines within an industrial company including the elements strategy/planning, implementation/operation, controlling, organization and culture and involving both production and support processes, which aim to continuously reduce the company's energy consumption and its related costs."

Jin et al. studied the EM maturity model for China: Linking ISO 50001: 2018 and domestic practices (Jin et al., 2020). Sola et al. reviewed the Influencing factors on EM in industries (Sola and Mota, 2020). Jafarnejad et al. (2020) designed a project management maturity assessment model of projects in the free zone petrochemical industry. EnMMM within the US manufacturing industries is a relatively underexplored domain.

Corporate social responsibility (CSR) incorporates ongoing firm commitments towards the active creation, deployment, and maintenance of ethical norms to improve the quality of life for stakeholders, the community, and society while also contributing to economic development (WBCSD, 2008). Within this domain is environmental management (Rahman and Post, 2012) which incorporates predicting future environmental changes while minimizing environmental degradation. The impact of CSR and environmental management on firm performance is not novel in literature. Several empirical insights have been made dating back decades ago. A traditional view points out that while complying with relevant social and environmental regulations, investment in limited resources specific to nonproductivity antipollution equipments with lower investment in productive equipment can reduce productivity (Conrad and Morrison, 1989). Other studies show that environmental performance has had no significant effect on business performance (Rockness, 1986). Contrarily, some research has shown that while compliance with environmental norms may generate additional cost, cost reductions can occur in a variety of areas including

(1) initial investment costs (2) enhancements of return on investments such as energy investments, saving paper, and recycling (3) increased logistics efficiency and (4) reduction in waste treatment technology costs (Ravindra and Pradeep, 2012). These benefits are also emphasized when firms invest in strategic communication mechanisms including Green IT capital (Chuang and Huang, 2018). Through the reduction of carbon dioxide emissions and energy waste, productivity can then be maximized while also reducing the inefficient use of resources to reduce the impact on the community and society (Mazurkiewicz, 2004).

More current literature discusses insights that should be made on what incorporates "good" corporate environmental initiatives for the purpose of effectively reducing energy use, waste generation and enabling businesses to achieve cost savings (Chuang and Huang, 2016). Hence, recent literature has discussed corporate maturity in CSR concepts including environmental management.

2.1. EM Maturity Matrix (EnMMM)

EnMMM organizes the essential EM activities across maturity levels to analyze the gap between the best possibility and actual organizational behavior. EnMMM aims to: (i) illustrate EM practices, (ii) provide a continuous improvement roadmap, (iii) propose the successful EM steps, (iv) provide benchmarking the current energy best practices, and (v) provide a guide for investment efforts.

The concept of environmental management maturity models gained prevalence in the mid-2010s through surveys and semi-structured interviews consisting of milestones or common practices where companies engage when progressing through varied maturity stages (Ormazabal et al., 2015). Gleaning insights from firms in the United Kingdom an energy management maturity matrix was identified providing both maturity stages and steps for firms to enhance progress. Following this, Ormazabal and Puga Leal (2016) identify drivers encouraging firms to progress in environmental management and specifies according to the maturity matrix. Doss et al. (2017) go on to provide a derivation of the integrated capability maturity model as an environmental management model, providing a new take as it relates to the applicability to quality management, control, and assurance. Ormazabal et al. (2017) then update the model to reflect insights from not only the UK but also Spanish and Italian companies yielding a robust version of the EnMMM which proposes six maturity stages. Bai et al. (2018) combine existing projects, group management theory, and a management maturity model to yield a 2-dimensional environmental management maturity model specific to construction. Other applications include water scarcity mitigation (Yatskovskaya et al., 2018) and other industrial economies (Campos et al., 2020). Recent developments involve mapping maturity dynamic progression through stages to provide an insight into feedback loops connected to actions to improve maturity levels (Ormazabal et al., 2021).

Foundations in energy management maturity focus on theory development in providing and adjusting fundamental steps. A few models have been derived from Ormazabal et al. (2015; 2016; 2017; 2021), Doss et al. (2017), and others. However, only recently has literature applied these models to contexts including water scarcity mitigation (Yatskovskaya et al., 2018), Swedish pulp and paper industry (Lawrence et al., 2018), and other industrial contexts (Doss et al., 2017). Application has also been focused in the UK, Sweden, Italian and Spanish areas.

Lawrence et al. (2018) provide an understanding of the differences among the varied maturity level aspects specific to the Swedish pulp and paper industry. They found energy policy, followed by organization, investments, and performance measurement were the highest-rated factors for the Swedish pulp and paper industry. This model provides not only an application context but also empirical validation of specific drivers in environmental management maturity thereby reflecting the research questions proposed in our model.

Inspired by the work in environmental management maturity we apply Lawrence et al. (2018) model to the U.S. manufacturing industry. Additionally, we separate the knowledge-based practices of organizations from the drivers, notably based on AC and KBV. This is an important insight in that knowledge precludes action and is driven by economic, organizational, and external drivers separate from KM itself. Our model includes the assessment framework for EnMMM (originating from (Carbon Trust, 2011), presented in Table 1).

2.2. Drivers of EnMMM

Lawrence et al. (2019) provide a breakdown of both the drivers and inhibitors of EnMMM as illustrated in Tables 2 and Table 3. Several of these drivers and inhibitors were determined to not be significant and thus were left out of our analyses. Additionally, for this study, only drivers were considered to analyze drivers of KM practices. In this study, we separate the KM practices from the organizational, external, and economic drivers as well as add a CSR driver categorization.

2.3. KM and Theory

Knowledge is a base for strategy and operations and includes a variety of different types including but not limited to scientific, technological, management, etc. (Edwards, 2008). KM in both forms of tacit and explicit bridges information demand and supply on behalf of learning processes and, consequently, organizational performance improvement (Curado and Bontis, 2011). KM provides

Table 1. EM maturity matrix (borrowed from Lawrence et al., 2018)

Maturity Level	0	1	2	3	4
Policy	No expressed policy	No formally stated routines (praxis)	Policy unadopted/ unestablished by organization	Formal policy, but no active commitment from top management	Energy policy action plan and Regular reviews, having an active Commitment from top management
Organization	No delegation or responsibility for managing energy	Informal responsibility for managing energy	Some delegation of responsibility, but no clear line management or authority to take decisions	Clear delegation of Responsibilities for energy use and improvement issues	Fully integrated into the Management structure with clear delegation of responsibilities
Training	No energy-related staff	training provided Technical staff occasionally attends specialist courses	Internal training for selected people if needed	Energy training targeted at major users following training-need analysis	Appropriate and comprehensive staff training tailored to identified needs, with evaluation
Performance measurement	No measurement of energy-use costs	Invoice checking only	Monthly monitoring by fuel type and energy-carrier type	Weekly performance measurement for each process, unit or building	Comprehensive performance measurement against targets with effective reporting to management
Communication	No communication or promotion of energy issues	Informal contacts used to promote energy efficiency if needed	Some use of official company communication mechanisms to promote energy efficiency	Regular staff briefings, performance reporting and energy promotion	Extensive communication of energy issues within and outside the organization
Investments	No investments in improving energy efficiency	Only low or no-cost measures implemented	Low or medium-cost measures considered if the payback period is short	Some appraisal criteria used, as for other cost-reduction projects	Resources routinely committed to energy efficiency supporting business objectives

Table 2. Drivers categories (modified from Lawrence et al., 2018)

Organizational	Economic
Well-functioning relations within organization* Commitment from top management* Improved working conditions* Long term energy strategy* Company's Environmental Profile Demand from owner Municipality energy planning/energy strategy Network within the company/group People with real ambition	Allocation of energy costs* Cost reduction from lower energy use* Decrease effect costs/avoid exceeding power loads Reduce production waste Reduced need for maintenance of equipment due to optimized energy use Taxes (energy taxes etc.)* Threat of rising energy prices * Voluntary agreements with tax exemption (e.g., PFE)
External	**Knowledge**
Pressure from environmental organizations* International competition* Network outside the company/group * Network within the sector* Demand and inquiries from customers Energy services e.g., third party financing energy performance contracting National requirements for Energy Efficiency	Energy advice through journal/booklets* Energy advice through seminars* Ability to use and spread employee's knowledge of maintenance and production processes* Internal training* Access to external competence with knowledge of the processes Access to internal competence with knowledge of the processes EM System Environmental Quality and/or other Management Systems Knowledge of daily operations

* kept as a measurement in the survey analysis based on significant results of Lawrence et al. 2019 Missing is CSR provided by Fang and Zhang (2011)

Table 3. Inhibitors Categories (modified from Lawrence et al., 2018)

Organizational	Economic
Costs for new recruitment or reeducation of employees Lack of budget funding for EM Uncertainty about the company's future Conflicts of interest within the company EM is not the main business Energy manager lacks influence Energy targets are not integrated into production maintenance or purchase routines High complexity of production processes Lack of time/other priorities Non-energy related working tasks are prioritized higher Risk for reduced performance after changed way of working (e.g., routines)	Hidden costs (e.g., for finding and analyzing information about EM) Top management doesn't prioritize energy issues Employees resist changes that the employees do not have experience of Lack of internal expert competence Slim organization Advantages of EM not considered worth the costs Costs for identifying opportunities and analyzing cost effectiveness Costs of production disruptions Department/employee has no share in benefits of reduced energy costs Difficulty to allocate energy costs Lack of access to capital Risk of changes affecting product quality Risk of changes affecting production capacity Uncertainty of how EM improves energy efficiency
External	**Knowledge**
Lack of external expert competence	Employees not directly involved in EM lack awareness of energy issues Lack of information on advantages of EM Lack of knowledge about daily operations

opportunities to reduce risks, improve business, enhance personnel engagement and morale, increase training efficiency and ultimately deliver financial benefit.

Various studies have examined the effect of KM in local manufacturing industries. Some examples include Buccieri et al. (2020) who present the application of an expert system prototype as an intelligent tool for the preliminary diagnostics of energy efficiency potential in Brazilian industrial plants focusing primarily on small and medium-sized enterprises. Older examples include Shaw and Edwards (2006) who analyzed components of KM strategy in UK manufacturing organizations noting that the integration of KM strategy is necessary across the organization through all levels. Other research has focused on specific areas of manufacturing. Gunasekaran and Ngai (2007) identified the gap between theory and practice, strategies, and techniques for the KM systems in advanced manufacturing environments. Inkinen (2016) presented a review of empirical research on KM practices and firm performance. Understanding the drivers, enablers, and performance of KM such as big data (Bihl et al., 2016) and applications such as Industry 4.0 and supply chain management (Dhamija et al. 2020; Kakhki et al., 2018) is crucial for managers. Identifying KM drivers can help organizations plan and implement specific practices needed within the organizational entity.

In energy-intensive industries, integrating KM with sustainability plays an important role (Abbas, 2020; Mardani et al. (2018). Knowledge is a major driving force for organizational development, and thus, KM can be utilized as an essential factor to enhance EM. KM helps organizations to create and use knowledge resources without exhausting natural resources or causing environmental damage, supporting sustainability (Abbas and Sağsan, 2019, Schniederjans and Khalajhedayat, 2021). Additionally, organizations that mature in their KM strategies and activities can support knowledge sharing internally and externally to facilitate EM goals (Abbas, 2020).

3. HYPOTHESES

3.1. Theory

"The ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" has been defined as AC by Cohen and Levinthal (1990, P. 128-152). Two important factors of this ability include prior related knowledge and diversity of background. Typically focused on R&D, AC can be applied in the KM context. Specifically indicating that by working externally organizations can absorb leverage knowledge, absorb new ideas, and ultimately convert knowledge into new innovations. Research in AC has investigated various factors that affect the inventive capability of the firms. Zahra and George (2002, P. 185-203) illustrate the potential AC and realized AC. They showed the process of absorbing and using the information can be expanding out of R&Ds. They defined AC as "a set of organizational routines and processes by which firms acquire, assimilate, transform and exploit knowledge to produce a dynamic organizational capability". In this case, potential AC includes knowledge acquisition and assimilation which focuses on interpreting and understanding the knowledge.

Realized AC includes the routines with which the firm is able to explore the knowledge and apply it into product or service as the capability of transformation. Recently other researchers explore other factors such as the effect of AC on Open Innovation in SMEs (Huber et al., 2020; Lu et al., 2020; Senivongse, 2020), KM (Barakat, 2020; Chichkanov 2020), financial (Papazoglou and Spanos, 2021), organizational structures (García-Sánchez et al. 2018; Siachou, 2021; Saeed, 2021), resources (Bhowmik, 2020), and manufacturing (Rehman et al., 2020; Duran et al., 2020). Most studies grounded in AC reflect the importance of bringing in outside sources of knowledge which is critical for the firm's AC.

Refined models of absorptive capacity bridge the concepts from Cohen and Levinthal (1989; 1990) with Zahra and George's (2002) model. Todorova and Durisin (2007) introduce that transformation of knowledge can be an alternative to assimilation rather than a subsequent step in a larger process. That is feedback loops exist in the dynamic nature of learning and processing. Future absorptive capacity is also determined by the current absorption of knowledge in organizational processes (Todorova and Durisin, 2007). Contingencies are also presented which enable a firm to greater recognize and exploit knowledge for the purpose of enhancing competitive advantage through flexibility innovation and performance in different contexts including sustainability (Dzhengiz and Niesten, 2020).

Power relationships both internally and externally are discussed to a large extent in Todorova and Durisin (2007). The refined model of AC focuses on the power of customers. Specifically, external relationships in the form of customers can influence a firm in directing resource allocation processes and new product development projects. However, when firms become customer-centric it can also hinder those processes. Adding to this, power relationships exist in a variety of formats including but not limited to supply networks, international competition, and regulatory bodies, all of which impact when and if companies invest in environmental management practices.

From a knowledge capability perspective, we hypothesize,

H1. External drivers are positively associated with KM practice in environmental management.

The refined model of AC adds by specifying the concept of power relationships interacting with cognitive processes, learning and capabilities internally as well as externally (Dosi et al., 2003). Within an organization, power relationships can influence the exploitation of new knowledge through resources. Top management that values environmental management is likely to allocate more resources toward enhancing environmental management. This includes not only monetary but also time, personnel, technological and educational varieties. Organizational processes consist of social interactions and thus learned social relationships can also influence knowledge-seeking behaviors (Borgatti and Cross, 2003). Well-functioning relationships, top management support, and a collaborative work environment provide greater incentives for knowledge attainment and performance.

When an organization is capable of developing procedures focused on absorption, transformation, and utilization of knowledge that will provide a context useful for enhancement of knowledge capabilities that can promote greater EnMMM. Of course, these processes require an internal environment that fosters greater KM practice. These activities may include improved working conditions, commitment from top management, and a strategy that is supportive of absorption, transformation, and utilization of EM knowledge. Hence, the following is hypothesized:

H2. Organizational drivers are positively associated with KM practice in environmental management.

A firm's maturity on CSR may also provide the groundwork for great AC as it relates to KM. This is mirrored in the refinements to Cohen and Levintha's (1990) and Zahra and George's (2002) models of absorptive capacity. Specifically, the ability to learn and absorb knowledge depends largely on the ability to value new knowledge. Organizations must be able to see and understand the potential of new external knowledge in order to adapt (Todorova and Durisin, 2007). According to the refined absorptive capacity model, the ability to recognize value is directly derived from prior knowledge. Additionally, all three models of AC suggest what Cohen and Levinthal (1990) purport that:

"By having already developed some absorptive capacity in a particular area, a firm may more readily accumulate what additional knowledge it needs in the subsequent periods in order to exploit any critical external knowledge that may become available" (Cohen and Levinthal, 1990, pg. 136)

For example, a firm with frequent public CSR initiatives enhances internal capacity level to adapt itself to environmental factors. These organizations are more likely to receive and use external knowledge as it relates to EM since they have experience within this domain.

CSR is defined as a firm achieving the balance amongst economic, social, and environmental aspects for the purpose of achieving the expectations of various stakeholders (Fang and Zhang, 2021). Continuously research is being developed that links environmental management with CSR and has, in turn, caused various organizations to integrate CSR into long-term strategy (Chen et al., 2019). In this study we measure proactive CSR leveraging recent work from Fang and Zhang (2021). Specifically, a firm with a proactive CSR identity is likely to carry out public activities, encourage managers and employees to participate in CSR activities within the local community, have strong integrity and ethical behavior that go beyond laws and regulations, and perform in a manner that is consistent of societal mores and ethical norms. Thus,

H3. Firm corporate social responsibility is positively associated with KM practice in environmental management.

To a lesser extent, economic drivers have been considered in knowledge based theories including absorptive capacity. Refinements to the absorptive capacity specify the exploitation of new knowledge can be influenced through resource allocation processes (Todorova and Durisin, 2007) which can then impact practice, however, in KM, economic drivers have typically been focused on to a lesser extent than psychological drivers.

However, Economic drivers are, arguably, one of the stronger drivers of sustainability practice as noted in previous research, particularly in a U.S. context (Yalcin and Schniederjans, 2019). Economic incentives promote action toward building knowledge capability in one particular area. Economic drivers including the allocation of energy costs, the threat of rising energy prices, tax incentives, etc. can promote greater resource allocation toward KM.

Effective KM, especially as it relates to investments in EM systems, internal training, etc. requires a substantial amount of economic resources. In order to promote further investments, an economic driver is likely to be necessary to encourage KM.

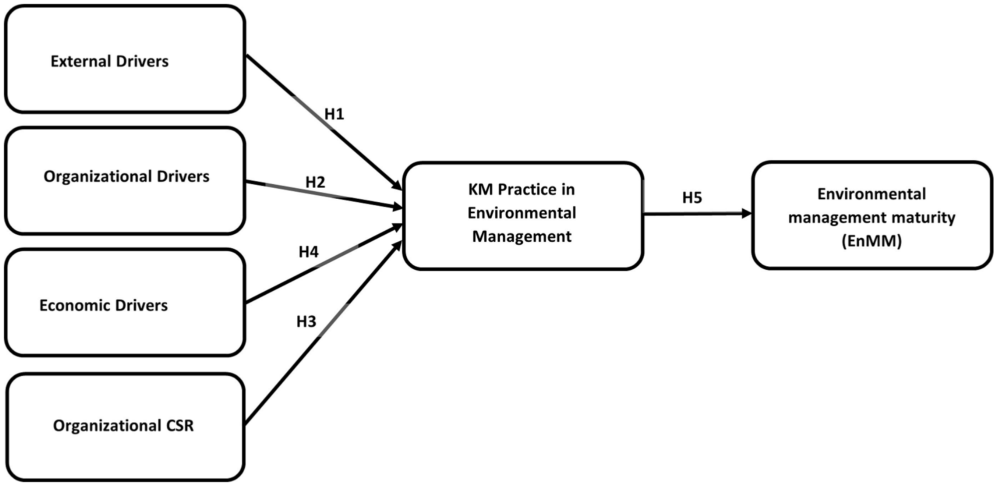
H4. Economic drivers are positively associated with KM practice in environmental management.

Originating from strategic management, the KBV of the firm considers knowledge as the most significant resource of a firm. The interest of KBV has been closely linked to the availability of knowledge resulting from fundamental economic changes during the last decade. The proponents of KBV (e.g. Grant, 2002) believe knowledge is the major determinants of sustained competitive advantage of this type of firm. This capability is essential in integrating effective EM practices in organizations (Roxas and Chadee, 2016). Viewing EnMMM as a KM capability, KM practices, are likely to synchronously impact, policy, the delegation of responsibility, training, performance measurement communications as well as investments in EM.

Absorptive capacity as it depends on the knowledge source and prior knowledge as well as being conditioned on appropriability regimes can have an impact on the performance of an organization (Todorova and Durisin, 2007). To the best of our knowledge, the purported relationship between knowledge and performance is unabashed in current literature. Corporate ongoing investment in absorptive capacity as operationalized through R&D leads to and explains performance difference in firms even after market discontinuity (Rothaermel and Hill, 2005). Figure 1 shows a graphical view of the proposed hypotheses. Thus,

H5. KM practice in environmental management is positively associated with environmental management maturity.

Figure 1. (Proposed hypotheses for the Research Model)



4. METHODOLOGY

The survey allowed us to collect a larger amount of quantitative data to assess the relationships presented in our research model. Additionally, the survey allowed us to gather qualified feedback from manufacturing professionals throughout the United States to help examine both the drivers as well as associated impacts on KM practices and EnMMM (Lawrence, 2019).

4.1. Survey Development and Deployment

To address the research questions, a survey was constructed based on previous literature. The survey and items as well as the associated literature from which it was derived are provided in Table 4.

The data collection occurred in Late to early 2020-2021. A survey via Surveymonkey was sent to manufacturing firms throughout the United States. Their demographics are depicted in Table 7 in the Appendix 1. The response rate was 79%. This is a larger response rate than expectations as set forth in current quantitative studies (Lawrence et al., 2019).

To assess the performance of organizations in EM, the EM maturity matrix (EnMMM) was utilized (Lawrence et al., 2019). The EnMMM is a common method for assessing EM and has been utilized in previous literature (i.e. Sa et al., 2017). A score of 0 represents no work, a score of one represents occasional work, scores of two-four represent increasing levels of regular and continuous work.

The drivers and KM practice were assessed through a list of studied drivers and barriers provided by Lawrence et al. (2019). Lawrence et al. (2019) provide an extensive list depicting drivers and barriers found in previous literature as well as those from the authors' experience gained from working in EM issues in the industry as well as those inspired by previous research (Thollander and Ottosson, 2008; Trianni et al., 2013). The drivers that were found to have a significant Spearman correlation with the EnMMM were included in the survey. Although KM was included in the list of drivers, we provide a breakdown of practices utilized by organizations based on the initial investment interest of companies. Additional items were adopted based on comments from experts in the area during a pre-test of the survey.

Added to these drivers were organizational corporate social responsibility (CSR). Previous literature has linked CSR to environmental protection and as such, it is becoming more important in a firm's long-term strategy (Karassin and Bar-Haim, 2016). As such we added four items derived from Fang and Zhang (2021).

Table 4. Survey items and associated literature

Variable	Code	Description	Literature
Control Variables			
Industry	CONT_IND_FB (food and beverage);	Manufacturing industry dummy variables	Qi et al. (2009)
	CONT_IND_EC (electronic and communication equipment		
	CONT_IND_T (transportation equipment)		
	CONT_IND_TG (textile and garment)		
	CONT_IND_EE (electrical equipment)		
	CONT_IND_M (machinery)		
	CONT_IND_CP (chemicals and petroleum)		
	CONT_IND_PO (plastic and other)		
	CONT_IND_HC (healthcare)		
	CONT_IND_OT (other)		
Job title	CONT_JT_GM (general manager)	Job title of respondent dummy variables	Qi et al. (2009)
	CONT_JT_POM (production and operations manager)		
	CONT_JT_LM (logistics manager)		
	CONT_JT_PM (purchasing manager)		
	CONT_JT_FD (factory director		
	CONT_JT_CO (chief operations officer)		
	CONT_JT_CEO (chief executive officer)		
	CONT_JT_MM (marketing manager		
	CONT_JT_RDM (R&D manager)		
	CONT_JT_OT (other)		
Company size	CONT_CS	How many employees are in your organizational unit (Less than 100, 101-200, 201-500, 501-1000, 1001-5000, greater than 5000)	Qi et al (2009)
Ownership	CONT_OWN_ST (state ownership)	Ownership dummy variables	Qi et al. (2009)
	CONT_OWN_CO (collective ownership)		
	CONT_OWN_PO (private ownership)		
	CONT_OWN_FO (wholly foreign ownership)		
	CONT_OWN_JV (joint venture)		
	CONT_OWN_JS (joint stock)		
	CONT_OWN_OT (other)		
Position in the supply chain	CONT_POS_MF (manufacturer)	Position in the supply chain dummy variables	Qi et al. (2009)
	CONT_POS_CS (components supplier)		
	CONT_POS_RM (raw materials supplier)		
	CONT_POS_OT (other)		
Independent variables			
External drivers	EX_DR_1	International competition	Lawrence et al. (2019)
	EX_DR_2	Long term energy strategy	
	EX_DR_3	Network outside organizational unit	
	EX_DR_4	Network within the sector	
Organizational drivers	ORG_DR_1	Well-functioning relations within an organization	Lawrence et al. (2019)
	ORG_DR_2	Commitment from top management	
	ORG_DR_3	Improved working conditions	

continued on following page

Table 4. Continued

Variable	Code	Description	Literature
Corporate social responsibility (CSR)	CSR_1	Firm public CSR activities	Feng and Zhang (2021)
	CSR_2	Expectation of society mores and ethical norms	
	CSR_3	Integrity and ethical behavior above laws and regulation	
Economic drivers	EC_DR_1	Allocation of energy	Lawrence et al. (2019)
	EC_DR_2	Cost reduction from lower energy use	
	EC_DR_3	Taxes (energy taxes)	
	EC_DR_4	Threat of rising energy prices	
	EC_DR_5	Voluntary agreements with tax exemption	
Knowledge management practices	G_K_DR_1	Energy advice through journals/booklets	Lawrence et al. (2019)
	G_ K_DR_2	Energy advice through seminar	
	D_ K_DR_3	Ability to use and spread employee knowledge of maintenance and production processes	
	D_ K_DR_4	Internal training	
	G_ K_DR_5	Environmental management systems (EMS)	
	G_ K_DR_6	Environmental, quality and/or other management systems	
Dependent Variables			
Energy Management Maturity Matrix (EnMMM)	EMM_POLICY	Please check the answer that most relates to the org unit (0: no expressed policy in energy management; 1: no formally stated routines in regards to energy management; 2: largely unadopted/unestablished; 3: formal energy management policy but no active commitment from top management; 4: energy policy action plan and regular reviews with active commitment from top management)	Lawrence et al. (2019)
	EMM_ORG	Please check the answer that most relates to the org unit (0: no delegation or responsibility for managing energy; 1: informal responsibility for managing energy; 2: some delegation of responsibility but no clear line of management or authority to make decisions; 3: clear delegation of responsibility for energy use and improvement issues; 4: fully integrated into the energy management structure with clear delegation of responsibilities)	
	EMM_TRAIN	Please check the answer that most relates to the org unit (0: no delegation or responsibility for managing energy; 1: no energy management related staff training; 2: technical staff occasionally attend energy management specialist courses; 3: energy training targeted at major users following a training need analysis; 4: appropriate and comprehensive staff training tailored to identify needs with evaluation)	
	EMM_PM	Please check the answer that most relates to the org unit (0: no measurement of energy use costs; 1: only conducts energy related invoice checking only 2: conducts monthly monitoring by fuel type and energy carrier type; 3: weekly energy performance measurement for each process, unit or building; 4: comprehensive performance measurement against targets with effective reporting management)	
	EMM_COMMUN	Please check the answer that most relates to the org unit (0: no communication or promotion of energy issues; 1: informal contacts used to promote energy efficiency if needed. 2: monthly monitoring by fuel type and energy carrier type; 3: regular staff briefings, performance reporting and energy promotion.; 4: extensive communication of energy issues within and outside the organization)	
	EMM_INVEST	Please check the answer that most relates to the org unit (0: no investments in improving energy efficiency; 1: low or no cost energy efficiency measures implemented. 2: low or medium cost energy efficiency measures considered if the payback period is short; 3: appraisal criteria used for energy efficiency and for other cost reduction projects. 4: resources routinely committed to energy efficiency supported business objectives)	

4.2. Sample and Reliability

The data collected can be classified based on the type of industry, size of company, ownership, and position in the supply chain. Additional demographics collected included the job title of the respondent. Table 7 depicts the distribution of the demographics. Cronbach's α was utilized to assess the reliability. All items loaded above or near 0.70 indicating acceptable reliability as seen in Table 5.

The correlation indices and descriptive statistics of the items are presented in Table 8 and Table 9 (Appendix 1). Control variables were left out due to the number and size; however, these correlations

Table 5. Item loadings

Variable	Code	Loading
External drivers	EX_DR_1	0.78
	EX_DR_2	0.72
	EX_DR_3	0.79
	EX_DR_4*	0.67
	EX_DR_5	0.78
Organizational drivers	ORG_DR_1	0.82
	ORG_DR_2	0.82
	ORG_DR_3	0.83
Corporate social responsibility (CSR)	CSR_1	0.81
	CSR_2	0.74
	CSR_3	0.85
Economic drivers	EC_DR_1	0.81
	EC_DR_2	0.76
	EC_DR_3	0.77
	EC_DR_4	0.76
	EC_DR_5	0.71
Knowledge drivers	G_K_DR_1	0.75
	G_ K_DR_2	0.77
	D_ K_DR_3	0.75
	D_ K_DR_4	0.81
	G_ K_DR_5	0.80
	G_ K_DR_6	0.77

*Removed from analysis

are available upon request. The relationships between variables were further investigated through multivariate analyses. In order to assess for normality of data, skewness and kurtosis of each item were collected. Skewness ranged from (-0.099-0.526) and kurtosis ranged from (-1.605-0.084) all of which were <2.0 and within the acceptable range as it relates to non-normality of data.

Internal consistency and unidimensionality were both assessed utilizing item-total correlations and exploratory factor analysis. All items exhibited high item to total correlations as well as significant loading on the factors (>0.70). Then a confirmatory factor analysis was conducted. The fit indices provided support of reasonable fit even with the sample size and the number of observed variables (degree of freedom = 152, chi-square = 308, comparative fit index: 0.93, RMSEA: 0.08) (Bai et al., 2016). The composite reliabilities range from 0.843 to 0.892 and all AVE's exceeded 0.50 thus indicating adequate convergent and discriminant validity.

In order to assess for non-response bias, we compared the demographic variables of respondents who started the survey but didn't finish the survey with the demographics of those who finished the survey in its entirety. We found no significant differences in industry (p-value: 0.9373), job title (p-value: 0.1111), ownership (p-value: 0.7553), position (p-value: 0.9652) and company size (p-value: 0.1455).

In assessing for multi-collinearity, tolerance and variance inflation was examined. Tolerance values ranged from 0.26099 to 0.39863. Additionally, variance inflation factors ranged from 2.50861 to 3.78547 indicating no serious issue with multicollinearity (Schreiber-Gregory and Jackson, 2017).

To address common method variance, based on the work of Richardson et al. (2009), we used a correlational marker technique (Lindell and Whitney, 2001). A marker variable was chosen based on the least correlated item with the criterion factors. The correlation was still significant after correction ($p<0.05$). Thus, this indicates the common method variance does not seem to be a large issue.

4.3. Factor Analysis

A confirmatory factor analysis (CFA) was utilized to evaluate the measures' validity. The results appeared to be in the "acceptable" range for model fit (degree of freedom = 152, chi-square = 307.585, comparative fit index: 0.934, RMSEA: 0.08). The chi-square goodness of fit was also significant ($p<0.01$). The factor loading ranges from 0.724 to 0.878 with p-values less than 0.01 showing that the constructs have acceptable significance. The item coefficients were higher than the standard errors indicating adequate reliability and convergent validity (Flynn et al., 2010).

4.4. Results

This study utilized multivariate analyses to examine the direct effects of external drivers, organizational drivers, CSR, and economic drivers on KM as well as KM on EnMMM (i.e. H1, H2, H3, H4, and H5).

4.4.1 Structural Model

Model 1 included only the control variables: industry, job title, company size, current ownership, and position in the supply chain. Coefficients, standard errors, and p-values are provided in Table 6 below. Model two adds the relationship with KM practices on EnMMM. Finally, model 3 depicts the relationships between external drivers, organizational drivers, CSR, and economic drivers on KM. The results confirm the positive association between KM practices with EnMMM ($\beta=0.11071$, p-value=0.0710). Additionally, the results confirm the positive association between organizational drivers and KM practices ($\beta=0.18272$, p-value=0.0077), CSR and KM practices ($\beta=0.17481$, p-value=0.0214) and economic drivers on KM practices ($\beta=0.47555$, p-value=<0.0001). This provides support for hypotheses 2, 3, 4, and 5. Hypothesis 1 was not confirmed ($\beta=0.04732$, p-value=<0.5196). The results are summarized in Table 6 below.

5. DISCUSSION

Lawrence et al. (2019) identify several drivers, barriers, and success factors for EM in the Swedish pulp and paper industry. Inspired by this study, the purpose of this paper was to identify how relevant drivers impact KM practices in the manufacturing industry in the United States as well as the ultimate impact on EM maturity through the lens of EnMMM.

The foundations of absorptive capacity stipulate that AC represents "a firm's ability to identify, assimilate and exploit knowledge from the environment (Cohen and Levinthal, 1989, 569-570)." A firm's stock of prior knowledge can then build upon existing knowledge through both potentials and realized AC. Previous studies elude to several motivational aspects including the transfer of knowledge across and within the organization, structures of communication, centralization of an interface function, and a broad and active network of external entities (Van den Bosch et al., 1999). Typically utilized to analyze research and development absorptive capacity represents extensive theoretical knowledge foundation in KM and especially within organizational behavior research.

To a lesser extent, AC is utilized in firm EM literature. In this study, we identify that the drivers elucidated in Lawrence et al. (2019) can actually be tied to KM practices in manufacturing organizations. Specifically, although KM can be seen as a driver, we view the knowledge drivers as outlined in Lawrence et al. (2019) as more tools for the EM maturity of organizations driven by

Table 6. Results

Model 1: DV: EnMMM						Model 2: DV: EnMMM				Model 3: DV: Knowledge Management			
Parameter	DF	Estimate	Standard Error	t Value	Pr > |t|	Estimate	Standard Error	t Value	Pr > |t|	Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	6.774	8.657	0.78	0.436	6.209	8.578	0.72	0.471	10.917	6.545	1.67	0.098
CONT_IND_FB	1	0.378	0.409	0.92	0.357	0.379	0.405	0.94	0.352	-0.223	0.316	-0.71	0.481
CONT_IND_EC	1	0.005	0.558	0.01	0.993	-0.107	0.556	-0.19	0.847	0.263	0.427	0.62	0.540
CONT_IND_T	1	0.418	0.635	0.66	0.511	0.375	0.629	0.6	0.553	-0.324	0.480	-0.67	0.502
CONT_IND_TG	1	0.193	0.480	0.4	0.688	0.201	0.475	0.42	0.673	0.164	0.364	0.45	0.653
CONT_IND_EE	1	0.532	0.605	0.88	0.381	0.420	0.603	0.7	0.488	-0.051	0.463	-0.11	0.912
CONT_IND_M	1	0.247	0.324	0.76	0.448	0.206	0.322	0.64	0.522	-0.047	0.247	-0.19	0.849
CONT_IND_CP	1	1.169	0.613	1.91	0.059	1.030	0.612	1.68	0.095	0.222	0.468	0.47	0.636
CONT_IND_PO	1	0.454	0.537	0.85	0.400	0.318	0.537	0.59	0.555	0.200	0.410	0.49	0.626
CONT_IND_HC	1	0.719	0.523	1.38	0.172	0.754	0.518	1.46	0.148	-0.718	0.397	-1.81	0.073
CONT_JT_GM	1	-0.129	0.413	-0.31	0.756	-0.175	0.410	-0.43	0.670	-0.329	0.315	-1.04	0.299
CONT_JT_POM	1	-0.216	0.384	-0.56	0.575	-0.230	0.380	-0.6	0.547	-0.482	0.296	-1.63	0.106
CONT_JT_LM	1	-0.953	0.550	-1.73	0.086	-0.822	0.549	-1.5	0.137	-0.721	0.417	-1.73	0.087
CONT_JT_PM	1	0.175	0.444	0.39	0.694	0.227	0.441	0.51	0.608	-0.546	0.334	-1.63	0.105
CONT_JT_FD	1	-0.143	0.346	-0.41	0.679	-0.132	0.343	-0.38	0.701	-0.235	0.262	-0.9	0.371
CONT_JT_GM	1	0.657	0.831	0.79	0.431	0.703	0.824	0.85	0.395	-0.464	0.630	-0.74	0.463
CONT_JT_CO	1	-1.762	0.963	-1.83	0.070	-1.733	0.954	-1.82	0.072	-1.083	0.736	-1.47	0.144
CONT_JT_CEO	1	-0.489	0.454	-1.08	0.283	-0.499	0.449	-1.11	0.269	-0.038	0.342	-0.11	0.912
CONT_JT_MM	1	1.261	0.847	1.49	0.139	1.620	0.862	1.88	0.063	-1.735	0.643	-2.7	0.008
CONT_JT_RDM	1	0.846	0.978	0.87	0.389	0.833	0.968	0.86	0.392	-0.191	0.745	-0.26	0.798
CONT_CS0	1	-0.897	0.440	-2.04	0.044	-0.865	0.436	-1.99	0.050	-0.303	0.333	-0.91	0.365
CONT_CS1	1	-0.090	0.502	-0.18	0.858	-0.142	0.498	-0.28	0.777	-0.196	0.382	-0.51	0.610
CONT_CS2	1	-0.631	0.545	-1.16	0.250	-0.543	0.542	-1	0.319	-0.010	0.413	-0.02	0.981
CONT_CS3	1	-0.241	0.449	-0.54	0.593	-0.255	0.445	-0.57	0.568	-0.240	0.340	-0.71	0.482
CONT_CS4	1	-0.653	0.505	-1.29	0.199	-0.707	0.501	-1.41	0.161	-0.133	0.382	-0.35	0.729
CONT_OWN_ST	1	-0.759	1.349	-0.56	0.575	-0.755	1.336	-0.57	0.573	-0.276	1.014	-0.27	0.786
CONT_OWN_CO	1	-1.411	1.366	-1.03	0.304	-1.354	1.353	-1	0.319	-0.190	1.037	-0.18	0.855
CONT_OWN_PO	1	-0.643	1.298	-0.5	0.621	-0.608	1.285	-0.47	0.637	-0.210	0.976	-0.22	0.830
CONT_OWN_FO	1	-0.215	1.528	-0.14	0.889	-0.268	1.513	-0.18	0.860	-0.938	1.153	-0.81	0.418
CONT_OWN_JV	1	-1.650	1.479	-1.12	0.267	-1.796	1.467	-1.22	0.223	-0.597	1.116	-0.54	0.594
CONT_OWN_JS	1	-1.366	1.417	-0.96	0.337	-1.200	1.406	-0.85	0.395	-1.045	1.068	-0.98	0.330
CONT_OWN_OT	1	-0.793	1.278	-0.62	0.537	-0.812	1.266	-0.64	0.523	-0.548	0.962	-0.57	0.570
CONT_POS_MF	1	-0.651	0.344	-1.89	0.061	-0.637	0.341	-1.87	0.064	-0.023	0.259	-0.09	0.930
CONT_POS_CS	1	-0.791	0.485	-1.63	0.105	-0.817	0.480	-1.7	0.092	0.303	0.366	0.83	0.410
CONT_POS_RM	1	-0.880	0.607	-1.45	0.150	-0.797	0.603	-1.32	0.189	-1.053	0.458	-2.3	0.023
K_DR						0.1107	0.0608	1.82	0.0710				
EX_DR										0.047	0.073	0.65	0.519
ORG_DR										0.182	0.067	2.71	0.007
CSR										0.174	0.074	2.33	0.021
EC_DR										0.475	0.074	6.35	<.0001
R2	0.283					0.303				0.807			
Adj. R2	0.074					0.074				0.742			

external, economic, CSR, and organizational practices as specified by AC theory literature (Van den Bosch, 1999). This utilizes AC by "looking backwards" into addressing the drivers of KM practices within and outside manufacturing entities.

This, however, is not addressing the larger question of EM within organizations. In February of 2021, the National Academies of Sciences Engineering and Medicine (Lowry et al., 2021), discussed achieving net-zero carbon emission in the U.S. by 2050 as completely "feasible" and would evidently help address not only climate change but build a competitive economy through job creation. However, with the looming climate change crisis and CO2 emissions as being the primary driver, organizations and their associated policies, training, performance measurements, communications and investments will become paramount in achieving this lofty goal.

Utilizing questionnaire (Appendix 2) data from manufacturing organizations across the United States, this study identifies three drivers of KM practices. Specifically, the results provide support for the positive association between organizational drivers including but not limited to relations within an organization, commitment from top management, improved working conditions, and a company's environmental profile with KM practices (i.e. utilization of energy information from external sources, ability to utilize and spread employee knowledge of maintenance and production processes, internal training, etc.). Additionally, the study provides support for the positive association between KM practices and economic drivers. Economic drivers include but are not limited to the allocation of energy costs, cost reduction from lower energy use, energy taxes, and voluntary agreements with tax exemptions. Contrary to AC, we did not find a positive association between KM practices and external drivers including pressure from environmental organizations, long-term energy strategy, and network outside the company/group. While this may allude to interesting insights regarding the complexities of networks and how this may or may not hinder KM within an organization as well as EM initiatives undertaken within an organization, future research is encouraged to reassess this deviance from AC.

Knowledge is essentially a distinctive resource. Firms are "dynamic, evolving, quasi-autonomous systems of knowledge production and utilization (93, p. 59), which essentially create value through the utilization of resources and knowledge integration. Of course, strategic alignment is paramount in the integration of knowledge for the purpose of creating stakeholder value (Kearns and Sabherwal, 2009). Testing the relationship between KM practices and EnMMM provides an understanding of the tools organizations can utilize to leverage maturity in an increasingly important aspect of sustainability. Specifically, through the use of knowledge generation, dissemination, and sharing.

Adding to the drivers provided by Lawrence et al. (2019), this study provides evidence for the impact of a firm's CSR activities on KM practices as they relate to EM. This finding indicates the possibility that firm experience in CSR may leverage greater absorptive capacity in other corporate responsibility initiatives outside social responsibility. Additionally, future studies might address actual CSR practices and their impact on EnMMM.

Finally, this study provides a breakdown of the strength of the associations between various drivers and KM practices. Economic drivers had, by far, the most impact on KM practices over, organizational and CSR. This indicates, that in the U.S. economic drivers are still a powerful force in EM within organizations.

6. CONCLUSION

The purpose of this study was to provide an understanding of how significant drivers (as indicated by Lawrence et al., 2019) impact KM practices within U.S. manufacturing organizations. Additionally, the purpose of this study was to examine how KM practices impact EnMMM. Our results provide the support that economic drivers followed by organizational drivers then followed by CSR positively impact KM practices within organizations. Additionally, this study provides support that KM practices within U.S. manufacturing organizations have a positive association with EnMMM.

Inspired by Lawrence et al. (2019), this study adds to the literature, by identifying the relationships between the drivers as indicated. Additionally, we find through a survey of U.S. manufacturers that KM practices can be driven by economic and organizational drivers as well as added CSR drivers within the firm. Finally, the KM practices have a positive association with EnMMM.

There are several limitations to the study that should be considered. First, the sample size is low in comparison to other survey studies in sustainability literature. Additionally, due to COVID, perceptions provided by manufacturing organizations may have been altered in a unique environmental setting. Future research is encouraged to re-evaluate the relationships presented in this model through different contexts as well as the utilization of other levels of analysis.

With the world's focus on transforming energy systems from on dominated by fossil fuel to net zero emissions of CO2 (Lowry et al., 2021), EnMMM in manufacturing organizations is becoming paramount. Understanding the role of not only KM but also other practices, investments, and policy, future research can begin to uncover various tools to help obtain sustainable global goals.

CONFLICT OF INTEREST

The authors of this publication declare there is no conflict of interest.

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