Knowledge management for sustainability in operations

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The purpose of this paper is to examine the effect of Knowledge Management (KM) as a platform to enable sustainability in firms' operations and to provide recommendations for managers to integrate sustainable operations into their business strategies. The urgency to create and implement sustainable operations in local and global firms is also argued. The conceptual framework underlying the prevalent effect of KM on sustainable practices is based on the hypothesis that KM contributes to the achievement of more suitable operations. To test this hypothesis, a model of structural equation was developed with data collected from 345 small and medium size enterprises (SMEs). Generally, the empirical evidence supported the hypothesis, indicating that KM represents an important alternative to the challenge of implementing sustainability in firms' operations. Thus, the results of this study suggest that managers need to improve their firms' practices, by implementing KM, as they will enable a better understanding and awareness regarding the global dangerous impacts from unsustainable operations mainly focused on sales and cost reduction. For this reason, the paper provides evidence that KM offers an alternative impulse on the quest for more sustainable operations.

Keywords: Knowledge management; Sustainability; Sustainable operations, Innovation.

1 Introduction

Research priorities and concerns of current international and national governments are based on the fact that if the global industrial economy does not act now, there will be dangerous consequences to the prosperity and health of planet Earth. This calls for immediate actions and policies with concrete targets and achievements (GFM 2016; Obama 2015; UNEP 2010; EC 2011). A sustainable development approach is therefore becoming fundamental to firms operations.

Since the industrial revolution, firms have been exponentially creating better strategies and operations to enhance their primary concern of accumulative economic

profits. However, in recent years, there has been an increasing interest in challenging business models that seem careless of their negative impacts to the planet as they represent an unsustainable approach to production (Rocha-Lona et al. 2015). This current model of production, has been argued, treats nature as an industry, whose real environmental cost is represented by several global negative impacts such as the increment of diseases, extinction of species, permanent damage to and scarcity of natural and un-renewable resources, global warming, etc. (Morgan 2015).

For this reason, nowadays people are more and more concerned on what we have lost, what exactly needs to be done now in order to recover it, but more importantly, if we are still on time to do this. In consequence, local and global industries are now under a mounting pressure from consumers, certifications and government regulations to take action into making their operations more sustainable (Bettley and Burnley 2008; Kleindorfer, Singhal, and Van Wassenhove 2005; Despeisse et al. 2012)

In the light of the serious environmental concerns and challenges currently faced by firms to operate more sustainably, researchers and practitioners alike have turned to operations management concepts, methods and tools to improve the sustainability performance of firms' operations. For example, extensive evidence exists in the academic literature that has focused on investigating how some operations management approaches such as green supply chain management (e.g. Colicchia, Creazza, Dallari, 2017; Kumar et al. 2015), reverse logistics (e.g. Daaboul et al., 2016; Abdulrahman et al. 2014), green manufacturing (Kleindorfer et al. 2005), circular economy (e.g. Ghisellini, Cialani, Ulgiati 2016), cleaner production (e.g. Chung et al. 2016), green lean (e.g. Thanki and Thakkar, 2016; Garza-Reyes et al. 2016; Garza-Reyes 2015), green lean six sigma (e.g. Cherrafi et al. 2016; Kumar et al., 2016), among others, can contribute to improve sustainability in firms' operations.

However, despite the wide application of operations management in this respect, evidence of the understanding and utilisation of KM to support the transition towards sustainability in local and global operations may be considered limited in the academic literature, especially when compared to the large amount of publications related to the aforementioned operations management concepts, methods and tools and sustainability. Therefore, in this endeavour, this paper contributes in filling this gap by exploring the relationship between KM and sustainability and providing a quantification of the influence that KM has on the sustainability of firms' operations. Moreover, this paper presents a review and discussion about the urgency for firms to become aware of the impact of their non-sustainable operations on the planet's prosperity and how KM may represent an effective alternative to thrive sustainability in local and global operations. In this context, as awareness of negative environmental impacts on the planet is needed, and firms are currently urged to incorporate sustainability interventions into their business operations, firms must generate a creative revolution of their current practices, for which the development of knowledge is a driving factor (Quinn 1992). Moreover, knowledge management (KM) has demonstrated some positive effects on business performance.

The paper is presented in the following order. First, the literature review is offered in regards to sustainability in firms' operations and knowledge management. Second, the methodology is presented, followed by the results, discussion and conclusions.

2 Literature review

A considerable amount of literature has been published and established based on traditional economic models such as those proposed at the beginning of the industrial revolution (Sloan, 1990). Firms based on these economic models have fostered

economic and technological developments, but at the same time, inherently they have caused a range of negative social and environmental problems (e.g. social inequality, poverty, diseases, severe negative impacts on natural resources and the environment, etc.). In terms of the environmental impacts (Song and Jinhui, 2014), the industrial activity is affecting the world oceans, land and atmosphere; which includes, among other negative impacts: increase of heat waves, intensification of rainfall patterns, extreme precipitation events, degradation of resources (e.g. low quality water), global warming, permafrost shrinking, greenhouse gases (GHG), sea level rising, ice caps disappearance, species extinction, among others (GCP 2013).

Consequently, the world natural resources, including the complex biodiversity systems, are facing depletion and extinction. For local and global industries it represents a big issue since it is now evident the lack of resources to sustain current and future production demands that require sustainable operations progress (Beltran-Esteve and Picazo-Tadeo 2017). To bring an example, consider the Food industry, which is of primary significance for societies and their economic development. This industry is now facing scarcity and low-quality natural resources (e.g. water, land, energy, animals, among others), which affect the entire production chain and its own processes. This ultimately affects final consumers, who are all of us. Similarly, other industries face the same problems with their supplies, which reinforce the idea of building sustainability in capacities and operations for the long-terms.

2.1 Integrating sustainable development into firms' strategies and operations

Sustainable development is a concept defined by the United Nations, in the Brundtland Report (1987), as 'to meet the needs of the present without compromising the ability of future generations to meet their own needs'. So this type of development represents the

relationship between mankind and its environment. Therefore, in this endeavour, it is urgent for every stakeholder to ensure the development of strategies and operations that allow a new economic model, one which cares for the creation of products friendly to the environment, is socially responsible and economically profitable (Dey, LaGuardia, and Srinivasan 2011).

In this regard, the challenge of the global industry economy is to converge traditional production systems into careful, ethical, and environmentally friendly production systems, by integrating sustainable operations into their traditional modes of production with the objective of improving their sustainability performance (Gadenne et at. 2012; Chan, Nan, and Chung 2017). We call all these efforts carried out by entire industries and companies' business sustainability. As previously established, some attempts to integrate business sustainability into companies operations could be seen through green supply chain management, reverse logistics, green manufacturing, circular economy, cleaner production, green lean, green lean six sigma, etc. Additionally, other contemporary initiatives that try to reduce the environmental negative effects from operations are the 3Rs (reuse, remanufacture, recycle) (Fleischer, Dose, and Ackermann 2007) and the Closed Loop Zero Waste (Despeisse et al. 2012).

However, in the current academic literature, in terms of sustainability, efforts are incomplete as these mainly focus on one dimension. For example, some have reported special emphasis on technology (Garetti and Taisch 2012) and only focused on the economical dimension, by incrementing sales and reducing costs (Dey, LaGuardia, and Srinivasan 2011). Similarly, in a comparative case study on companies implementing sustainable practices, it was reported that from such implementations major benefits were directed to the economical area, medium benefits to the environmental area, and lastly, lower benefits to the social area (Despeisse et al. 2012). Additionally, there are

weak efforts reported from environmental institutions to support initiatives that explore alternatives for sustainable operations that could protect the world's condition (Andresen 2007).

Adding to this problem, even though supply chain management has been a broader approach and one of the most recognised business frameworks, the incorporation of sustainable operations into this framework requires the complete participation of stakeholders to create such sustainable supply chain (Dey, LaGuardia, and Srinivasan 2011). So, firms cannot work alone anymore, and focus only on one dimension of sustainability, such as, the economic-profit aspect. Therefore, it is now required that stakeholders get better comprehension and creativity to understand and integrate business sustainability into their business operations, for instance, understanding and measuring suppliers environmental performance (SEP) (Chiarini 2015); as they need to be aware of and understand the reasons and specific ways so this kind of integration can take place (Koplin, Seuring, and Mesterharm 2006). This necessary integration and participation is underlined in the supply chain definition: 'sequential key business processes and actors that working as a coordinated network creates products and services valuable to ultimate customers' (Grant et al. 2006; Butcher, Christopher, and Mangan 2007; Lambert and Cooper 2000; Cooper 1993). In this regard, it is also essential to propose and develop broader strategies for business sustainability and firms' operations that include a long-term goal for sustainability ensuring a vision that includes almost everyone and everything: producers and consumers, as well as, economic, social and environmental care issues. Some of the sustainable frameworks suggested in the literature to 'pursuing strategies to facilitate long-term sustainability' (Kleindorfer, Singhal, and Van Wassenhove 2005) are described in Table 1.

Table 1 Sustainable Operations Framework (Kleindorfer, Singhal, and Van Wassenhove 2005)

	Present	Future
Internal	• Employee involvement • Waste reduction • Energy conservation • Emission control	• Investing in capabilities to recover pollution-causing chemicals during manufacturing • Developing substitutes for non-renewable inputs • Redesigning products to reduce their material content and energy consumption during manufacturing and use
External	• Analysing upstream supply chains to make trade-offs of materials and processes • Pursuing closed-loop supply chain for remanufacturing and safe waste disposal	• Developing core capabilities in products, processes and supply chains for long-term sustainability • Pursuing strategies to facilitate long-term sustainability

These proposed framework for sustainable operations reflect some best practices based on the continuous improvement of operations, including socially viable conditions and environmentally friendly operations in a more cost effective manner (Despeisse et al. 2012). Consequently, firms require a more creative and comprehensive approach to develop sustainable operations, for example, including resource-use productivity by identifying losses from the system that can be used elsewhere (Dey, LaGuardia, and Srinivasan 2011) and new processes and tools for more sustainable operations in firms (Chiriani 2014).

Therefore, it seems to be required a creative and broader operations´ strategy point of view for the supply chain. Mainly because it is also implied that some companies are not fully aware and committed to act and pursue business sustainability and contribute to sustainable development in the long-term. In this line, Small and Medium Enterprises (SMEs) are entities intrinsically linked to these local and global

challenges for sustainability development. Besides, these contribute outstandingly on economic growth, employment generation, added value to businesses and poverty decrease; as these carry out around 80% of enterprises globally (Murphy 2013). The tendency towards sustainable development has recognised that it cannot move forward without considering SMEs. The main challenge is to start dealing with thriving sustainability in their internal operations. It is necessary to produce the right frameworks to face this challenge, and more important in a developing country like Mexico, where SMEs constitute 99% of the total economic units, 52% of GDP and 70% of jobs creation (PROMEXICO 2017). Accordingly, it is a challenge to develop sustainability initiatives in SMEs operations, mainly because of their complex and unique conditions due to firm size, localisation, and job role overlap (Murphy 2013). In the Law for Competitiveness Development for SMEs (*Ley para el Desarrollo de la Competitividad de la PYME – LDCP*), these have been divided into three sized-related enterprises: medium-sized enterprise (<250 employees, ≤ $250 annual millions of Mexican pesos), small enterprise (<50 employees, ≤ $100 annual millions of Mexican pesos); or microenterprise (<10 employees, ≤ $4 annual millions of Mexican pesos)(DOF 2009). Thus, it is becoming urgent to implement effective strategies that enable a continuous understanding and development of sustainability in their operations.

One of the main motivations of the present investigation to study this complex context of SMEs is because the majority of this type of enterprises have great influence on the economy of countries, especially developing ones (Murphy 2013). On the other hand, KM initiatives also seem to help SMEs while facing challenges such as qualified human resource. For instance, KM main processes seem to allow active preparedness while streamline operations (Wiig 1997). KM enables human resources to get involved in discussions of strategy development and not as administrators only. KM organic

growth of knowledge helps to define better scenarios and vision for the firm, this while promoting the analysis of long-terms opportunities. Therefore, KM permits to expand firms' perceptions – knowledge, by continually measuring performance, and thus to improve its sustainability operations (Hansen, Nohria, and Tierney 2000; Stewart 2001; Nonaka and Takeuchi 1995). Basically KM through its main continuous processes, such as, capture relevant knowledge, storing information, disseminates information and generation of ideas; allow linking massive updated knowledge to improve, to avoid errors (Davenport and Glaser 2002) and to foster eco-innovation for more sustainable operations in SMEs (Wong and Aspinwell 2004).

For this to happen, it seems to be required a knowledge-based approach that permits creativity for innovative changes, managing an effective change of mind-set both in society and in the industry. Actually, as Dey, LaGuardia and Srinivasan (2011) commented, 'if people do not know or do not realise the consequences of their own behaviour, the situation will not change'. For this reason, from the academic literature it is implied that a new awareness or knowledge seems to be required for a revolution of current practices to occur. In order for firms to create an improvement and care of our planet's prosperity, they have to know and be aware of the negative impacts of their operations and committed to minimising them. This leads to the urgency of including the role of workers (Milanez and Puppim de Oliveira 2013) so they acknowledge their roles' impacts onto a whole sustainable development approach.

Therefore, to support sustainability in operations education about the new roles in management is required; along with new infrastructure, sustainability indicators and political changes (Despeisse et al. 2012). In fact, this challenge of integrating sustainability in firms' operations represents a source of new knowledge, innovation and inspiration, to adapt general operations strategies, concepts, methods and/or tools

(Longoni and Cagliano 2015). Similarly, companies have reported value creation practices while implementing sustainable practices. This is based on a business model innovation, hence becoming a more sustainable company (Carayannis, Sindakis, and Walter 2014). However, Despeisse (2012) concluded that 'information is particularly deficient regarding quantification of benefit, implementation difficulties and knowledge management about sustainability in companies'.

In summary, a more systematic learning and innovation paradigm for value creation is required, a change into a more organic paradigm (Brown 2014), which appears reflected in the processes of knowledge management (KM). For this reason, the philosophy of KM is clarified next for the challenging endeavour of developing sustainability in firms' operations, especially in SMEs.

2.2 Knowledge management for sustainability in firms' operations

To improve their sustainability performance, companies need to ensure they incorporate sustainability into their vision. Accordingly, they require to be 'aware' of why and how to incorporate it, then to translate its overall objective into specific sustainability practices for each area of performance; finally, to control and measure indicators to assess actual achievement for each area (Gadenne et al. 2012).

In fact, knowledge is defined as 'awareness of something' (Knowledge (n.d.) 2016) and it has been classified into tacit and explicit; the tacit knowledge is mental models, beliefs and perspectives, whereas, the explicit knowledge is the articulated knowledge. The transition from tacit to explicit is essential by firms in order to produce innovations (Nonaka and Takeuchi 1995). In this regard, knowledge is considered the firms' survival power, and the foundation of firms' capabilities (Marr and Schiuma 2001).

Therefore, knowledge management (KM) is considered as an innovation strategy (Carayannis, Sindakis, and Walter 2014) and its implementation has been reported to be linked to organisational performance (Mills and Smith 2011; Carlucci, Marr, and Schiuma 2004). KM appears as a potential framework to pursue sustainability due to its action learning orientation (Gloet 2006), which can define how a company fits, implements and operationalises strategies with sustainability initiatives. Hence, KM represents an effective way to help firms to be educated about the incorporation of sustainability in operations, which means to improve its awareness and understanding of the issues involved for the required transformation.

The OECD (2003) defines KM as 'any intentional and systematic process or practice of acquiring, capturing, sharing and using productive knowledge, wherever it resides, to enhance learning and performance in organisations'. Furthermore, KM has also been defined as 'performing the activities involved in discovering, capturing, sharing, and applying knowledge so as to enhance, in a cost-effective fashion, the impact of knowledge on the unit's goal achievement' (Becerra, Gonzalez, and Sabherwal 2004). Thus, such KM processes: discovering, capturing, sharing and applying knowledge may impact sustainability by enabling the creativity and innovation required for a transformation of strategies and operations.

In the creation or discovery of knowledge, workers are crucial since they are not only users of a system but captors and creators of know-how that is relevant to achieve a company's objectives (Ortiz-Fournier et al. 2010) and it depends of personal commitment (Nonaka and Takeuchi 1995). So they actually can be able to select the relevant knowledge for later dissemination for sustainable practices (Sarkis, Zhu, and Lai 2011). With the proper knowledge (e.g. training) workers can innovate, for example, designing new techniques that will potentially become the new specifications

(product, method). Among the reported techniques to foster personal commitment, on which knowledge creation depends, are the use of figurative language from metaphors, analogies, models, umbrella concepts and qualitative criteria to product specifications (Nonaka and Takeuchi 1995).

The capture of knowledge is another relevant process in KM, since firms need to extend their knowledge base in order to create innovation. This should help in not only summarising information in reports but to make sure tacit and explicit knowledge interact, while from this innovation can emerge. This is, firms should help workers to articulate part of their tacit knowledge and know-how through policies and tools. Some recent techniques reported in the literature to make this and stimulate change management include arts for business (Fiske 1999; Schiuma 2011).

Knowledge sharing is another KM process that seems key for supporting improvements in sustainable development (Meese and McMahon 2012), through making personal (tacit) knowledge available or explicit, which is reported to be the central activity in a knowledge-creating company (Nonaka and Takeuchi 1995). This comes from the basic fact that knowledge not frequently discussed becomes obsolete (Bolis, Brunoro, and Sznelwar 2012).

The active dissemination of intra-organisational knowledge is also important; in fact, the transfer of best practices is considered as one of the essential success factors in supply chains (Al-Mudimigh, Zairi, and Ahmed 2004; De Wit and Meyer 1998; Cooper 1993). The enhancement of knowledge sharing can be promoted, according to the literature, mainly by observation, imitation practice, and socialisation (tacit and explicit knowledge interacting) (Tsai 2002).

The application of knowledge is important and representative for sustainable operations to ensure people actions in the company are actually based on adequate top-down management of information (Bolis et al. 2012).

Besides the limited evidence regarding the general understanding and utilisation of KM to support the transition towards more sustainable operations, exposed in the Introduction section, the literature review showed that limited research has also been conducted to specifically study the link between knowledge management and sustainability in operations, especially within the context of SMEs (Bolis et al. 2012). From the literature, KM seems to help increasing awareness of workers' practices, particularly for sustainability in firms' operations. In this line, KM could also serve and facilitate the achievement of more sustainable operations. Therefore, the present research focuses on measuring the influence of KM on sustainability in firms' operations with the context of SMEs, because to date, there has been little agreement on the effect and contribution of KM to achieve more sustainable operations. The investigation of this phenomenon is considered the main theoretical contribution derived from this work.

3 Research Methodology

The review of the literature conducted and presented in the previous section theoretically suggests that KM depicts an effective strategy to address the complexity of new sustainability endeavours in firms operations. However, no previous studies were identified that have focused on empirically investigating whether a prevalent relationship between KM and sustainability exists, and if this is the case, quantifying such relationship. In this regard, a key question emerges and is concerned with the extent to which KM impacts sustainability practices within the context of firms' operations. Following the previous arguments and literature review, the following

hypothesis is formulated:

H1. Knowledge management has a positive effect on sustainability in operations.

Based on the purpose of this investigation, a quantitative empirical investigation was conducted in SMEs operating in the state of Aguascalientes, Mexico. To this end, the business directory of the 'Sistema de Información Empresarial de México 2016' (Business Information System of Mexico) was taken as a base and reference framework for data collection. A questionnaire survey instrument was designed, validated and distributed among all the 990 manufacturing SMEs that were members of the directory such year. In particular, the sample of firms was distributed as follows, 60% automotive, 20% textile and 20% furniture sector in the Aguascalientes region of México. The validation of the questionnaire was carried out through a Confirmatory Factor Analysis evaluation, which included a confirmation validity by three tests: convergent, content, and discriminant validity. Finally, the reliability of the questionnaire (Bagozzi and Yi 1990) was tested by evaluating data consistency of the theoretical model examined by the Cronbach's alpha test along with the calculation of the Composite Reliability Index (CRI). These testes are presented in subsequent parts of this section.

The data collection process resulted in 345 SMEs responding to the questionnaire, which contributed to the achievement of a response rate of about 35%. The final sample of 345 organisations was selected by means of a simple random method, with a reliability level of 95% and a maximum error level of ±5%. The questionnaires were administrated via personal and telephone interviews to managers that were in charge of, or closely related to, the operations (e.g. operation managers, production managers,

supply chain managers, quality managers, etc.) of the 345 firms that participated in the study. This data collection process took place between May and November 2016.

The design of the questionnaire was based on constructs dimensions that have been previously introduced and validated to measure KM and sustainability in firms (Bozbura 2007; Gadenne et al. 2012; OECD 2003). In particular, the KM construct was measured through four factors, namely: *1) workers training, 2) KM policies and strategies, 3) creation and acquisition of external knowledge,* and *4) organizational culture effects,* as investigated by Bozbura (2007), please refer to Table 2.

According to Bozbura (2007) these four factors accurately measure the fundamental components of KM for SMEs' success and these also represent the basic elements proposed by the OECD's (2003) definition of KM. Additionally, this scale has been previously introduced and validated in similar contexts to those of this study (Metaxiotis 2009; Chadha and Kapoor 2010; Shahriza, Razi, Jalaldeen, Norshidah 2012*).*

To measure sustainability in firms' operations seven factors were employed, specifically: *1) Environment management, 2) Customer focus, 3) Product innovation, 4) Process and employee effectiveness, 5) Internal processes improvement, 6) Social responsibility,* and *7) Improvement of cash flow and finance* (Gadenne et al. 2012), see

Table 2. These factors were depicted for this research scale because these were associated to firms' sustainability performance indicators and include the three dimensions of sustainability (i.e. social, economic and environmental dimensions). Additionally, these factors have been previously introduced, demonstrating consistency and validity in contexts similar to the studied here (Lu et al. 2016; Morioka and de Carvalho 2016; Parisi 2013).

For both constructs, sustainability in firms' operations and KM, a five-point Likert scale was employed, where: 1 = totally disagree, 2= disagree, 3= nor disagree, nor agree 4=agree and 5=totally agree. Based on this scale, managers were asked to provide insights regarding their current sustainability practices in their overall firms' operations. Figure 1 illustrates the theoretical framework that underlined this investigation and Table 2 presents the operationalisation of the constructs and a description of items used.

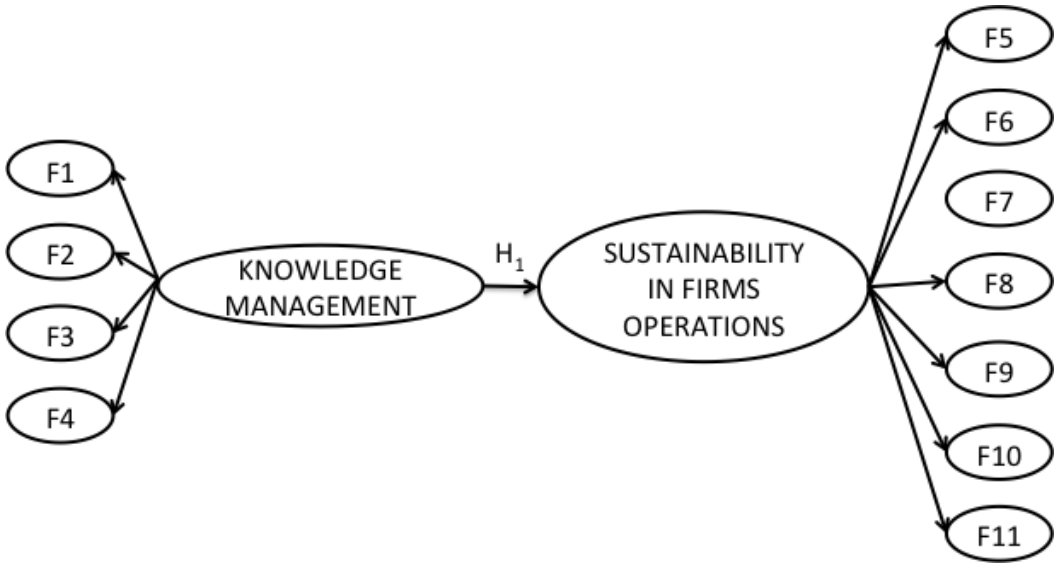

Figure 1 Path analysis of the theoretical model

Table 2 Operationalisation of KM and Sustainability in Operations

Constructs / Factors	**Items**
Knowledge Management:	
Workers training (F1 – BFT)	Provide formal training related to knowledge management
	Provide informal training related to knowledge management
	Use formal mentoring practices
	Encourage workers to continue their education by reimbursing tuition fees for successfully completed work-related courses
	Offer off-side training to workers in order

	to keep skills current
Policies and strategies of knowledge management (F2 – BPE)	Implement new ideas
	Support development of ideas
	Quick access to information
	Procedure support innovation
	Existence of a bureaucratic system
	Access number of database per second
	Access to information without any limitation
	Systems contain all knowledge
	Strategic definitions
	Number of patents
	R&D investments
	Technology investment
	Updating the database
Creation and acquisition of external knowledge (F3 – BKO)	Uses knowledge obtained from other industry sources
	Uses knowledge obtained from public research institutions
	Dedicates resources to obtaining external knowledge
	Uses the internet to obtain external knowledge
	Encourages workers to participate in project teams with external experts
Organisational culture effects (F4 – BOC)	Experienced workers or managers transfer their knowledge to new or less experienced workers
	Has a value system or culture promoting knowledge sharing
	Teamwork is encouraged
	Has an encouraging environment to develop and implement ideas and express opinions
Sustainability in Firms' Operations:	
Environmental management (F5 – PAA)	Greenhouse gas emissions
	Water conservation
	Carbon trading
	Investment in pollution-free technology
	Use of quantified environmental targets
	Other environmental management systems
	Waste management
	Disclose of CSR/TBL information
Customer focus (F6 – PEC)	Customer acquisition
	Customer retention
	Customer profitability
	Employee productivity
Product innovation (F7 – PIP)	Per cent sales from new product/services
	New products/service introduction

	Time to market with new product/service
	Length of cycle time from order to delivery
	Increase of market share
Process and employee effectiveness (F8 – PEP)	Information system capability
	Dollars spent for employee develop and train
	Online information flow systems
	Use of e-commerce
	Spending for new/improved process
Internal process improvement (F9 – PMP)	Reducing employee absenteeism
	Reducing number of customer complaints
	Incidents of defective products or services
	Number of incidents: employee health and safety
Social responsibility (F10 – PRS)	Community engagement/sponsorship
	Donations to community
Improvement of cash flow and finance (F11 – PMF)	Improved cash flow from operations
	Improve profit before tax from operations
	Sales growth
	ROI focused
	EVA focused

The instrument used based on the theoretical model (Figure 1), or measurement model, was evaluated in terms of its validity and reliability. The results are presented in Tables 3 and 4. The validity of the instrument was evaluated through a Confirmatory Factor Analysis (CFA) (Brown 2015), following the method of maximum likelihood and using the software EQS 6.1. Table 3 presents the results of the CFA evaluation, which included confirmation validity (convergent, content, discriminant) and reliability (Bagozzi and Yi 1990).

In the case of content validity, it was evaluated through examining the factor loads of the instrument. Bagozzi and Yi (1990) indicate that these should be > 0.60 to demonstrate convergent validity. Table 3, column 3, present the results (>0.6) and t-values greater than 2.54 (***). Consequently, this examination revealed convergent validity of the model with 99% confidence level (Hair et al. 2007).

Reliability, or data consistency of the theoretical model, was examined by carrying out a Cronbach's alpha test along with the calculation of the Composite Reliability Index (CRI). The results are presented in Table 3. The alphas and CRIs obtained were all > 0.070 as suggested by Bagozzi and Yi (1990), providing evidence of reliability on the scales employed in the theoretical model (Nunnally and Bernstein 1994; Bentler and Bonnet 1980).

Table 3 Convergent Consistency and Internal Validity of the Theoretical Model

Variable	Indicator	Factor Load	Robust t-value	Cronbach	IFC	EVI
Workers training (F1)	BFT1	0.970 ***	1	0.981	0.981	0.910
	BFT2	0.980 ***	78.878			
	BFT3	0.955 ***	52.727			
	BFT4	0.945 ***	48.783			
	BFT5	0.920 ***	36.028			
Policies and strategies of Knowledge Management (F2)	BPE1	0.764 ***	1	0.970	0.951	0.688
	BPE2	0.730 ***	36.147			
	BPE5	0.707 ***	16.246			
	BPE6	0.720 ***	18.535			
	BPE9	0.746 ***	12.686			
	BPE10	0.855 ***	14.348			
	BPE11	0.926 ***	13.896			
	BPE12	0.988 ***	15.114			
	BPE13	0.983 ***	14.657			
Creation and Acquisition of External Knowledge (F3)	BKO1	0.892 ***	1	0.965	0.965	0.847
	BKO2	0.893 ***	49.848			
	BKO3	0.949 ***	25.785			
	BKO4	0.955 ***	25.684			
	BKO5	0.912 ***	23.437			
Organizational and Cultural Effects (F4)	BOC2	0.935 ***	1	0.978	0.979	0.940
	BOC3	0.996 ***	37.236			
	BOC4	0.977 ***	35.118			
Environmental Management (F5)	PAA1	0.975 ***	1	0.973	0.994	0.918
	PAA2	0.980 ***	86.93			
	PAA3	0.918 ***	54.37			
	PAA4	0.872 ***	34.704			
	PAA5	0.843 ***	27.684			
	PAA6	0.827 ***	23.67			
Customer focus (F6)	PEC1	0.904 ***	1	0.946	0.964	0.817
	PEC2	0.884 ***	23.362			
	PEC3	0.944 ***	21.607			
	PEC4	0.890 ***	20.666			
Products Innovation **(F7)**	PIP1	0.912 ***	1	0.940	0.940	0.758
	PIP2	0.867 ***	30.689			
	PIP3	0.878 ***	27.341			
	PIP4	0.863 ***	23.632			
	PIP5	0.830 ***	20.852			
Process and Employees Effectiveness **(F8)**	PEP1	0.904 ***	1	0.941	0.937	0.748
	PEP2	0.896 ***	28.632			
	PEP3	0.909 ***	21.887			
	PEP4	0.848 ***	19.68			
	PEP5	0.759 ***	14.712			
Improvement of Internal Processes **(F9)**	PMP1	0.921 ***	1	0.925	0.921	0.797
	PMP2	0.918 ***	25.501			
	PMP3	0.836 ***	21.074			
Social Responsibility (F10)	PRS1	0.910 ***	1	0.943	0.944	0.807
	PRS2	0.949 ***	34.228			
	PRS3	0.902 ***	30.364			
	PRS4	0.829 ***	20.254			
Improvement of Cash Flow and Profits **(F11)**	PMF2	0.852 ***	4.39	0.948	0.953	0.870
	PMF3	1.000 ***	4.539			
	PMF4	0.941 ***	4.388			
$S\text{-}BX^2$ (df = 1218) = 3506.4772 $p < 0.000$; NFI = 0.820; NNFI = 0.863; CFI = 0.874; RMSEA = 0.079						
[a] = Parameters constrained to this value during the identification process						
*** = p < 0.01; ** = p < 0.05						

Additionally, two more tests were carried out in order to evaluate the discriminant validity of the model, specifically, the Extracted Variance test and the Confidence Interval test. The results of these tests presented in Table 4 confirmed the discriminant validity of the model. In general, these examinations provided evidence of a good adjustment of data from the theoretical model, where in order to verify discriminant validity the Extracted Variance Indexes (EVI) had values >0.5, as recommended by Fornell and Larcker, (1981) and as shown on the diagonal in Table 4.

Table 4 Discriminant Validity of the Theoretical Model

FACTORS	1	2	3	4	5	6	7	8	9	10	11
1	0.91	0.408	0.262	0.428	0.363	0.244	0.256	0.289	0.269	0.284	0.236
2	0.254-0.562	0.688	0.267	0.296	0.173	0.103	0.154	0.111	0.219	0.144	0.126
3	0.112-0.412	0.161-0.373	0.847	0.456	0.079	0.083	0.134	0.075	0.202	0.16	0.19
4	0.25-0.606	0.172-0.42	0.306-0.606	0.94	0.182	0.163	0.187	0.252	0.244	0.354	0.249
5	0.175-0.551	0.043-0.303	-0.079-0.237	0.008-0.356	0.918	0.413	0.429	0.355	0.44	0.424	0.361
6	0.1-0.388	0.015-0.191	-0.033-0.199	0.045-0.281	0.259-0.567	0.817	0.449	0.392	0.357	0.353	0.33
7	0.094-0.418	0.048-0.26	0-0.268	0.067-0.307	0.261-0.597	0.327-0.571	0.758	0.466	0.429	0.445	0.471
8	0.143-0.435	0.021-0.201	-0.047-0.197	0.122-0.382	0.203-0.507	0.262-0.522	0.33-0.602	0.748	0.494	0.406	0.389
9	0.117-0.421	0.105-0.333	0.072-0.332	0.118-0.37	0.286-0.594	0.225-0.489	0.291-0.567	0.352-0.636	0.797	0.565	0.492
10	0.118-0.45	0.036-0.252	0.014-0.306	0.208-0.5	0.256-0.592	0.207-0.499	0.287-0.603	0.252-0.56	0.393-0.737	0.807	0.624
11	0.066-0.406	0.01-0.242	0.032-0.348	0.085-0.413	0.177-0.545	0.174-0.486	0.257-0.685	0.223-0.555	0.26-0.724	0.388-0.86	0.87

Moreover, it was also possible to verify the model discrimant validity by analysing its confidence intervals (second test); these values are also presented in Table 4, below the diagonal. For this, each confidence intervals of every pair of variables should not contain the unit to demonstrate discriminant validity (Hair et al. 2007). As seen in Table 4, the confidence intervals did not posses the unit; consequently, it was possible to establish the appropriate variability of the model, as shown also by their co-variances values organised and presented above the diagonal (Table 4).

In summary, prior examination of the instrument used in this investigation, validating its appropriateness in terms of reliability and validity (Tables 3 and 4) allowed the possibility to run the hypothesis test with Structural Equations Modelling (SEM) to get also appropriate fit adjustments of the model and final results, as presented next.

4 Results

The literature review revelled a critical urgency for firms to improve sustainability in their operations to support the negative impact of these on the planet and society. For this reason, a new challenge for firms was determined to be the development of awareness for long-term sustainability. In addition, the literature also revelled the potential of KM frameworks to enable learning for innovation, and in consequence the overall business performance. However, the literature review also indicated the lack of quantification of the effect of KM on sustainability in operations. Thus, the hypothesis (H1) of this investigation was concerned with the measurement of the influence of KM to enhance sustainability in firms' operations, particularly, within the context of SMEs. To test the hypothesis, a model of structural equations was developed using the software EQS 6.1 (Bentler 2005; Byrne 2006; Brown 2015).

The results of the SEM analysis indicated that KM has a positive effect on the sustainability of firms' operations, with a standardised coefficient of 0.491 (i.e. $\beta = 0.491$, $p < 0.01$). The results are summarised in Table 5 and illustrated in Figure 2.

Table 5. Results from the Hypothesis Test using Structural Equation Modelling (SEM)

Hypothesis	Structural Relationship	Standardized Coefficient	Robust t value
H1: Knowledge management has a positive effect on sustainability in operations	KM → Sustainable Operations	0.491***	13.944
***S-BX*^{2} (df = 1192) = 3301.1376; p < 0.000; NFI = 0.831; NNFI = 0.871; CFI = 0.884; RMSEA = 0.077**			

Furthermore, from this analysis, using EQS 6.1, adequate fit indexes were examined (S-BX3301.1376: df=1192; p=0.000; NFI=0.831; NNFI=0.871; CFI=0.884; RMSEA=0.077), which basically indicate the nomological validity of the model,

referring to the extent to which the constructs maintained the relationships proposed by the theory (Bentler and Bonnet 1980; Byrne 2006; Hair et al. 2007; Heck 1998).

Figure 2 SEM Model

In general, the results obtained from this investigation add to sustainability management and KM frameworks, within the context of SMEs, by quantifying the influence that KM has onto sustainability in their firms' operations. As previously commented, the literature suggests long-term sustainability in operations through developed frameworks that could integrate social, economical and environmental areas (sustainable development). However, the literature showed limited research on how much KM can impact sustainability on firms operations. Addressing this gap, this investigation provided an SEM analysis approach measuring the relationship between KM frameworks and sustainability in operations. The quantification of such influence of KM onto sustainability operations adds to understanding KM potential, which represents a fundamental contribution to sustainability development in the area of business administration. Hence, offering insights regarding how KM frameworks can help developing awareness or knowledge for innovation, thus helping on the transformation required in firms operations to solve the planet's social, economic and ecological issues.

The literature and the results obtained from this research suggest that KM seems to be an alternative strategy to provide a collective solution to reduce the world's

negative - unsustainable impacts from all types of firms' contexts operations. Therefore, it is believed that the results from this investigation have a basic common to all firms' contexts in the sense that sustainability practices represent a priority now for which it is necessary to design operations differently, and for which KM offers a vision to possibly work on these issues.

5 Discussion

Business sustainability is critical to reach sustainable development targets in the medium and long-terms (Moldan, Janoušková, and Hák 2012). This is now becoming a major concern for the local and global industrial activity and its impact on environmental, social, and economical aspects. Evidence from this study suggests that KM enacts sustainability in firms' operations, and hence it can be used as one of the strategies to move towards a more sustainable industrial activity.

In this sense, firms need to integrate in their strategies these three fundamental aspects (Elkington 1997), since it is necessary to improve production systems under the current economic model in order to achieve sustainable operations in the long-term. This means that new business models should not only be able to provide sustainable operations in the whole production chain but also consider the integration of customers' demands and consumption patterns. As mentioned in the literature review, firms, and specially SMEs, require incorporating sustainability practices as a priority in their business models, their processes and products.

In agreement with Despeisse et al. (2012), firms are urged to adapt their operations and strategies. They have to be creative and innovative to meet the market demands with high quality goods in the most efficient way. In addition, firms that adopt sustainability practices may obtain a better reputation, which can result in high sales and better financial performance. Thus, SMEs can use sustainability as growth strategy. It is

also expected that customers will demand more sustainability characteristics from firms' operations as they are becoming more aware of the negative impacts of all sort of industry activities.

The literature review also showed the lack of research on KM and its association to sustainability in firms' operations. The results from this research indicate that besides contributing to the enabling of a more efficient use of resources, higher degree of innovativeness and better organisational performance (Rašula, Vukšić, and Štemberger 2012; Darroch 2005), KM also enables and has a positive effect on sustainability in firms' operations. This finding has an important implication to the endeavour of developing more sustainable production models; as this indicates that KM can offer processes and experiences to generate changes or innovations and promote creativity. These are resulting KM activities that in turn can address existing negative impacts to the environment. Better and positive effects are expected to the environmental world condition from sustainable operations, which appear to be derived from better comprehension/understanding of the firm's operations itself and a number creative ideas that can really innovate or transform operations into more sustainable ones; and innovation is precisely what KM seems to foster (Davenport and Glaser, 2002), 'creative ideas that have been made to work' (Hussey, 1997).

Another implication is the possibility that through developing KM capability firms can become more aware, and innovative, producing and improving processes and operational practices to enrich and systematically control production systems. This can also allow a systematic production of knowledge to support the continuous development of creativeness. Since creativeness is required to evolve into sustainable firms, a necessary transformation is calling for new products and processes that care for the environment, social and financial aspects together.

In the recent literature, KM has been considered as an innovation strategy (Carayannis, Sindakis, and Walter 2014) enabling continuous creation of knowledge and learning that is required to generate changes or improvements. In fact, a 'knowledge creating company' has been defined as a company that carries out a continuous renewal itself, by knowing what they want, where they are going and taking real action to succeed (Nonaka and Takeuchi 1995). Therefore, a similar knowledge-based business approach, monitoring continuous learning and openness to ideas, seems appropriate to generate the awareness, learning and actions necessary to thrive sustainability in firms' operations.

Firms have to decide which ideas to develop, so they need to value everyone's contribution to the company knowledge base, with continuous reflection, by challenging employees to re-examine what they take for granted. This also means that firms should continuously reinvent themselves, through a monitored systematic conversion of tacit knowledge into explicit knowledge, which based on the literature, promotes innovation. Managers should synthesise tacit knowledge so made it explicit to incorporate it into new sustainable products and processes. And firms require personal commitment and identity in this spiral of knowledge, which sometimes requires specific adjustments related to the dynamics of knowledge (Sorenson, Rivkin, and Fleming 2006; Andriessen 2006). For instance, people's interpretation of knowledge, proximity between people sharing knowledge, patent system, etc.

Basically, firms need to face the complexity of today's economic challenges by taking advantage of their most valuable resource, humans, and therefore, firms should not only be focused on processes and products but on the intangible force as foundation of the firms' capabilities (Marr and Schiuma 2001). Therefore, firms should pursue a systematic and continual assessment/monitoring of its knowledge assets, hence, firms

are forced to change the way they think, this means to consider the theory of evolution where firms are seen as living organisms that are never static but open and with a multiplicity of perspectives.

In general, this research indicates that KM enacts sustainability in firms' operations, specifically SMEs. Hence, firms should work on the spiral of knowledge, through continuously discovering, capturing, sharing and applying knowledge to integrate sustainability into their operations. For instance, firms need to consider looking for knowledge that is related to sustainable operations, such as, collective intelligence, best practices and ecological systems management. It is also important that firms improve teamwork to enhance knowledge sharing, and introduce activities like arts, as mentioned in the literature review. This is because KM activities can enrich, activate the creation and sharing and transforming tacit into explicit knowledge for the required transformations required to thrive sustainability in firms operations.

6 Concluding remarks, limitations and future research

This research argues the urgency to develop more sustainable production models. In this line, this study suggests that firms require a change of mind and to act responsibly by also integrating the environmental and social dimensions of sustainability into their strategies and business priorities. The results of this research indicate that KM can be employed as an effective strategy for firms to produce the necessary transformation towards more sustainable operations. Firstly, by making them aware of the negative impacts of their operations, and secondly, by supporting them with the adoption of new approaches and strategies that would allow them to integrate sustainable practices and technologies into their operations.

This investigation referred to some approaches and adjustments that attempt to conceptually represent a sustainable development. An insight identified in the literature

review was that KM processes and characteristics provide emphasis on continually creating awareness on individuals. Therefore, with the objective of supporting the development of a more sustainable operations model, this investigation tested the relationship and effect that KM has on the sustainability of firms' operations. This was done particularly within the context of manufacturing SMEs operating in the Aguascalientes region of Mexico. In this line, this research is among the very first studies that have investigated such relationship and effect. Therefore, this research contributes to theory of KM, sustainability and operations management through extending our knowledge in these fields by:

- Exploring and helping us to understand the relationship and effect that KM has on the sustainability of firm's operations;
- Quantifying the degree of strength of the relationship and effect of KM on the sustainability of firm's operations; and
- Explaining their given relationships and effects.

These contributions have significant practical implications for operations managers who aim to gain a better understanding of how effectively managing knowledge in their organisations can support the transformation of their firms' operations into more sustainable operations. Based on this improved understanding, operations managers will be able to take better decisions and formulate more effective strategies to make the operations of their organisations more sustainable. This will help their organisations in not only improving profitability but also contributing in tackling environmental and social challenges such as climate change, environmental degradation, natural resources scarcity and social inequality.

On the other hand, although this study was carried out within the context of manufacturing SMEs, it also has important practical implications for organisations operating in other industrial sectors. For instance, since organisations in sectors such as healthcare, services, logistics and transport, among many others, are also under governmental and social pressures to become more sustainable, they can also benefit from this research and its results. Similarly as the manufacturing sector, these other industries also need to respond to those pressures by appropriately balancing the profitability, environmental and social aspects of their business operations. The results of this study indicate that the implementation of KM frameworks can provide them with an opportunity to achieve this endeavour by generating a greater level of sustainability.

Generally, the paper provides some interesting insight into the relationship and effect of KM on the sustainability of firms' operations. This study can therefore serve as a platform to motivate and inspire organisations of all sizes, but in particular SMEs, not currently embarked on, or fully committed to, sustainability to consider the business benefits that KM may bring to their operations and business model.

However, firms need to know how to develop sustainability in their current operations. Thus, this study concluded that the first step is to become aware of the sustainability phenomenon, and then to enable specific changes and improvements in firms' operations than can derive through KM experiences in the firms' context. Accordingly, KM appears as a potential alternative to continuously, almost routinely, generate the required changes/innovations for sustainability in firms' operations. In this regards, the present investigation provides trustworthy evidence for practitioners and scholars alike of the positive effect of KM on the sustainability of firms' operations.

In terms of the limitations of this research study, it is important to mention that the sample taken for this research was limited to manufacturing, in particular, 60%

automotive, 20% textile and 20% furniture sector in the Aguascalientes region of México. Due to its reach and strong manufacturing industry, which is underpinned by the operations of both national and international large companies and SMEs, this region represented an excellent context for the conduction of this study. However, and due to this characteristic, the results must be treated with caution because of the possible imprecisions from this contextual limitation. Hence, to validate the results obtained in this study future research should broaden the data collection scope to other regions of Mexico, or even other countries, and also consider whether the studied organisations had already implemented sustainability systems and/or practices. This can also create the opportunity of regional factors to be taken into consideration, compare them with those of other regions and differentiate between companies that have already taken precise steps towards sustainability from those that are only intending to do so. Similarly, since the study was conducted within the boundaries of the manufacturing industry only, further research is needed to determine the relationship and effect of KM on the sustainability of firm's operations in other industrial sectors. This will contribute in providing further insights into the role that industry characteristics may have on the relationship of KM and the sustainability of firm's operations. Additionally, this research is also limited due to the Likert-style rating scale used for the survey as it limits the ability of respondents to pre-set answers, rather than providing them with the opportunity to freely express their views and opinions. For this reason, future research can be complemented with qualitative interviews with selected companies to overcome this limitation. This will also serve as a strategy to validate the results further. Finally, an important issue identified for further research is related to how to improve workers performance and interactions with KM initiatives, models and systems. And other problem that still remains unresolved is how firms can identify and select an effective

KM framework and/or system that can be contextualized for them in order the develop sustainability in their firms' operations. These are potential research streams that will take the present research further and are hence suggested as future research directions derived from this study.

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