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The impact of lean manufacturing practices on operational and financial performance: the mediating role of agile manufacturing

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Abstract

Purpose – This empirical study aims to explore the link between lean manufacturing practices (total quality management, just-in-time production, just-in-time purchasing, total productive/preventive maintenance), agile manufacturing, and operational and financial performance.

Design/methodology/approach – Data were collected from 205 Tunisian manufacturing firms, and the results were analyzed using structural equation modeling.

Findings – The results indicate that (1) lean manufacturing practices have a direct positive relationship with agile manufacturing except for just-in-time production, (2) agile manufacturing has a positive impact on operational performance and (3) lean manufacturing practices did not seem to contribute directly to operational performance. However, this relationship is significant when it is mediated through agile manufacturing.

Research limitations/implications – This paper shows practitioners the importance of lean manufacturing practices to support agile manufacturing and the key role of agile manufacturing to ensure operational performance.

Originality/value – This paper presents an innovative approach since it studies simultaneously the three dimensions of lean manufacturing and their relationship with agile manufacturing and organizational performance.

Keywords Agile manufacturing, Total quality management, Just-in-time purchasing, Just-in-time production, Total productive/preventive maintenance, Organizational performance

Paper type Research paper

1. Introduction

Increasing globalization, uncertain environment, rapid technological development and competitive pressures force manufacturers to adopt different practices and tools to improve manufacturing processes, operations and their supply chains. Manufacturers have adopted first lean practices such as just-in-time (JIT), total quality management (TQM) and total productive/preventive maintenance (TPM) to attain high degree of productivity and quality through waste elimination (Inman *et al.*, 2011). Such practices are necessary but insufficient to adapt continuously to a complex, turbulent and uncertain environment (Yusuf and Adeleye, 2002). Against this new competitive background, many firms have adopted new improvement initiatives like agile manufacturing (AM) (Vazquez-Bustelo *et al.*, 2007; Inman *et al.*, 2011; Iqbal *et al.*, 2018, etc.). Agile manufacturing is considered as the aptitude of an organization to adapt rapidly to environmental changes (Gunasekaran, 1999; Yusuf, *et al.*, 1999; Charbonnier, 2011) and to meet quickly the ever changing customer requirements (Jin-Hai, *et al.*, 2003). As a result, many studies focus on the principal enablers and drivers for agile manufacturing such as turbulent environment (dynamism, competition, hostility)

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(Yusuf *et al.*, 1999, 2002; Zhang and Sharifi, 2007; Vazquez-Bustelo *et al.*, 2007), the company's strategy (Hallgren et Olhager, 2009; Charbonnier, 2011) and lean manufacturing (LM) practices (Inman *et al.*, 2011; Narasimhan *et al.*, 2006). Existing literature review reveals development towards the relationship between lean manufacturing and agile manufacturing (Iqbal *et al.*, 2018; Zelbst *et al.*, 2010). However, the amount of existing research is limited, and there are some gaps and a little focus on the direct and indirect effects of lean manufacturing practices and agile manufacturing on organizational performance. This can be explained by the non-inclusion of some principal practices (Iqbal *et al.*, 2018) like TQM and TPM elements (Inman *et al.*, 2011).

Therefore, further improvement is needed in order to respond particularly to the following research questions:

(1) What is the nature of the relationship between lean manufacturing practices and agile manufacturing?

(2) How are lean manufacturing practices related (directly/indirectly) to organizational performance?

(3) How are lean manufacturing practices interrelated?

(4) What is the relationship between agile manufacturing and organizational performance?

The main aim of this paper is thus to investigate the impact of lean manufacturing practices (JIT-production, JIT-purchasing, TQM and TPM) on agile manufacturing. We also explore the impact of lean manufacturing practices and agile manufacturing on operational performance (OP) and financial performance (FP).

We conducted a survey for Tunisian manufacturing firms to collect data necessary to assess the proposed model using a structural equation methodology.

The remainder of this paper is structured as follows: in the next section, a review of relevant literature is followed by theoretical background and hypotheses development. The subsequent sections present the methodological details and statistical outcome. Finally, discussion of the findings and conclusion of this research are presented.

2. Literature review and hypotheses formulation

It is widely recognized that lean manufacturing practices and agile manufacturing contribute to improved business performance (Shah and Ward, 2003; Vazquez-Bustelo *et al.*, 2007; Zelbst *et al.*, 2010; Inman *et al.*, 2011, Iqbal *et al.*, 2018, etc.). Several studies reveal that there is a relationship between lean manufacturing practices and agile manufacturing that can lead to different effects on business performance. Recent researchers highlight the complexity of the relationship between lean manufacturing practices and agile manufacturing. Existing literature states that there are three general positions regarding the relationship between lean manufacturing and agile manufacturing: (1) lean and agile as mutually exclusive concepts, (2) lean and agile as mutually supportive concepts and (3) lean as antecedent to agility (Krishnamurthy and Yauch, 2007; Inman *et al.*, 2011). Most of the studies adopted the last view and argued that lean must be a precursor to agile manufacturing (Narasimhan *et al.*, 2006; Inman *et al.*, 2011; Iqbal *et al.*, 2018).

Agile manufacturing can be achieved through the incorporation and utilization of existing managerial and manufacturing systems and methods (Vazquez-Bustelo *et al.*, 2007) such as lean manufacturing (Gunasekaran, 1999), JIT and TQM (Jin-Hai *et al.*, 2003).

Agile manufacturing is considered as the next logical step or a logical progression from existing manufacturing systems (Gunasekaran, 1999) such as mass production and lean production (Jin-Hai *et al.*, 2003). Several authors, as cited by Vazquez-Bustelo *et al.* (2007), consider that agile manufacturing is based on elements of existing systems, like lean manufacturing, or on improved versions of them (Vazquez-Bustelo *et al.*, 2007; Jin-Hai *et al.*, 2003). Results found by Narasimhan *et al.* (2006) support this assumption and assert that lean manufacturing is an antecedent to agile manufacturing. They state that "the pursuit of agility might presume leanness, pursuit of leanness might not presume agility." Similarly, recent studies adopt the idea that lean practices are considered as an antecedent to achieving agility (Zelbst *et al.*, 2010; Inman *et al.*, 2011; Iqbal *et al.*, 2018). Their results indicate that lean practices (JIT, TQM) have a positive impact on agile manufacturing (Zelbst *et al.*, 2010; Inman *et al.*, 2011).

Despite the fact that lean manufacturing has frequently been promoted as a means of improving agile manufacturing development/implementation, little empirical evidence exists in the literature validating the positive link between lean manufacturing practices and agile manufacturing. There exist only a few articles that deal with the impact of each practice on agile manufacturing (Zelbst *et al.*, 2010; Inman *et al.*, 2011; Iqbal *et al.*, 2018).

Shah and Ward (2003) identified four principal practices (bundles) of lean manufacturing: just-in-time, total quality management, total preventive maintenance and human resource management. The literature did not include some principal practices of lean manufacturing in investigating the relationship between lean manufacturing practices and agile manufacturing. Existing studies discuss only the impact of JIT and TQM on agile manufacturing (Inman *et al.*, 2011; Iqbal *et al.*, 2018). Inman *et al.* (2011) examined the impact of JIT (production and purchasing) on agile manufacturing. Zelbst *et al.* (2010) studied the direct effect of TQM on agile manufacturing and the indirect effect of JIT on agile manufacturing through TQM. Iqbal *et al.* (2018) examined the impact of JIT and TQM on agile manufacturing. To narrow the gap in the literature, our study purports to include the effect of TPM on agile manufacturing. Thus, we aim to explore the lean manufacturing practices (JIT, TQM and TPM) relationship with agile manufacturing.

This research aims to continue the study of Inman *et al.* (2011), Zelbest *et al.* (2010) and Iqbal *et al.* (2018).

The theoretical model is proposed in Figure 1.

2.1 TQM and agile manufacturing

Authors reveal that the implementation of the TQM is an essential element to support agile manufacturing (Zelbest *et al.*, 2010; Bottani, 2010; Narasimhan *et al.*, 2006). Bottani (2010) noted that TQM is one of the enablers of agile manufacturing. Brown and Bessant (2003) argue that lean manufacturing practices such as TQM provide a vital foundation for the development of agile manufacturing capabilities. TQM can be viewed as a management approach that seeks continuous improvement in all functions of an organization (Kanyak, 2003) in order to improve product/service quality and meet customer expectations. TQM dimensions help the companies to create an environment which can support the implementation of agile manufacturing (Zelbest *et al.*, 2010). For example, "customer focus" (principal practice of TQM) allows meeting customer requirements efficiently and quickly (Youssef *et al.*, 2002). This practice is also a basic principle of agile manufacturing. Youssef *et al.*'s (2002) results indicated a positive correlation between TQM and the capacity of companies to meet the customer requirements quickly.

The relationship between TQM and agile manufacturing can be explained by other practices such as "employees participation and training" and "continuous improvement" (Narasimhan *et al.*, 2006). These practices allow the employees to be up-to-date with the latest developments and technological progress. The participation of the employees and the continuing education will enable them to adapt more easily to the environmental changes. Such flexibility is essential to ensure a high level of agile manufacturing. Several studies argue that skills development (the capacities of the employees to adapt to the changes and to

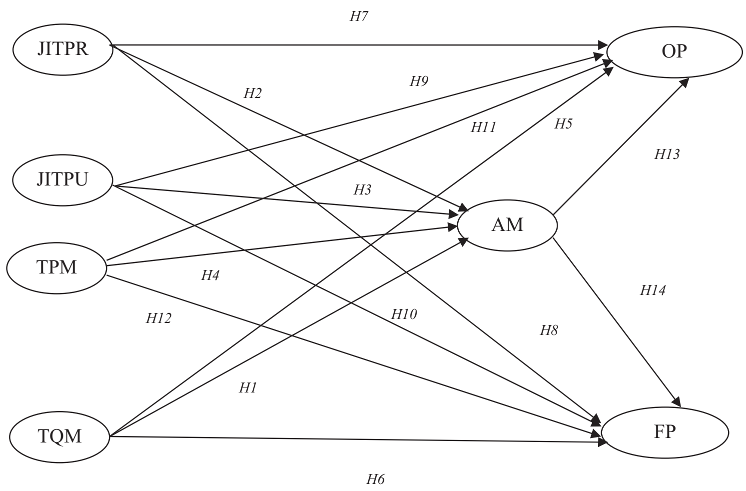


Figure 1.
Theoretical model

react quickly) constitutes a principal element of agile manufacturing (Lin, *et al.*, 2006; Charbonnier-vorin, 2011).

A review of the literature supports the positive bond between TQM and agile manufacturing. Zelbest *et al.* (2010) concluded that the implementation of the TQM is a necessary "precursor" for agile manufacturing. They found out that the TQM has a significant positive impact on agile manufacturing, and hence they concluded that the implementation of TQM is necessary for agile manufacturing. Iqbal *et al.* (2018) have also found out that the effective establishment of TQM practices is positively associated with ensuing agile manufacturing practices. According to what has been stated above, we can state the following hypotheses:

H1. TQM influences positively agile manufacturing.

2.2 JIT (Purchasing and production) and agile manufacturing

JIT is regarded as a "subset" of lean manufacturing. It is identified as one of the four important lean manufacturing bundles (Shah and Ward, 2003). As stated previously, agile manufacturing is based on lean manufacturing practices, and it encompasses lean technique (Kidd, 1995). Several authors recognized that some elements are required to apply and develop agile manufacturing (e.g. JIT-production) (Gunasekaran *et al.*, 1998; Vazquez-Bustelo *et al.*, 2007).

JIT is a comprehensive approach based on the notion of eliminating all forms of waste in the manufacturing process (Sakakibara *et al.*, 1993).

It is a "*process and delivers finish goods just-in-time to be sold, components just-in-time to be assembled into finished goods and materials bought just-in-time to be converted into components*" (Nollet *et al.*, 1994). Mehra and Inman (1992) identified two principal elements of JIT: JIT-production (JITPR) and JIT-purchasing (JITPU). JIT-production, as cited by Inman *et al.* (2011), is considered as a manufacturing system based on the identification and the elimination of all forms of waste throughout the production process (Brox and Fader, 2002). However, the JIT-purchasing is considered as a set of methods and techniques which eliminate waste and inefficiency throughout the purchasing process (Freeland, 1991). The principal assumption of JIT is that an organization can benefit from coordination between the production process and the purchase planning process (Kannan and Tan, 2005). Its aim is to provide products “just-in-time” in order to meet the customer’s requirements quickly and to increase the reactivity of the company. Such reactivity is an essential element for agile manufacturing.

Gunasekaran (1998) concluded that JIT can be appropriate to facilitate quick response manufacturing, and thus it may be used to achieve agility.

A number of researchers support the positive relationship between JIT (purchasing and production) and agile manufacturing. Inman *et al.* (2011) found a direct effect of JIT-purchasing and an indirect effect of JIT-production on agile manufacturing. Similarly, Zelbst *et al.* (2010) found an indirect positive impact of JIT on agile manufacturing. Narasimhan *et al.* (2006) has empirically found that JIT is a precursor to acquiring agility. The above discussion leads to the following hypotheses:

H2. JIT-production influences positively agile manufacturing.

H3. JIT-purchasing influences positively agile manufacturing.

2.3 TPM and agile manufacturing

TPM is a manufacturing program intended principally to maximize equipment effectiveness and to eliminate breakdowns through the participation and motivation of the entire work force (Nakajima, 1988). TPM helps to maintain plant and equipment at its highest productive (Ahuja and Khamba, 2008a) and availability (Shah and Ward, 2007) levels.

The ultimate goals of TPM are zero defects, zero breakdowns and zero accident (Ahuja and Khamba, 2008a).

TPM is not only a maintenance-specific policy (Ahuja and Khamba, 2008a). TPM includes different practices. Shah and Ward (2003) identified five elements of TPM: predictive or preventive maintenance, maintenance optimization, safety improvement programs, planning and scheduling strategies and new process equipment or technologies. Similarly, Cua *et al.* (2001) recognized three principal practices: autonomous and planned maintenance, technology emphasis and proprietary equipment development. Therefore, TPM can be an efficient factor in improving the technological base of a firm by enhancing equipment technology and improving the employees’ skills (McKone *et al.*, 2001; Cua *et al.*, 2001).

Technology is also an essential element of agile manufacturing (Zhang and Sharifi, 2007; Kidd, 1995; Vazquez-Bustelo *et al.*, 2007). Agility is recognized as the use of the developed and well-known technologies and production methods (Kidd, 1995).

Khatri *et al.* (2018) identified that tools and technology (group technology, material requirement planning, etc.) are important enablers for agile manufacturing. They have found that tools and technology has significant impact on agile manufacturing. As stated earlier, agile manufacturing is developed from the concept of lean manufacturing. The latter is considered as one of the enablers of agility (Vazquez-Bustelo *et al.*, 2007). Agile manufacturing execution requires effective establishment of lean manufacturing practices. TPM is identified as one of the four practices (bundles) of lean manufacturing (Shah and Ward, 2003). Therefore, TPM may help agile manufacturing execution.

Furthermore, agile manufacturing needs to be highly flexible in order to respond quickly to changes. Flexibility and reactivity (responsiveness) are the main components of agile manufacturing (Gunasekaran, 1998: Sharifi, and Zhang, 2001; Lin *et al.*, 2006; Zhang and Sharifi, 2007). Several studies have recognized that flexibility is a key characteristic of an agile organization (Prater *et al.*, 2001). However, to ensure such flexibility, it is essential to use certain practices, namely, TPM elements (Nakajima, 1988; Savsar *et al.*, 2004). Companies cannot ensure a high level of responsiveness and a flexible production system without reliable and available equipment. This availability of equipment can be achieved through the use of TPM practices (Ahuja and Khamba, 2008a; Sharma *et al.*, 2006; Shah et Ward, 2007). Several studies confirm that preventive maintenance is important for companies seeking process control and flexibility (Ahuja and Khamba, 2008a). Savsar *et al.* (2004) have found that maintenance of any form has a significant impact on the availability of the flexible manufacturing systems. Similarly, Sharma *et al.* (2006) found that TPM had improved firm flexibility. Vinodh *et al.* (2010) state that TPM is an enabler of agile manufacturing.

TPM practices are paramount to ensure the flexibility and the reactivity (Sharma *et al.*, 2006; Savsar *et al.*, 2004; Konecny and Thun, 2011), and hence the agility of the company.

According to what has been revealed so far, we can state the following hypotheses:

H4. TPM influences positively agile manufacturing.

2.4 TQM and performance

The role of TQM is widely recognized as being a critical determinant of competitive advantage (Douglas and Judge, 2001). Numerous studies have been written on TQM and its crucial role in improving organizational performance. Literature on TQM implementation advocates that TQM is positively associated with organizational performance (Shafiq *et al.*, 2019). TQM implementation success provides companies with several organizational advantages (Antony, 2002). As mentioned earlier, TQM is a "holistic management philosophy" that strives and seeks for continuous improvement in all functions of an organization (Kaynak, 2003). Antony *et al.* (2002) conclude that the successful implementation of TQM will result in improved quality, employee involvement and communication, less rework, increased productivity, reduced cost of poor quality and improved customer satisfaction. Several studies confirm the positive correlation between TQM and organizational performance (Anderson and Sohal, 1999; Choi and Eboch, 1998; Baird *et al.*, 2011; Al-Dhaafri and Al-Swidi, 2016; Shafiq *et al.*, 2019). The studies of Samson and Terziovski (1999) and Lakhal *et al.* (2006) demonstrate that several TQM practices (infrastructure practices) are significantly related to operational performance. Kaynak (2003) has empirically found a positive relationship between TQM practices and the firm performance. Douglas and Judge (2001) have found that TQM practices are positively correlated to both the perceived financial performance and industry expert-rated performance. Easton and Jarrell's (1998) finding indicates that financial performance is improved for the firms adopting TQM. Similarly, O'Neill *et al.* (2016) empirically report a positive association between quality management implementations and financial performance. Carmona-Márquez *et al.* (2018) have empirically found a significant positive effect of TQM on overall performance based on efficiency. Lamine and Lakhal (2018) found a significant positive impact of TQM/Six Sigma practices on performance. Shafiq *et al.* (2019) found that TQM has a highly positive effect on organizational performance.

The literature discussed above leads to the following hypotheses:

H5. TQM influences positively operational performance

H6. TQM influences positively financial performance

2.5 JIT and performance

The contribution of JIT in improving firm performance is widely recognized (Sakakibara *et al.*, 1993; Salaheldin, 2005). The literature review supports the positive relationship between JIT and organizational performance (Danese *et al.*, 2012; Chen, 2015; Uhrin *et al.*, 2017; Bond *et al.*, 2019).

JIT is a strategy with the principal aim of eliminating all forms of waste, improving product quality (Brown and Mitchell, 1991) and optimally utilizing resources (Green *et al.*, 2014). Such aims can be achieved, for instance, by reducing cycle times (Shah and Ward, 2003), excess inventories, non-value adding (Brox and Fader, 2002) and rejects and rework (Brown and Mitchell, 1991). Therefore, it is reasonable to associate JIT implementation with increased efficiency (Zelbst *et al.*, 2010) and improved delivery performance.

Several authors confirm that JIT contributes to improve the operational performance (Shah and Ward, 2003; Salaheldin, 2005; Furlan *et al.*, 2011) as well as the financial performance (Inman and Mehra, 1993; Germain and Dröge, 1997; Claycomb *et al.*, 1999).

Zaid *et al.*'s (2016) finding reveals that JIT-selling directly affects operational performance, and JIT-production indirectly affects operational performance through JIT-selling.

Avittathur and Swamidass's (2007) findings reveal that JIT-deliveries from suppliers are significantly correlated to increased aggregate performance.

Germain and Dröge (1997) found that JIT-purchasing predicted both financial and marketing performances. Claycomb *et al.*'s (1999) results indicate that JIT strategy (JIT-production, JIT-purchasing and JIT-selling) has improved the financial performance.

According to what precedes, we can state the following hypotheses:

H7. JIT-production influences positively operational performance

H8. JIT-production influences positively financial performance

H9. JIT-purchasing influences positively operational performance

H10. JIT-purchasing influences positively financial performance

2.6 TPM and performance

The role of TPM in improving manufacturing performance is also widely recognized. As stated earlier, TPM helps to maintain equipment at its highest productive level (Ahuja and Khamba, 2007, 2008a). It is an innovative approach to maintenance that eliminates breakdowns, enhances equipment effectiveness and promotes autonomous maintenance (Nakajima, 1988). TPM implantation allows to reduce the occurrence of unexpected machine breakdowns that disrupt production and to increase their efficiency and their availability (Shah and Ward, 2003; Ahuja and Khamba, 2008a, 2008b). This efficiency and this availability permit enhancing the competitive advantages of decreased stocks, improved quality and improved delivery without excessive maintenance investments (Ahuja and Khamba, 2008a). According to Ahuja and Khamba (2007), TPM is a partnership between production functions and maintenance in order to improve product quality, reduce waste and reduce manufacturing cost. This can consequently increase profits. Ultimately, the organizational performance will be improved (Gupta and Vardhan, 2016).

Furthermore, successful TPM implementation has contributed towards realization of intangible benefits (Ahuja and Khamba, 2008a). TPM is not a specific maintenance policy; it is a philosophy, a culture and a new attitude towards maintenance (Ahuja and Khamba, 2007) based on the empowerment, participation and encouragement of all employees (Ahuja and Khamba, 2008a, 2008b). In other words, TPM implementation helps to foster motivation in the workforce through team working, adequate empowerment, employee participation, knowledge sharing, more open communication, training and felicitations (Ahuja and Khamba, 2008a). According to McKone *et al.* (2001), TPM breaks down traditional barriers between maintenance and production by increasing technical skills of production personnel, including maintenance in daily production tasks and sharing information among different functional areas. Therefore, TPM can develop firm's capabilities to identify and resolve production problems and subsequently improve manufacturing performance (McKone *et al.*, 2001). In addition, TPM implementation can ensure a clean, neat, safe, attractive and motivating working environment (Ahuja and Khamba, 2008a; Habidin *et al.*, 2018), and consequently, it can improve employees' satisfaction. This results in an increase in productivity, an improved quality, a reduction in costs (Ahuja and Khamba, 2008a) and thus an improvement in the organizational performance.

The literature review defends the positive relation between TPM and the operational and financial performance. Many studies have found statistically significant correlation between TPM and organizational performance (Ahuja and Khamba, 2007, 2008a; McKone *et al.*, 2001; Gupta and Vardhan, 2016; Habidin *et al.*, 2018, etc.). This discussion leads to the following hypotheses:

H11. TPM influences positively the operational performance

H12. TPM influences positively the financial performance

2.7 Agile manufacturing and organizational performance

There is an increasing recognition that agile manufacturing is a means of improving business competitiveness (Yusuf *et al.*, 1999). Hence, firms have become more agile with the aim of improving performance (Yusuf and Adeleye, 2002; Inman *et al.*, 2011). Agile manufacturing is a firm capacity to survive and thrive in a turbulent and unforeseeable competing environment by reacting rapidly and effectively to the market evolution (Gunasekaran 1999). Several authors reveal that agile manufacturing is the most adapted system to respond quickly to environmental contingencies (Kidd, 1995; Gunasekaran, 1998; Yusuf *et al.*, 1999; Jin-Hai *et al.*, 2003). It is generally approved that agile manufacturing not only focuses on flexibility and responsiveness (Sharifi and Zhang, 2001), but also gives, simultaneously, a special attention to all the competing objectives: cost, quality, flexibility, reactivity, reliability, proactivity, innovation and so forth (Yusuf and Adeleye, 2002). This allows companies to be more competitive, and to henceforth improve their total performance (Zelbest *et al.*, 2010; Inman *et al.*, 2011; Yusuf *et al.*, 2014; Leite and Braz, 2016; Nabass and Abdallah, 2019). Literature review supports the positive link between agile manufacturing and organizational performance (Narasimhan *et al.*, 2006; Hallagran and Olhager, 2009; Vazquez-Bustelo *et al.*, 2007; Zelbest *et al.*, 2010; Inman *et al.*, 2011; Yusuf *et al.*, 2014; Leite and Braz, 2016; Iqbal *et al.*, 2018; Abdallah and Nabass, 2018; Nabass and Abdallah, 2019).

Therefore, we propose the following hypotheses:

H13. Agile manufacturing influences positively operational performance

H14. Agile manufacturing influences positively financial performance

3. Methodology

3.1 Data collection

Data were collected from manufacturing via a combination of direct contact with relevant managers and Internet-based survey methods. Respondents were invited by mail to participate in the survey. The invitation letter contained the Internet address where the questionnaire was hosted. Based on recommendations from practitioners and literature, managers who are at higher managerial levels were targeted as respondents for the present study. The sample covers a diversity of industries and plant sizes. Enterprise lists were obtained from the "Tunisian Industry Portal" (http://www.tunisianindustry.nat.tn). The survey was sent to 900 certified industrial enterprises (the total number of the list). Certified industrial companies were chosen because they are the most concerned with the implementation of TQM, JIT and TPM. A total of 205 surveys were returned, and at least 100% were complete (details of sample description are presented in Appendix 1).

3.2 Measurement of constructs

The scales used in this study were assessed and developed in prior studies. The JIT-production (internal JIT) scale is taken from Furlan *et al.*, (2011); it measures the adoption of a set of practices commonly associated to JIT-production programs (Danese *et al.*, 2012). To measure TPM, we have opted for the scales used by Cua *et al.* (2001). TQM scale incorporates multiple dimensions and includes items related to process quality, human resources, strategic quality planning and information and analysis. This scale is developed by Choi et Eboch (1998). JIT-purchasing, agile manufacturing and financial performance scales are taken from Inman *et al.* (2011). The operational performance is adopted from Peng *et al.* (2008). All the items comprising JIT-production, JIT-purchasing, TPM, TQM and agile manufacturing were developed from Likert-scale items; the respondents were asked to indicate the extent to which the items represented practices in their firms (1 = "very low" to 5 = "very high"). The items concerning operational and financial performances were measured using 5-point Likert scale, and respondents were asked to rate their organization's (operational and financial) performance compared to that of their competitors (1 = "much worse than competition" and 5 = "much better than competition").

4. Results for the measurement model

Measurement scales must reveal content validity, unidimensionality, reliability, convergent and discriminant validity analyses (O'Leary Kelly and Vokurka, 1998). Actually, content validity is assumed since the studied scales were taken directly from previous research. The detailed statistical results from the assessments for unidimensionality, reliability coefficients and convergent validity are presented in the following tables (Table 1).

4.1 Unidimensionality analysis

The unidimensionality can be verified by using confirmatory factor analysis (Gerbing and Anderson, 1988). To verify, it is recommended to use the root mean square error of approximation (RMSEA) under 0.08 (Garver and Mentzer, 1999), the goodness-of-fit index (GFI) coefficients greater than 0.90 (Bentler et Bonett, 1980) and the Tucker–Lewis (TLI) coefficient and comparative fit index (CFI) coefficients greater than 0.90 (Garver and Mentzer, 1999). All scales indicate a sufficient unidimensionality (Table 1). All scales were treated as first-order factors, except TQM and TPM. Choi et Eboch (1998) described TQM as comprising four distinct factors: process quality, human resources, strategic quality planning and information and analysis. Cua *et al.* (2001) presented TPM as being based on three distinct factors: autonomous and planned, technology emphasis and proprietary equipment development. To assess unidimensionality, TQM and TPM were treated as a second-order construct. Values for each of the four factors of TQM and the three factors of TPM were calculated by averaging across factor items, and we used the factor values in the unidimensionality assessment.

		Unidimensionality		
Scale	GFI	RMSEA	TLI	CFI
TQM	0.953	0.025	0.995	0.997
JITPU	0.996	0.049	0.989	0.998
JITPR	0.995	0.067	0.989	0.998
TPM	0.979	0.024	0.997	0.998
AM	0.969	0.071	0.972	0.986
OP	0.991	0.033	0.997	0.999
FP	0.991	0.066	0.992	0.997

Table 1. Measurement scale unidimensionality results

4.2 Reliability analysis

The internal reliability was tested through the Cronbach's index, which, for all the constructs, is higher than the recommended threshold of 0.6 (Evrard *et al.*, 2003).The reliability analysis was also performed by using the coefficient of Jöreskog's rho (Jöreskog's ρ) of internal consistency (Jöreskog *et al.*, 1999). This coefficient should be higher than 0.70 (Fornell and Larker, 1981). The results are illustrated in Table 2.

4.3 Convergent and discriminant validity

The convergent validity analysis was proved according to Fornell and Larcker's (1981) approach. Therefore, it is necessary to calculate the coefficient rho of convergent validity. This coefficient should be higher than 0.50. The results are given in Table 3.

The convergent validity analysis can be also verified by using the coefficient of the normed fit index (NFI), which should be greater than 0.9 (Bentler et Bonett, 1980). The results are given in Table 4.

The convergent validity was achieved; all the estimated coefficients of all the indicators were significant.

Discriminant validity was assessed by comparing the chi-square of the constrained model (where the correlation is fixed to 1 between factors) with the unconstrained model or "free" model (where the correlation is released) (Anderson and Gerbing, 1988). A significant chi-square difference between the constrained and the unconstrained model demonstrates

Latent variables	Alpha de Cranach	Jöreskog's ρ
TQM process quality	0.842	0.828
TQM human resources	0.919	0.881
TQM strategic quality planning	0.947	0.909
TQM information and analysis	0.925	0.977
JITPU	0.798	0.801
JITPR	0.895	0.906
TPM autonomous and planned maintenance	0.905	0.902
TPM technology emphasis	0.931	0.926
TPM proprietary equipment development	0.800	0.897
AM	0.902	0.923
OP	0.927	0.936
FP	0.924	0.936

Table 2.
Reliability coefficients

Latent variables	Rho of convergent validity
TQM process quality	0.620
TQM human resources	0.651
TQM strategic quality planning	0.770
TQM information and analysis	0.926
JITPU	0.511
JITPR	0.715
TPM autonomous and planned maintenance	0.692
TPM technology emphasis	0.807
TPM proprietary equipment development	0.814
AM	0.635
OP	0.746
FP	0.778

Table 3.
Rho of convergent validity

discriminant validity (Gerbing and Anderson, 1988; Roussel *et al.*, 2003). This test indicates that the difference of the chi-square for 1 degree of freedom is significant for all dimensions [e.g. ($\Delta\chi = 73.349$; $\Delta \text{ddl} = 1$; $p = 0.01$)]. Hence, the discriminant validity is confirmed.

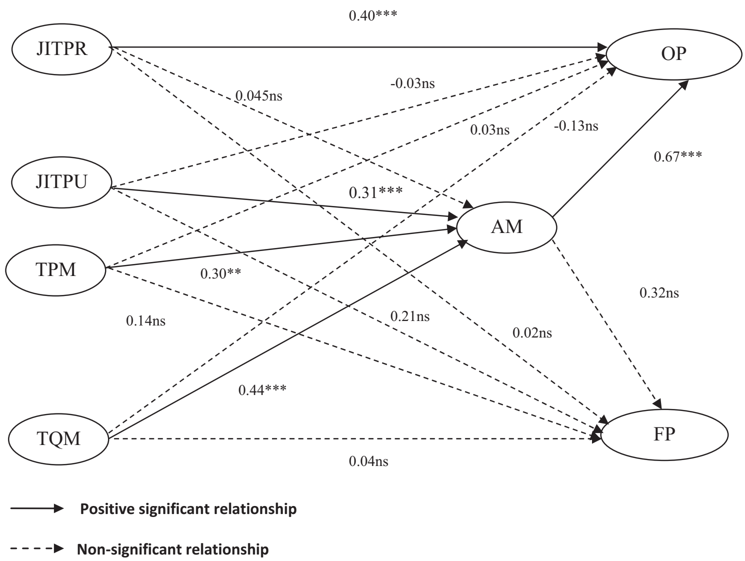
Fornell et Larker (1981) recommend that discriminant validity can also be verified if the square root of the average variance extracted (AVE) of each construct is greater than the correlations it shares with other constructs. The results are shown in Appendix 2.

5. Results of the structural model

Figure 2 represents the model with the structural equation modeling results specified in the Amos 18 output. To test the model, various fit criteria must be verified. The relative chi-square (1.09) is below the suggested maximum of 3.00 (Pedhazur et Pedhazur Schmelkin, 1991). The RMSEA (0.023) is under the recommended maximum of 0.08 (Roussel *et al.*, 2003). Although all the other coefficients CFI (0.98), TLI (0.98) and NFI (0.89) exceed the recommended 0.90 level (Bentler et Bonett, 1980), the GFI (0.85) is slightly below the recommended 0.90 level (Bentler et Bonett, 1980). This index is very sensitive to the degree of complexity of the model (Roussel, 2005) and to the size of the sample (Byrne, 1998). The

Scales	NFI
TQM	0.970
JIT-purchasing	0.994
JIT-production	0.996
TPM	0.998
AM	0.972
OP	0.994
FP	0.994

Table 4.
Convergent validity



Note(s): Significant at: $**p < 0.05$ and $***p < 0.001$ levels, ns: not significant

Figure 2.
Model with the structural equation modeling results

threshold usually used for this index (GFI) is 0.9. Although some authors have proposed different thresholds of 0.9 and 0.8, they attest that the value of GFI between 0.8 and 0.9 indicates a good fit, while values greater than 0.9 indicate a very good fit (Hair *et al.*, 1998; Etezadi-Amoli et Farthoomand, 1996). For Byrne (1998), the incremental-fit index (IFI) and comparative-fit index (CFI) are more appropriate when the sample size is small. The IFI (0.98) and CFI (0.98) both exceed the recommended 0.90 level (Byrne, 1998). According to what has been mentioned above, we can state that our model benefits from a satisfactory degree of adjustment, which allows us to test our hypotheses.

5.1 Direct effects

The results reveal that five hypotheses are supported out of 14 hypotheses (Table 5). First, there are significant and positive relationships between TQM and agile manufacturing; the standardized coefficient is 0.44 and $p < 0.01$ ($C.R = 4.66$). Thus, H1 is supported. Second, the relationship between JIT-production and agile manufacturing (H2) is not significant with an estimate of 0.045 and $p > 0.05$ ($C.R = 0.90$).Third, the relationship between JIT-purchasing and agile manufacturing is positive and significant, with a standardized estimate of 0.31 and an associated $p < 0.01$ ($C.R = 4.230$), which consolidates H3. We also found a positive and significant relationship between TPM and agile manufacturing; the standardized coefficient is 0.30 and $p < 0.05$ ($C.R = 2.73$). Therefore, H4 is supported. The relationship between TQM and operational performance (H5) is not significant with an estimate of −0.13 and $p > 0.05$ ($C.R = 1.04$). Hypotheses 6, which indicates that TQM has a direct impact on financial performance, is also not supported, as the standardized coefficient is 0.04 and $p > 0.05$ ($C.R = 0.26$). The relationship between JIT-production and operational performance (H7) is statistically significant, with an estimate of 0.40 and $p < 0.01$ ($C.R = 6.58$). Thus, H7 is supported. Hypotheses 8, which states that JIT-production has a direct impact on financial performance, is not supported, as the standardized coefficient is 0.02 and $p > 0.05$ ($C.R = 0.34$). Hypotheses 9, which indicates that JIT-purchasing has a direct impact on operational performance, is not supported, as the standardized coefficient is −0.03 and $p > 0.05$($C.R = 0.36$). The relationship between JIT-purchasing and financial performance (H10) is not significant with an estimate of 0.21 and a $p > 0.05$ ($C.R = -1.51$). The relationship between TPM and operational performance (H11) is not significant as well; the standardized coefficient is 0.03 and $p > 0.05$ ($C.R = 0.25$). The link between TPM and financial performance (H12) is not significant with a standardized coefficient of 0.14 and a $p > 0.05$ ($C.R = 0.74$). Moreover, there are significant and positive relationships between agile manufacturing and

Hypotheses	Paths(VID→VD)	(Estimate/Standardized regression weight)	C.R.	*P*
H1	TQM→AM	0.444	4.666	***
H2	JITPR→AM	0.045	0.906	0.365 ns
H3	JITPU→AM	0.313	4.230	***
H4	TPM→AM	0.302	2.736	**
H5	TQM→OP	−0.132	1.040	0.299 ns
H6	TQM→FP	0.048	0.264	0.792 ns
H7	JITPR→OP	0.403	6.588	***
H8	JITPR→FP	0.028	0.344	0.731 ns
H9	JITPU→OP	−0.035	0.363	0.716 ns
H10	JITPU→FP	0.215	−1.517	0.129 ns
H11	TPM→OP	0.033	0.257	0.797 ns
H12	TPM→FP	0.142	0.747	0.455 ns
H13	AO→OP	0.676	3.459	***
H14	AO→FP	0.320	1.194	0.232 ns

Table 5.
Direct effects results

operational performance. The standardized coefficient is 0.67, which is statistically significant at $p < 0.01$ ($C.R = 3.45$). Therefore, H13 is supported. Finally, the relationship between agile manufacturing and financial performance (H14) is not significant with a standardized coefficient of 0.32 and an associated $p > 0.05$ ($C.R = 1.19$).

5.2 Mediating effect

In this model, it is also possible to analyze the indirect effects of the three practices – TQM, JIT-purchasing and TPM – on operational performance. The results showed significant indirect effects of these practices on operational performance through agile manufacturing. However, as previously indicated, the results showed insignificant direct effects of these practices on operational performance. This means that the agile manufacturing fully mediates the relationship between these practices (TQM, JIT-purchasing, TPM) and the operational performance. Table 6 displays the results of indirect effects.

6. Discussion

The literature review indicates that TQM, JIT-production, JIT-purchasin, and TPM have a positive effect on agile manufacturing. Similarly, the results of the structural equation modeling support these positive relations except for the link between JIT-production and agile manufacturing. These practices (TQM, TPM and JIT-purchasing) are considered as the levers or the drivers for agile manufacturing, as they provide it a fertile environment. This result corroborates the studies of Narsimhan *et al.* (2006), Vazquez-Bustelo *et al.* (2007), Inman *et al.* (2011) and Zelbst *et al.* (2010). For example, Inman *et al.* (2011) have found that JIT-purchasing has a positive effect on agile manufacturing. Zelbst *et al.* (2010) have indicated that the relation between TQM and agile manufacturing is statistically significant. Similarly, Narsimhan *et al.* (2006) have found that the practices of leanness are a precursor to agile manufacturing.

We find that the direct impact of JIT-production on agile manufacturing is not significant. This is not in line with literature, but this is consistent with Inman *et al.*'s (2011) study that suggests that JIT-production and JIT-purchasing generate synergistic effects to help a firm in enhancing their agile manufacturing capability. They reveal that JIT-production is an antecedent to JIT-purchasing. This means that the JIT-production has an indirect effect on agile manufacturing through JIT-purchasing.

Zelbst *et al.* (2010) reveal a positive relation between JIT-production and TQM. They stated that JIT-production is considered as an essential precursor to the success of the implementation of TQM. Their results indicate that JIT-production has a positive indirect effect on agile manufacturing through TQM. Our findings support the results of Inman *et al.* (2011) and Zelbst *et al.* (2010) and can indicate an indirect effect of JIT-production on agile manufacturing through JIT-purchasing or TQM. The lack of support for the hypothesized relation between JIT-production and agile manufacturing can be explained by the complementarity that exists between these practices (TQM, JIT-production, JIT-purchasing and TPM).

The literature review also reveals that TQM, JIT-production, JIT-purchasing and TPM have positive effects on operational performance, but our results do not support this relation and indicate that the impacts of these practices (TQM, JIT-purchasing and TPM) are not

Table 6. Indirect effects of TQM, JIT-purchasing and TPM on operational performance through agile manufacturing

Indirect relations	Standardized indirect effects
TQM and operational performance	0.300
JIT-purchasing and operational performance	0.211
TPM and operational performance	0.204

significant. As previously mentioned, the business environment has become more and more turbulent and uncertain. Such practices are fundamental but insufficient to deal with a turbulent and uncertain environment. Indeed, these practices (TQM, JIT and TPM) lack certain flexibility, reactivity, proactivity and agility. Hence, there is a need for new practices such as agility practices, which increase their capacity to react quickly to change. Yusuf and Adeleye (2002) admit that lean practices (TQM, JIT, TPM, etc.) are "insufficient and that survival requires the adoption of agile practices." Zelbest *et al.* (2010) state that low cost and high quality are no longer sufficient to respond to customer needs; TQM and JIT, in combination with agility, "appear to be the key to improving operational performance." The results of their study exhibit the indirect effect of JIT and TQM on operational performance through agile manufacturing. Moreover, the results of Inman *et al.* (2011) indicate a positive effect of JIT-purchasing on operational performance through agile manufacturing. Similarly, in this research, it has been found that agile manufacturing has a positive impact on operational performance. It has also been revealed that TQM, JIT-purchasing, and TPM have an indirect effect on operational performance through agile manufacturing. In conclusion, agile manufacturing forms a determining factor for the organization sustainability; it not only presents a positive effect on operational performance but also mediates the relation between these practices (TQM, JIT-purchasing and TPM) and the operational performance, so we can conclude that agile manufacturing contributes to enhance firms' performance and to respond efficiently to environmental changes.

7. Conclusion, limitations and future research

7.1 Conclusion

This study provides empirical justification for a framework that describes the relationship between lean manufacturing practices, agile manufacturing and organizational performance. It examines three research questions: (1) does successful implementation of lean manufacturing practices support agile manufacturing implementation/development? (2) Do organizations with successful implementation of lean manufacturing practices have a high level of organizational performance? (3) Do organizations with high levels of agile manufacturing have a high level of organizational performance?

This research provides empirical evidence to support conceptual and prescriptive statements in the literature concerning the impact of lean manufacturing and agile manufacturing approaches. In fact, the current paper provides empirical evidence that lean manufacturing practices are directly and indirectly related to organizational performance, while agile manufacturing is directly related to organizational performance. The results indicate that the successful implementation of lean manufacturing practices can support agile manufacturing, but cannot enhance organizational performance. The findings also show that higher levels of agile manufacturing may lead to improved operational performance. Furthermore, this provides empirical evidence to support the mediating role played by agile manufacturing in the explanation of the relationship between lean manufacturing practices and operational performance. This study also reveals that lean manufacturing practices are directly related to each other.

From a managerial point of view, this work has given rise to results that are likely to interest practitioners seeking to improve their agility and performance. First, it identifies the practices on which we must focus to ensure a successful implementation and a high level of agile manufacturing. Accordingly, it is relevant to recommend an effective implementation of TQM, JIT and TPM. Second, it shows the importance of implementing agile manufacturing system in improving the operational performance. The study clearly reveals that lean manufacturing practices are necessary but insufficient to ensure and improve operational performance. Hence, it is essential to recommend an effective implementation of agile manufacturing system.

7.2 Limitations and future research

While this research has allowed us to highlight various theoretical and empirical contributions, several limitations should be discussed. First of all, the nonsignificant results of several variables on financial performance have led us to think that the study carried out is inappropriate to demonstrate the effect of these variables (agile manufacturing, TQM, JIT, TPM) on financial performance.

Quality, agility and financial performance are constructs that are dynamic in nature, requiring elements of time, and might be better examined over an extended period. Therefore, a longitudinal study is recommended in future research.

Second, this study has ignored the effect of several other variables which are considered as an important driver for agile manufacturing such as the turbulent environment (dynamism and hostility) (Vazquez-Bustelo *et al.*, 2007) and competitive strategy (differentiation) (Hallgren and Olhager, 2009); so, future research could be expanded by including the turbulent environment (dynamism and hostility) as a variable.

Finally, this research has neglected certain relationships between TQM, JIT-production, JIT-purchasing and TPM, although it has been found that these practices are complementary and related in a complex way. That's why a detailed study of this complementarity should be considered in future research.

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Appendix 1. Descriptive analysis

Table A1. Business sector

Business sector	Number of enterprise	Percentage
Electrical, electronic and appliance industries	63	30.7%
Food industry	33	16.1%
Mechanical and metallurgical industry	53	25.9%
Ceramic and glass building materials industry	12	5.9%
Chemical industry	37	18.0%
Leather and footwear industries	4	1.9%
Wood and cork industries	3	1.5%

Table A2. Classification of firms by workforce

Number of employees	Number of enterprise	Percentage
From 10 to 49	21	10.2%
From 50 to 199	51	24.9%
From 200 to 499	72	35.1%
More than 500	61	29.8%

Appendix 2

	TQMpq	TQMhr	TQMsqp	TQMia	JITPR	OP	FP	JIPU	AM	TPMapm	TPMte	TPMped
TQMpq	*0.787*											
TQMhr	0.764	*0.806*										
TQMsqp	0.683	0.758	*0.877*									
TQMia	0.451	0.592	0.574	*0.962*								
JITPR	0.324	0.382	0.379	0.364	*0.845*							
OP	0.482	0.572	0.521	0.401	0.666	*0.863*						
FO	0.299	0.301	0.279	0.206	0.202	0.296	*0.882*					
JITPU	0.381	0.462	0.404	0.369	0.291	0.518	0.125	*0.714*				
Am	0.624	0.778	0.702	0.591	0.461	0.754	0.339	0.709	*0.796*			
TPMapm	0.418	0.477	0.535	0.221	0.346	0.394	0.202	0.352	0.532	*0.831*		
TPMte	0.535	0.601	0.611	0.336	0.369	0.594	0.294	0.458	0.739	0.635	*0.898*	
TPMped	0.439	0.451	0.430	0.297	0.395	0.469	0.291	0.410	0.559	0.485	0.635	*0.902*

Note(s): The square root of the average variance extracted (AVE) of each construct (to facilitate comparison with the values quoted below)

Table A3.
Discriminant validity

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