# Linkage between knowledge management and manufacturing performance: a structural equation modeling approach

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**Abstract**

**Purpose** – *The purpose of this study is to examine the effect of knowledge management (KM) on manufacturing performance and the relationships among three KM measures, namely, knowledge resources, KM processes and KM factors. It also determined a collective set of KM metrics based on these three measures.*

**Design/methodology/approach** – *Data were collected using questionnaires posted to 700 manufacturing companies in Malaysia from which 206 usable responses were obtained. The analysis and hypotheses testing were implemented using structural equation modeling.*

**Findings** – *The results showed that the constructs of knowledge resources, KM processes and KM factors have significant and direct effects on manufacturing performance. In terms of covariance, the results also indicated that these three constructs were correlated with each other.*

**Research limitations/implications** – *The sample over-represented large firms and the study was a cross-sectional approach that collected data at a single point in time.*

**Practical implications** – *The results obtained would help managers to better understand the linkage between KM and manufacturing performance. They could use the results to manipulate their KM practices to improve their manufacturing performance. The proposed set of KM metrics could also act as a common language and provide directions for future research.*

**Originality/value** – *This paper is one of the first empirical studies that has examined the relationship between KM and manufacturing performance. Furthermore, it has investigated the relationships among knowledge resources, KM processes and KM factors.*

**Keywords** *Manufacturing performance, Knowledge management, Structural equation modeling, KM processes, KM factors, Knowledge resources*

**Paper type** *Research paper*

## Introduction

Knowledge, as a basis of competition, is the leading resource for business survival and development. Hence, knowledge management (KM) has become one of the foremost agendas in many companies. It is considered as a competitive strategy that can give multiple advantages to a company (Gunasekaran and Ngai, 2007). Organizations are increasingly implementing a range of KM initiatives to consolidate, expand and reconcile their knowledge assets (Grant, 1996). Accordingly, KM has been widely performed in various industries, including manufacturing.

Meanwhile, a lot of knowledge has been accumulated in the daily production of manufacturing companies. This includes product knowledge and manufacturing process knowledge (Wang *et al.*, 2010). Due to the increasing competitive pressure resulting from

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> **"An effectual KM Performance can bring a lot of benefits such as getting updated information for production, solving production problems in a shorter time, and improving product and process quality."**



the globalization of manufacturing activities and markets, manufacturing organizations have realized the importance of KM and adopted its practices with a view to increase their efficiency. Typically, manufacturing performance (MP) is critical to the success of these companies in which superior performance leads to improved competitiveness (Amrina and Yusof, 2011). To stay competitive, they have to regularly assess their MP. Even though KM and MP are crucial to manufacturing companies, information describing the linkage between these two entities is rare and scarce. Without understanding this linkage, effort aimed at achieving substantial competitiveness through KM practices may not bear fruit (Foray and Gault, 2003). The connection between KM and MP remains vague. Yet, the majority of previous studies focused on the relation between KM and organizational performance (Rasula *et al.*, 2012; Noruzy *et al.*, 2013) and the literature is apparently limited by the scarcity of empirical studies investigating the effect of KM on MP (Ganesh *et al.*, 2014). Due to these, organizations could be clueless on which KM aspects should be emphasized and implemented to associate with their MP.

In addition, there is a need to develop a more inclusive set of KM metrics that covers the crucial aspects of KM. To date, no researcher has developed a collective set of metrics which groups knowledge resources (KR), KM processes (KMP) and KM factors (KMF) together (Wong *et al.*, 2015). Moreover, the relationships among these categories of measures as well as their relationships with MP have not been examined. In response to the above, this paper seeks to identify the linkage between KM measures and MP to provide a clear picture of the relationships between them and the relationships among KM measures. Furthermore, this paper also intends to address the gaps of previous studies by determining a collective set of KM metrics according to three categories of measures (KR, KMP and KMF).

The paper begins with an overview on knowledge and KM. Then, a review on KM measures and MP is provided. Subsequently, hypotheses are formulated and the preliminary relational model is developed, followed by a description of the methodology used for conducting a survey. The next section presents the findings of the survey and the results of data analysis and hypotheses testing. A discussion of the overall results and implications of the study follows. The paper culminates with conclusions, together with limitations of study and future research directions.

## Knowledge and KM

Knowledge is derived from thinking and is a combination of information, experience and insight (Hu, 2009). Zack (1999) emphasized that organizations consider it to be their most valuable and strategic resource. Organizations need to manage their knowledge efficiently to enhance their performance, produce greater payoff and obtain a competitive advantage (Meso and Smith, 2000). Two types of knowledge are usually defined, namely, explicit and tacit knowledge. The former refers to codified knowledge, such as that found in documents, databases, etc., while the latter refers to skill, experience and "know-how" that is embedded in a person and cannot be easily shared.

According to Chow *et al.* (2005), KM can be regarded as a set of activities that enables the creation, storage, distribution and application of knowledge in organizations. It is the

process through which firms create and use their institutional or collective knowledge (Civi, 2000). Similarly, KM can be defined as a set of processes and activities that supports, facilitates and leverages the development and use of knowledge (Dalkir *et al.*, 2007). To track whether KM is enabling an organization to achieve its underlying objectives, KM measures and metrics are used as indicators or variables for measurement. According to Wong *et al.* (2015), KM measures are classified into three categories, namely, KR, KMP and KMF, as they are the main themes that researchers tend to evaluate by generating various appropriate metrics. The first category denotes the knowledge assets of an organization. The second category represents the processes that facilitate KM in an organization, while the third one signifies the elements that support and drive KM activities. The KM measures used in this study and their constituents are enumerated and described in the following section.

## Knowledge resources

### *Human capital*

Human capital embodies the collective value of employees' competence, as well as the knowledge embedded and captured from relationships with external parties (suppliers and customers). Competence of employees can be judged by their years of experience in the profession and education level (Pinto, 2013). The number of years in the profession is a simple and useful measure of the skill and experience of employees (Sveiby, 1997). Education level reflects the quality of their competence and thus the company's ability to achieve future success (Sveiby, 1997). Retaining employees to continue working for a company is crucial to prevent a loss of knowledge due to their departure (Bontis *et al.*, 2000). In addition, human capital also includes suppliers and customers as they are knowledge providers (Chong *et al.*, 2006). In short, human capital is the valuable knowledge asset, which is inherent in people and cannot be owned by an organization.

### *Knowledge and information capital*

Knowledge and information capital indicates the quantity and quality of knowledge owned by a company (Wong *et al.*, 2015). It is often stored in a company's data repository system in various forms and categories (Choo *et al.*, 2007; Lee and Van den Steen, 2010). Generally, it can be stored in either manual filing systems or hard drives of computers (Egbu *et al.*, 2005). In this technological era, computers should be provided adequately to aid the storing of knowledge. It is important to classify knowledge according to some categories or taxonomies in a repository (Davenport *et al.*, 1998). A higher number of taxonomies usually imply a higher amount of stored knowledge.

### *Intellectual property*

Another resource is intellectual property, which is viewed as the intellectual asset owned by a company and legally protected from outside use or implementation without consent (WIPO, 2004). According to Stewart (1997), it can be defined as the product or creation of a company either in the form of technology, service or knowledge that can be used to create wealth. Intellectual property drives competitiveness, provides revenues and encourages research and development activities for producing more quality knowledge and technologies within a company. It has been increasingly exploited as an organizational resource to generate alternative revenue streams (Clarke and Turner, 2004).

**"This study provides evidence linking KM to Manufacturing Performance which is beneficial for manufacturing companies."**

> **"The results show that KM Factors should be addressed at the outset because it will lay a strong and productive foundation or groundwork for organizations to manage their knowledge."**



## KM processes

### *Knowledge acquisition*

In terms of processes, knowledge acquisition is where workers gain, collect and obtain useful knowledge to perform their job activities. Acquiring knowledge from reliable and well-developed sources could help employees to handle the problems at work and improve their job performance. According to Kuah *et al.* (2012), new ideas and solutions may be imported into a company by acquiring knowledge externally. So, external knowledge sources like customers and suppliers are important and employees should, therefore, seek information from them if necessary (Gamble and Blackwell, 2001). Internally, useful knowledge can be attained from a company's repositories (Lyles and Schwenk, 1992; von Krogh *et al.*, 1994). Employees also rely on the Internet to acquire important work-related knowledge to perform their daily work (Lee and Lan, 2011). In addition, appropriate and essential training programs, workshops or seminars are another means for employees to gain new knowledge and expertise (Chen *et al.*, 2006; Lee and Lan, 2011).

### *Knowledge creation and generation*

Knowledge creation and generation is recognized as the process where new ideas, best practices or solutions are generated (Morey, 2001). Learning is the key input element in this process (Ng, 2008) whereby new knowledge is created by employees through a learning process. Creating new knowledge requires an organization and everyone to work in teams and be involved in a non-stop process of personal and organizational self-renewal (Nonaka, 1991). Perhaps the most famous method of knowledge creation in groups is brainstorming by gathering a list of ideas contributed by the members (Rollett, 2003). Besides this, rewards given to those who are able to create useful knowledge can build up an environment that encourages employees to generate more new knowledge for an organization (Liebowitz, 1999).

### *Knowledge utilization and application*

Knowledge utilization and application is to make good use of knowledge (O'Dell and Grayson, 1998). Employees can do this by applying and adopting the best practices in their daily tasks (O'Dell and Grayson, 1998). In addition, this process also means to put knowledge into practice, where employees should apply lessons learnt from previous cases, mistakes or experiences (Datta, 2007). Kuo (2011) has shown that companies should utilize existing organizational knowledge assets to enhance organizational learning and performance. Davenport and Klahr (1998) mentioned that the effective application and utilization of knowledge can assist companies to improve efficiency and reduce costs.

### *Knowledge storing and updating*

This process consists of codifying, storing, classifying, reviewing, updating and refining knowledge in an organization's repositories (Rollett, 2003; Shannak, 2009). Knowledge is meaningful when it is codified, put in a useful format and stored. This is not only vital for the effective use of knowledge but also important for re-using it when needed so that knowledge, especially tacit knowledge, is going to belong to the organization rather than

the knower (Nemati, 2002). Thus, employees are encouraged to contribute their knowledge to the company's repositories. Organizing and classifying knowledge adds value by establishing an appropriate structure and increasing the efficiency and effectiveness of retrieving knowledge (Rollett, 2003). Moreover, revising and updating the existing stored knowledge reduces redundancy, enhances consistent representation and minimizes obsolescence (Davenport and Klahr, 1998) so that the organizational knowledge is always up-to-date.

#### *Knowledge sharing and transferring*

Knowledge sharing and transferring is where tacit and explicit knowledge are disseminated throughout the whole organization. This process can be driven by formal and informal approaches such as meeting, discussion, mentorship, social network, collaboration and interaction. Interactive and effective meetings and discussions provide opportunities for sharing knowledge and learning. Through mentorship, experienced individuals can share their knowledge with newcomers or novices so that the newcomers become better equipped to meet future challenges (Swap *et al.*, 2001). Tacit knowledge is normally shared most effectively through personal interaction (Kuah *et al.*, 2012). Davenport and Prusak (1998) believed that the working knowledge in an organization is often transferred via social networks, collaboration and daily interaction whereby chatting, conversation and other less formal means are applied. In addition, technological tools such as groupware, e-mails, networking tools and others can certainly support and boost knowledge sharing (Tampoe, 1993).

#### *Knowledge protection*

This is described as a process where knowledge is secured from inappropriate, illegal use or from theft and loss with the use of feasible approaches. Knowledge protection is crucial to safeguard organizational knowledge, which is the critical resource that creates and sustains the competitive advantage of an organization (Nonaka and Takeuchi, 1995; Liebeskind, 1996). According to Bertino *et al.* (2006), organizations have to protect their intellectual assets from loss, unauthorized access or being stolen. Intellectual property rights have long been recognized for protecting knowledge (Xu and Tan, 2010). Investment in knowledge protection can prevent or limit outgoing knowledge flow that could hamper an organization's competitive advantage, especially when social media are widely used at the moment (Faria and Sofka, 2010).

### KM factors

#### *Culture*

Many studies have insisted that culture is a key driver of knowledge sharing (Chase, 1997). It is described as the shared value, belief or perception held by employees within an organization or organizational unit (Edwards, 1988). As stated by Long (1997), culture determines the value of knowledge in providing a competitive advantage for an organization. To promote KM, a collaborative climate where employees support and help each other in their tasks has to be fostered instead of a competitive climate (Sveiby and Simons, 2002). A culture that emphasizes trust is helpful to alleviate the issue of knowledge hoarding (Kankanhalli *et al.*, 2005). Successful KM requires employees to share their ideas,

**"This implies that the strategic aspect (KM Factors) should be addressed first before dealing with the operational issues (Knowledge Resources and KM Processes)."**

experiences and lessons learnt, and their mistakes without the fear of punishment (Disterer, 2001). A positive orientation to knowledge is indicated by employees who display not only intelligence but also curiosity and willingness to explore new possibilities (Disterer, 2001).

### *Management leadership and support*

Management leadership and support plays a key role in ensuring the success of almost any initiative within an organization. Top management needs to understand the importance of KM and provide proactive entrepreneurial support to the initiative (Wong and Aspinwall, 2005). In addition, it is important that top management acts as a role model in KM rather than just as a facilitator (Huysman and de Wit, 2003). Nevertheless, the costs of implementing it can be a significant barrier (Davis and Riggs, 1999). Hence, management should provide the necessary funding for knowledge infrastructure and establish the essential conditions for KM (Davenport *et al.*, 1998; Disterer, 2001). Many studies have suggested that incentive given by management plays a major role in the success of KM initiatives (Davenport *et al.*, 1998; Liebowitz, 1999; Massey *et al.*, 2002). It motivates employees to adopt KM practices especially in promoting knowledge creation and sharing in an organization.

### *Organizational infrastructure and technology*

In addition, organizational infrastructure and technology is required for KM to be successful (Davenport *et al.*, 1998; Liebowitz, 1999). Without it, the tasks of implementing KM activities and sharing information on a large scale will be difficult. Organizations should provide venues such as meeting rooms for employees to interact and discuss their work to facilitate KM (Chong *et al.*, 2011). As stated by Chong and Choi (2005), information systems have been identified as one of the most critical success factors in KM implementation. Accordingly, investment in developing and maintaining an information system is necessary. Technologies such as Internet, collaborative tools, content management systems and others can make an important contribution by connecting people with each other and enabling them to find useful information (Rollett, 2003). Ease of use and user-friendliness of an information system are especially important to gain acceptance among employees and to prevent them from abandoning it before they start to reap its benefits (Masterton and Watt, 2000).

### *Strategy*

A KM strategy is simply a plan that describes how an organization will manage its KR better for its benefit. In this respect, it is important to have a clear strategy and objectives for effective KM (Zack, 1999). The strategy needs to be communicated to all employees so that they are aware and ensure their personal intentions are coherent with their company's interests (O'Dell and Grayson, 2004; Storey and Barnett, 2000). While there should be a distinct KM strategy, it must of course be aligned with and firmly linked to the overall business strategy of an organization (Zack, 1999). Additionally, identifying the key business issue of an organization that relates to knowledge is an important part of implementing a KM strategy (Zack, 1999). It provides insights into the problems that should become the focus of the strategy before implementation.

## Manufacturing performance

In the manufacturing sector, it is imperative for companies to identify, evaluate and improve their MP, which is mainly related to their production and operational performance. According to Hon (2005), MP metrics are regularly used to monitor and manage operational efficiency, reflect the current state of manufacturing situations, drive improvement programs and gauge the effectiveness of manufacturing decisions. Based on the review of prior studies, El Mola and Parsaei (2010) summarized that the most commonly used MP metrics are quality, time and delivery, cost, flexibility and customer satisfaction.

## KM effect on MP and hypotheses development

As mentioned earlier, very little studies have analyzed the relationship between KM and MP. Therefore, this research aims to discover the linkage between these two aspects. Although there is a scarcity of prior studies which associate KM with MP, several studies that relate KM to performance have been found to support the hypotheses development.

Firstly, KR is composed of human capital, knowledge and information capital and intellectual property. West III and Noel (2009) stated that resources such as human capital and knowledge are connected to better firm performance because they provide the initial foundation for competitive advantage and lead to the development of other important resources. According to Ling (2013), she revealed that human capital is positively associated with organizational performance. Employees with expert skills and experience create value for their firms, while companies that value human capital tend to enjoy better shareholder return or market value. There is also evidence of a significant impact of knowledge capital on organizational performance (Lööf and Heshmati, 2002). Namvar *et al.* (2010) have proven that intellectual property significantly influences human capital, relational capital and structural capital, which are positively related to firm performance. For gaining more value from knowledge, intellectual property is essential for companies to stay competitive. Consequently, it is believed that KR will have a significant relationship with MP.

Secondly, KMP comprises knowledge acquisition, creation and generation, utilization and application, storing and updating, sharing and transferring and protection. Jennex (2005) believed that organizations will be more effectual if they capture, share, retain and reuse organizational knowledge to generate a successful business environment. In the study done by Noruzy *et al.* (2013), it showed that KMP has an effect on organizational performance through organizational innovation. Besides this, knowledge sharing has a significant impact on the effectiveness of supply chain management and product development in helping companies to achieve the desired business performance (Huang *et al.*, 2008). Chuang and Chang (2011) also verified that KMP significantly influences firm performance. Through KMP, managers can have more related information to come out with a more effective strategy to acquire the utmost benefits for their companies. Accordingly, it is suggested that KMP will have a significant relationship with MP.

Thirdly, KMF involves culture, management leadership and support, organizational infrastructure and technology and strategy. In the analysis conducted by Bagnoli and Vedovato (2014), it revealed that a significant coherence exists between KM and strategy, which in turn has a significant impact on the overall organizational performance. Findings also showed that KMF measured through information technology, culture, climate and collaboration positively affects organizational performance (Rasula *et al.*, 2012). Robinson *et al.* (2005) indicated that learning culture and KM strategy are imperative to enhance organizational performance and to keep a company innovative in its processes, products and technologies. Haque and Anwar (2012) posited that both information technology infrastructure and management support significantly enhance the overall performance of an organization. As a result, it is believed that KMF will also have a significant relationship with MP.

Apart from these, the covariances among KR, KMP and KMF will be explored in this research to gain further information on the relationships among them. Many scholars have attempted to measure KM by different models, but they have rarely considered these three categories jointly. Thus, it is interesting to test the relationships among the KM measures. Eventually, a total of six hypotheses have been formulated as below (see Figure 1):

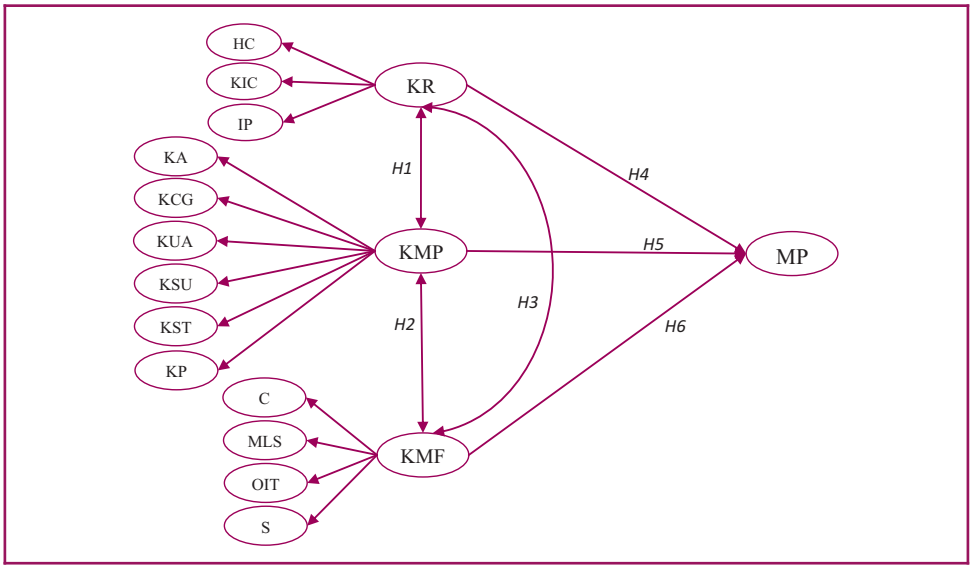
*H1*. The covariance between KR and KMP is significant.

*H2*. The covariance between KMP and KMF is significant.

*H3*. The covariance between KR and KMF is significant.

*H4*. KR has a significant and direct effect on MP.

**Figure 1** The schematic diagram of the relational model




*H5*. KMP has a significant and direct effect on MP.

*H6*. KMF has a significant and direct effect on MP.

All the measurement items and their constructs are listed in the Appendix.

## Survey and data collection

A survey questionnaire was designed to determine and understand the linkage between KM and MP. It was split into four main sections. The first section was to gain the general background information of a company, such as the size of the company, type of industry in the manufacturing sector, number of years implemented KM and department in-charge of KM. The second part investigated the critical metrics for measuring KM that were derived from the literature. Respondents were asked to rate the extent to which the metrics were practiced using a six-point scale (from 1 = not practiced at all, to 6 = very highly practiced). The third part explored the critical MP metrics, where respondents were also asked to indicate the current level of MP in their companies on a scale from 1 (no performance at all) to 6 (very high performance). The final section of the questionnaire sought additional information for the research, in particular examining the importance of KM in improving MP.

Before running the actual survey in Malaysia, the questionnaire has gone through a pilot test, which involved ten experts from the academia and industry to ensure the objectives of the questionnaire are clear, the questions are well-structured and understandable and the metrics are appropriate and adequate for measuring KM and MP. The academics have more than five years of experience in doing KM research, while the industry experts have more than five years of experience in practicing KM in manufacturing companies. Based on their comments and assessment, improvements have been made and incorporated into the questionnaire. After this, questionnaires together with covering letters explaining the purpose of the survey were posted to a total of 700 manufacturing companies selected randomly from the Federation of Malaysian Manufacturers directory. We requested the questionnaire to be completed by the key person in-charge of KM in the company. Of the 700 questionnaires sent out, 206 usable ones were obtained and the overall response rate was 29.4 per cent.

## Analysis and results

The first and fourth sections of the questionnaire were analyzed and the results are illustrated in Tables I-V. As can be seen in Table I, about 70 per cent of the respondent companies have more than 200 employees, which were classified as large organizations according to Small and Medium Enterprise Corporation Malaysia. Table II shows that the types of industry were diverse, with the electronics and electrical industry (26.2 per cent) being the major respondent, followed by food and beverage (17 per cent) and metal (15 per cent). In terms of the number of years for which KM has been implemented, the majority of the respondent companies have implemented it for more than 10 years (see Table III). From Table IV, the results depict that the human resource (HR), training and administration department was the main department in-charge of KM. Table V shows that all the respondents unanimously agreed that KM plays a crucial role in improving MP.

After analyzing the descriptive statistics, further analysis was conducted by using structural equation modeling (SEM) via the Analysis of Moment Structures (AMOS) software. SEM is capable of estimating a series of inter-relationships among latent constructs simultaneously in a model (Byrne, 2009). According to Kline (2005), as a rule of thumb, any sample size

**Table I** Size of company

| *Size* | *Frequency* | *(%)* |
|---|---|---|
| Small (<75 employees) | 22 | 10.7 |
| Medium (75-200 employees) | 39 | 18.9 |
| Large (>200 employees) | 145 | 70.4 |
| Total | 206 | 100.0 |

**Table II** Industry type of company in the manufacturing sector

| *Industry type* | *Frequency* | *(%)* |
|---|---|---|
| Electronics/electrical | 54 | 26.2 |
| Automotive | 18 | 8.7 |
| Food/beverage | 35 | 17.0 |
| Chemical/petrochemical | 19 | 9.2 |
| Machinery/equipment | 27 | 13.1 |
| Metal | 31 | 15.0 |
| Plastic | 15 | 7.3 |
| Others | 7 | 3.4 |
| Total | 206 | 100.0 |

**Table III** Number of years implemented KM

| *No. of years* | *Frequency* | *(%)* |
|---|---|---|
| < 5 | 6 | 2.9 |
| 5-10 | 81 | 39.3 |
| > 10 | 119 | 57.8 |
| Total | 206 | 100.0 |

**Table IV** Department in-charge of KM in the company

| *Department* | *Frequency* | *(%)* |
|---|---|---|
| Management level | 12 | 5.8 |
| HR/training/administration | 109 | 52.9 |
| IT/technical support | 26 | 12.6 |
| Others | 59 | 28.6 |
| Total | 206 | 100.0 |

**Table V** Perception on whether KM plays an important role in improving MP

| *Option* | *Frequency* | *(%)* |
|---|---|---|
| Yes | 206 | 100.0 |
| No | 0 | 0 |
| Total | 206 | 100.0 |

above 200 is understood to provide sufficient statistical power for data analysis in SEM. Apparently, the sample size of this study has met the minimum requirement. Basically, two types of models are involved in SEM analysis, namely, the measurement model and structural model. The former demonstrates the relationships between response items and their underlying latent construct, while the latter demonstrates the correlational or causal dependencies among the measurement models. In this study, the analysis was divided into three parts, which were the first-order confirmatory factor analysis (CFA) and second-order CFA for the measurement models, and the structural model analysis.

So, firstly, the measurement models have to go through the assessment of unidimensionality, reliability, validity and normality. Unidimensionality is achieved when the items have acceptable factor loadings that are 0.5 or higher (Hair *et al.*, 2006). Reliability is the extent to which the items are consistently measuring the intended latent construct. To satisfy the reliability criterion, a Cronbach's alpha value of more than or equal to 0.7 is required (Nunnally, 1994). The results of the unidimensionality and reliability analysis for all the constructs are shown in Table VI. Items which have factor loadings less than 0.5 were deleted and all the constructs were shown to be reliable.

Validity is the ability of a construct to measure what it is supposed to measure. Convergent validity and discriminant validity were checked for each construct. Convergent validity refers to the degree to which items that should be related are in reality related, while discriminant validity signifies the degree to which items that should not be related are in fact not related. For convergent validity, the composite reliability (CR) value must be more than or equal to 0.7 and the average variance extracted (AVE) value must be greater than or equal to 0.5 (Hair *et al.*, 2010). As shown in Table VI, all the constructs have fulfilled these two requirements. Discriminant validity is achieved when the square root of AVE for each construct is higher than the correlation coefficients among the constructs (Hair *et al.*, 2010). Referring to Table VII, this condition has been satisfied. In addition, the normality of the data at hand was examined. To achieve normality, the value of skewness should fall within the range of −1 to 1 (Coakes and Steed, 2009) and the value of kurtosis should be within the range of −3 to 3 (Balanda and MacGillivray, 1988). Table VIII exhibits that the data for every item have met the normality requirements.

Next, the second-order CFA was conducted for the first-order constructs of the study. It was used to confirm that the underlying measurement constructs loaded into their respective theorized construct (KR, KMP or KMF). In this respect, the factor loadings between the first-order constructs and second-order constructs must be higher than or equal to 0.5 (Hair *et al.*, 2010) and this condition has been fulfilled. The results of the second-order CFA are displayed in Table IX and the finalized models of the KR, KMP and KMF constructs are illustrated in Figure 2. The curved bi-directional arrow (as shown in Figure 2) represents the covariance or correlation between the indicated pair of measurement errors of the respective items due to redundancy. So, the correlated errors were set to be "free parameter estimates" using the double-headed arrow (Byrne, 2009).

The final stage was analyzing the correlational and causal relationships among the constructs simultaneously. To ensure the fitness of the structural model, the comparative fit index (CFI) must be more than or equal to 0.9 (Bentler, 1990), Tucker–Lewis index (TLI) must be more than or equal to 0.9 (Bentler and Bonett, 1980), Incremental fit index (IFI) must be more than or equal to 0.9 (Hu and Bentler, 1999), root mean squared error of

**Table VI** Results of unidimensionality, reliability and convergent validity analysis

| *First-order construct* | *Item* | *Factor loading (≥0.5)* | *Cronbach's alpha (≥0.7)* | *CR (≥0.7)* | *AVE (≥0.5)* |
|---|---|---|---|---|---|
| Human capital (HC) | HC1 | 0.788 | 0.707 | 0.710 | 0.551 |
| | HC2 | 0.694 | | | |
| Knowledge and information capital (KIC) | KIC1 | 0.807 | 0.791 | 0.793 | 0.562 |
| | KIC2 | 0.732 | | | |
| | KIC4 | 0.706 | | | |
| Intellectual property (IP) | IP1 | 0.633 | 0.896 | 0.889 | 0.670 |
| | IP2 | 0.900 | | | |
| | IP3 | 0.928 | | | |
| | IP4 | 0.781 | | | |
| Knowledge acquisition (KA) | KA1 | 0.701 | 0.828 | 0.829 | 0.549 |
| | KA2 | 0.756 | | | |
| | KA3 | 0.751 | | | |
| | KA4 | 0.754 | | | |
| Knowledge creation and generation (KCG) | KCG1 | 0.766 | 0.860 | 0.863 | 0.678 |
| | KCG2 | 0.854 | | | |
| | KCG3 | 0.847 | | | |
| Knowledge utilization and application (KUA) | KUA1 | 0.718 | 0.848 | 0.852 | 0.591 |
| | KUA2 | 0.814 | | | |
| | KUA3 | 0.834 | | | |
| | KUA4 | 0.700 | | | |
| Knowledge storing and updating (KSU) | KSU1 | 0.769 | 0.846 | 0.848 | 0.583 |
| | KSU2 | 0.840 | | | |
| | KSU3 | 0.719 | | | |
| | KSU4 | 0.720 | | | |
| Knowledge sharing and transferring (KST) | KST1 | 0.800 | 0.836 | 0.836 | 0.562 |
| | KST2 | 0.725 | | | |
| | KST3 | 0.733 | | | |
| | KST4 | 0.737 | | | |
| Knowledge protection (KP) | KP1 | 0.802 | 0.899 | 0.901 | 0.694 |
| | KP2 | 0.788 | | | |
| | KP3 | 0.863 | | | |
| | KP4 | 0.876 | | | |
| Culture (C) | C2 | 0.744 | 0.880 | 0.882 | 0.653 |
| | C3 | 0.804 | | | |
| | C4 | 0.863 | | | |
| | C5 | 0.816 | | | |
| Management leadership and support (MLS) | MLS1 | 0.846 | 0.909 | 0.915 | 0.685 |
| | MLS2 | 0.846 | | | |
| | MLS3 | 0.859 | | | |
| | MLS4 | 0.874 | | | |
| | MLS5 | 0.701 | | | |
| Organizational infrastructure and technology (OIT) | OIT1 | 0.645 | 0.822 | 0.830 | 0.623 |
| | OIT2 | 0.867 | | | |
| | OIT3 | 0.838 | | | |
| Strategy (S) | S1 | 0.767 | 0.921 | 0.923 | 0.751 |
| | S2 | 0.902 | | | |
| | S3 | 0.917 | | | |
| | S4 | 0.873 | | | |
| MP | Q | 0.695 | 0.856 | 0.862 | 0.556 |
| | TD | 0.773 | | | |
| | CT | 0.795 | | | |
| | F | 0.668 | | | |
| | CS | 0.787 | | | |

**Note:** Items with low factor loadings (<0.5) have been removed

approximation (RMSEA) must be less than or equal to 0.08 (Browne and Cudeck, 1993) and chi-squared per degree of freedom (Chisq/df) must be less than or equal to 5.0 (Marsh and Hocevar, 1985). The developed model has been proven to meet all the requirements and the results are shown in Table X. Hence, the model was utilized to test the hypothesized relationships among the constructs (see Figure 3). Hypotheses which have a significance value ($p$) of less than 0.05 were significant and accepted. Table XI shows the hypotheses testing results for the covariances among KR, KMP and KMF, while Table XII

**Table VII** Results of discriminant validity analysis

| *Construct* | *HC* | *KIC* | *IP* | *KA* | *KCG* | *KUA* | *KSU* | *KST* | *KP* | *C* | *MLS* | *OIT* | *S* | *MP* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HC | 0.742 | | | | | | | | | | | | | |
| KIC | 0.689 | 0.750 | | | | | | | | | | | | |
| IP | 0.455 | 0.579 | 0.819 | | | | | | | | | | | |
| KA | 0.527 | 0.545 | 0.360 | 0.741 | | | | | | | | | | |
| KCG | 0.374 | 0.494 | 0.416 | 0.668 | 0.823 | | | | | | | | | |
| KUA | 0.618 | 0.606 | 0.398 | 0.670 | 0.714 | 0.769 | | | | | | | | |
| KSU | 0.408 | 0.516 | 0.377 | 0.690 | 0.653 | 0.719 | 0.764 | | | | | | | |
| KST | 0.412 | 0.496 | 0.426 | 0.666 | 0.638 | 0.655 | 0.718 | 0.750 | | | | | | |
| KP | 0.432 | 0.443 | 0.408 | 0.579 | 0.615 | 0.628 | 0.655 | 0.603 | 0.833 | | | | | |
| C | 0.473 | 0.508 | 0.421 | 0.541 | 0.556 | 0.581 | 0.652 | 0.568 | 0.564 | 0.808 | | | | |
| MLS | 0.226 | 0.390 | 0.293 | 0.543 | 0.606 | 0.557 | 0.556 | 0.557 | 0.532 | 0.576 | 0.828 | | | |
| OIT | 0.394 | 0.468 | 0.388 | 0.495 | 0.532 | 0.565 | 0.563 | 0.455 | 0.594 | 0.587 | 0.659 | 0.789 | | |
| S | 0.354 | 0.449 | 0.395 | 0.442 | 0.434 | 0.504 | 0.471 | 0.442 | 0.454 | 0.525 | 0.650 | 0.666 | 0.867 | |
| MP | 0.600 | 0.685 | 0.568 | 0.730 | 0.682 | 0.713 | 0.737 | 0.731 | 0.722 | 0.728 | 0.684 | 0.722 | 0.702 | 0.746 |

**Note:** The square root of AVE value for each construct is printed along the diagonal, while the correlation coefficient between each pair of constructs is presented as the off-diagonal element

presents the hypotheses testing results for the causal effects of KR, KMP and KMF on MP. The results revealed that KR, KMP and KMF were significantly correlated with each other, and each of them has a significant and direct effect on MP. Therefore, *H1*, *H2*, *H3*, *H4*, *H5* and *H6* were supported and accepted.

## Discussion and implications

This study has applied the SEM approach to examine and prove the existence of a significant impact of KM on MP. As evident from the analysis conducted above, KR, KMP and KMF were found to have a significant effect on MP in the respondent companies in Malaysia. This signifies that the adoption of KR, KMP and KMF will directly increase the production performance of a company. The results are consistent with the findings from past studies. For instance, Kiessling *et al.* (2009) found that KM positively affects performance in terms of innovation, product improvement and employee improvement. In addition, Rasula *et al.* (2012) also verified that performance in the various aspects of finance, innovation and learning, supplier, customer, internal process and reputation is influenced by KM.

From the results, KMF is the seminal measure that contributes to MP improvement as it comprises critical factors that supply the necessary conditions for KM such as working environment, management support and organizational infrastructure, which could help to create an effective and efficient environment for production. The second important measure is KR. Particularly, employees and knowledge assets play the main role in performing and facilitating the daily manufacturing activities of a company. In fact, manufacturing companies with computerized-based machines require competent employees and useful knowledge assets to boost up their production performance and stay ahead of competitors. Without KR, it is difficult for these organizations to sustain their performance in the long term. The third significant measure is KMP. An effectual KMP can bring a lot of benefits such as getting updated information for production, solving production problems in a shorter time, and improving product and process quality. Hence, these three KM measures definitely have a positive effect on MP.

In addition, the analysis results also revealed that KR, KMP and KMF were significantly correlated with each other and could be grouped under KM. So, a newly defined model that consists of these three empirically tested constructs has been derived from the literature and justified using SEM.

In terms of managerial implications, this study provides evidence linking KM to MP, which is beneficial for manufacturing companies. It attests the notion that KM is a means to

**Table VIII** Results of normality assessment

| *Item* | *Skewness value* | *Kurtosis value* |
|---|---|---|
| HC1 | −0.163 | −0.167 |
| HC2 | −0.113 | −0.129 |
| KIC1 | −0.372 | −0.220 |
| KIC2 | −0.292 | 0.696 |
| KIC4 | −0.457 | −0.493 |
| IP1 | −0.768 | 1.189 |
| IP2 | −0.722 | 0.857 |
| IP3 | −0.479 | 0.462 |
| IP4 | −0.648 | 0.733 |
| KA1 | 0.055 | −0.314 |
| KA2 | −0.201 | −0.167 |
| KA3 | −0.041 | −0.518 |
| KA4 | −0.149 | −0.386 |
| KCG1 | −0.072 | −0.135 |
| KCG2 | 0.030 | −0.424 |
| KCG3 | 0.083 | −0.725 |
| KUA1 | 0.077 | −0.506 |
| KUA2 | 0.017 | −0.580 |
| KUA3 | −0.214 | 0.008 |
| KUA4 | −0.432 | −0.160 |
| KSU1 | 0.126 | −0.497 |
| KSU2 | 0.137 | −0.270 |
| KSU3 | 0.023 | −0.356 |
| KSU4 | 0.050 | −0.214 |
| KST1 | −0.281 | 0.093 |
| KST2 | −0.238 | −0.196 |
| KST3 | −0.357 | 0.119 |
| KST4 | −0.193 | −0.454 |
| KP1 | −0.267 | −0.031 |
| KP2 | −0.315 | −0.068 |
| KP3 | 0.099 | −0.667 |
| KP4 | −0.283 | −0.599 |
| C2 | −0.522 | 1.014 |
| C3 | −0.089 | −0.309 |
| C4 | 0.054 | −0.565 |
| C5 | 0.014 | −0.448 |
| MLS1 | −0.128 | −0.323 |
| MLS2 | −0.169 | −0.354 |
| MLS3 | −0.080 | −0.345 |
| MLS4 | −0.069 | −0.127 |
| MLS5 | −0.245 | −0.066 |
| OIT1 | −0.116 | −0.262 |
| OIT2 | −0.375 | 0.497 |
| OIT3 | −0.181 | −0.398 |
| S1 | 0.319 | −0.006 |
| S2 | −0.181 | 0.121 |
| S3 | −0.110 | −0.130 |
| S4 | −0.057 | −0.366 |
| Q | −0.552 | 0.391 |
| TD | −0.425 | 0.044 |
| CT | −0.305 | −0.525 |
| F | −0.037 | −0.492 |
| CS | −0.343 | −0.636 |

improve production performance. It also offers a general guideline for managers to implement KM and provides a direction on what elements should be included in the implementation process to improve MP. The results show that KMF should be addressed at the outset because it will lay a strong and productive foundation or groundwork for organizations to manage their knowledge. It is an enabler of KM and a precursor of KR and KMP. Without it, KR and KMP will not be viable. This implies that the strategic aspect (KMF) should be addressed first before dealing with the operational issues (KR and KMP). By utilizing this guideline, it is believed that the path toward implementing KM in manufacturing

**Table IX** Factor loadings between first-order constructs and second-order constructs in the second-order CFA

| *Second order construct* | *First order construct* | *Factor loading (≥0.5)* |
|---|---|---|
| KR | HC | 0.744 |
| | KIC | 0.932 |
| | IP | 0.618 |
| KMP | KA | 0.806 |
| | KCG | 0.809 |
| | KUA | 0.842 |
| | KSU | 0.854 |
| | KST | 0.810 |
| | KP | 0.748 |
| KMF | C | 0.693 |
| | MLS | 0.812 |
| | OIT | 0.828 |
| | S | 0.793 |

**Figure 2** Finalized models of KR, KMP and KMF constructs in the second-order CFA

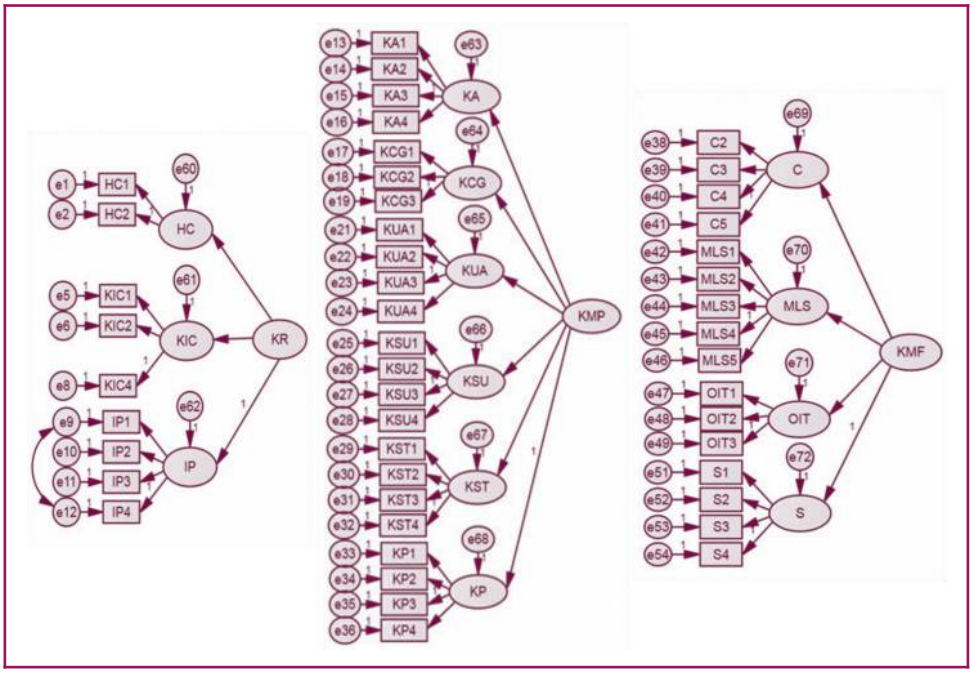



**Table X** Fitness indexes of the overall model

| *Name of index* | *Index value* | *Comment* |
|---|---|---|
| CFI (≥0.9) | 0.932 | The required level is achieved |
| TLI (≥0.9) | 0.928 | The required level is achieved |
| IFI (≥0.9) | 0.932 | The required level is achieved |
| RMSEA (≤0.08) | 0.043 | The required level is achieved |
| Chisq/df (≤5.0) | 1.382 | The required level is achieved |

organizations will be effective and this will, consequently, enhance MP. From the study, a comprehensive set of critical KM metrics rooted in KR, KMP and KMF has also been identified. From a practical standpoint, this set of metrics serves as a holistic measurement tool for managers. By using it, they will have a clearer picture of which elements should be measured to reflect KM performance. As companies may not be able to manage everything

**Figure 3** The finalized model of the study

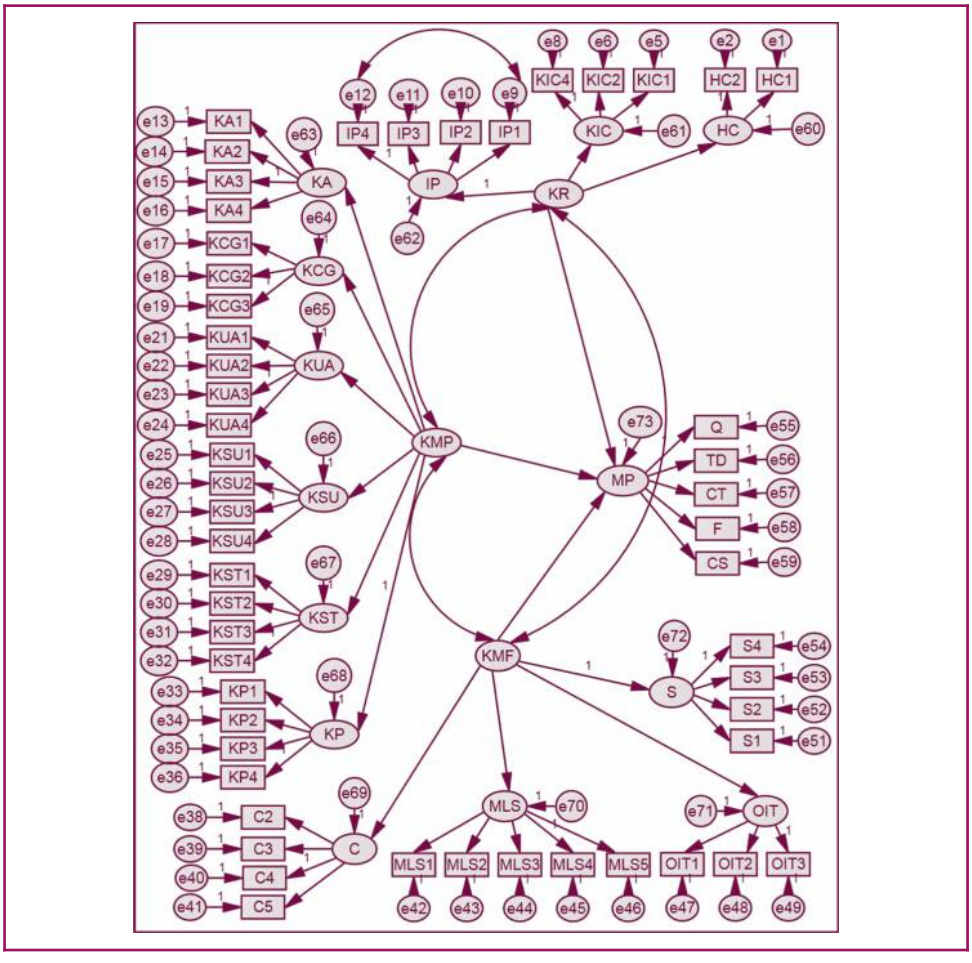



**Table XI** Hypotheses testing results for the covariances among KR, KMP and KMF

| *Hypothesis* | *Beta value* | *p-value* | *Comment* |
|---|---|---|---|
| *H1*: KR <—> KMP | 0.266 | *** | Significant |
| *H2*: KMP <—> KMF | 0.315 | *** | Significant |
| *H3*: KR <—> KMF | 0.222 | *** | Significant |

Note: ***Indicates highly significant at the 0.001 level (two-tailed)

**Table XII** Hypotheses testing results for the causal effects of KR, KMP and KMF on MP

| *Hypothesis* | *Beta value* | *p-value* | *Comment* |
|---|---|---|---|
| *H4*: KR —> MP | 0.259 | 0.002 | Significant |
| *H5*: KMP —> MP | 0.198 | 0.040 | Significant |
| *H6*: KMF —> MP | 0.422 | *** | Significant |

Note: ***Indicates highly significant at the 0.001 level (two-tailed)

at the same time, this study also provides a hint for them to prioritize and adjust their KM facets to effectively improve their production performance.

With respect to theoretical contributions, this study represents a pioneer and meaningful empirical examination on the relationship between KM and MP, as past studies tended to

focus on the linkage between KM and organizational performance. It substantiates the role of KM as an antecedent of MP and enriches the understanding of researchers on the connection between these two concepts. Moreover, the proposed set of KM metrics can also act as a common language in the field of KM measurement and provide new perspectives for future research in this area.

## Conclusions

Recognizing the importance of KM, many organizations including manufacturing companies have practiced it. However, its connection with MP is still vague and ambiguous. Findings on the interaction between KM and MP are surprisingly scarce. Thus, organizations may be clueless on how to manipulate their KM aspects to improve their production performance. Hence, this study has been conducted to address these issues.

Initially, a collective set of KM metrics was derived from the literature and six hypotheses were formulated. A preliminary model was established to give a rough picture of the relationships among the constructs. Then, a survey was carried out and a total of 206 usable questionnaires were collected from the manufacturing companies in Malaysia. The first stage of data analysis was executed to summarize the descriptive statistics for the respondent companies. The second stage was the SEM analysis, which entailed the running of the first-order CFA, execution of the second-order CFA and analysis of the structural model. The results showed that the covariances among KR, KMP and KMF were significant and they were closely related to each other. In addition, KR, KMP and KMF have significant and direct effects on MP. In short, this study has provided better insights into the relationships among KM measures and their linkages with MP.

In terms of limitations, the sample used in this study was over-representing large organizations with more than 200 employees. Thus, it might not be reflective of small and medium companies that also play an important role in the manufacturing sector. Although the sample size has met the minimum requirement for SEM, a larger number of respondents would probably yield a more accurate finding. Due to time and cost constraints, this research has utilized the cross-sectional design, where data were collected at a single point in time and analyzed through statistical techniques. Future studies can consider the longitudinal design and collect data through in-depth interview and observation.

Future research can also replicate this study in different geographical contexts. This is because manufacturing companies in other countries may provide different results due to dissimilarities in terms of working culture and practices. Finally, future studies can consider exploring the relationships between KM and other performance measures such as leanness and agility.

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## Appendix

**Table AI** KM constructs and their related metrics

*Knowledge resources (KR)*
Human capital (HC)
- HC1: Years of experience of employees in the profession
- HC2: Education level of employees
- HC3: Retention rate of employees in the company*
- HC4: Number of customers or suppliers.*

Knowledge and information capital (KIC)
- KIC1: Number of computers in the company
- KIC2: Number of knowledge categories or taxonomies in knowledge repositories
- KIC3: Amount of knowledge stored in traditional or manual filing systems*
- KIC4: Amount of knowledge stored in computers

Intellectual property (IP)
- IP1: Number of intellectual properties (patents, trademarks, copyrights, etc) owned
- IP2: Number of successful products launched
- IP3: Number of new technologies
- IP4: Revenue generated from intellectual properties

*Knowledge management processes (KMP)*
Knowledge acquisition (KA)
- KA1: Employees acquire knowledge from customers or suppliers
- KA2: Employees acquire knowledge from the company's knowledge repositories
- KA3: Employees acquire knowledge from the internet or world wide web
- KA4: Employees acquire knowledge from trainings, workshops or seminars

Knowledge creation and generation (KCG)
- KCG1: Employees create new knowledge, ideas or solutions related to their tasks
- KCG2: Employees participate in brainstorming sessions to create new knowledge
- KCG3: Employees work in teams to create new knowledge
- KCG4: Rewards are given to employees who create new knowledge*

Knowledge utilization and application (KUA)
- KUA1: Employees apply the best practices in their tasks
- KUA2: Employees apply knowledge from previous cases to solve problems
- KUA3: Employees apply the existing knowledge assets to generate value
- KUA4: Employees apply lessons learnt from mistakes or experiences

Knowledge storing and updating (KSU)
- KSU1: Employees spend time to codify and store knowledge in the company's knowledge repositories
- KSU2: Employees organize and classify knowledge for ease of retrieval
- KSU3: Employees update the stored knowledge
- KSU4: Employees are willing to contribute knowledge to the company's knowledge repositories

Knowledge sharing and transferring (KST)
- KST1: Employees participate in meetings, discussions or other knowledge sharing activities
- KST2: Employees use technological tools (groupware, e-mails, networking tools, etc) to share knowledge
- KST3: Mentorship is encouraged in the company
- KST4: Employees share knowledge through collaboration and interaction with each other

Knowledge protection (KP)
- KP1: Knowledge is protected from loss
- KP2: Knowledge is protected from unauthorized access or being stolen
- KP3: Knowledge is protected via intellectual property rights
- KP4: Investment is given for knowledge protection

*Knowledge management factors (KMF)*
Culture (C)
- C1: Employees support and help each other in their tasks*
- C2: Employees trust each other in sharing knowledge
- C3: Employees share mistakes without the fear of punishment
- C4: Employees are empowered to explore new possibilities
- C5: Employees are encouraged to share ideas, experiences and lessons learnt

Management leadership and support (MLS)
- MLS1: Top management understands and supports KM
- MLS2: Top management gives financial support for knowledge infrastructure
- MLS3: Leaders act as role models in KM
- MLS4: Top management establishes the necessary conditions for KM
- MLS5: Incentives are given to encourage employees for practicing KM

(*continued*)

**Table AI**

Organizational infrastructure and technology (OIT)
OIT1: The company has sufficient meeting or discussion rooms
OIT2: Investment is given to develop and maintain the information systems
OIT3: The information systems are user friendly and effective
OIT4: Technologies (internet, collaborative tools, content management systems, etc) are applied to facilitate KM*
Strategy (S)
S1: Employees are aware and supporting the company's KM strategy
S2: The company has clear objectives and goals for KM
S3: The KM strategy is aligned with the company's strategy
S4: The KM strategy is supporting a vital business issue

*Manufacturing performance (MP)*
Q: Quality
TD: Time and delivery
CT: Cost
F: Flexibility
CS: Customer satisfaction

**Note:** *Indicates items that have been removed due to low factor loadings (<0.5)


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