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Agile manufacturing relationship building with TQM, JIT, and firm performance: An exploratory study in apparel export industry of Pakistan

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ABSTRACT

Recent research on Agile Manufacturing (AM) has examined its relationship with Total Quality Management (TQM), Just in Time (JIT), and different levels of firm performance. Mixed results have been reported, probably due to non-availability of well validated AM constructs. This research develops a 3-stage model and examines AM's direct and/or indirect relationship with common infrastructures, TQM, and JIT and its effects on different levels of firm performance in the context of the Pakistani industrial sectors, specifically the apparel export industry. Data is collected from 248 Pakistani apparel export firms and the model is estimated using structural equation modelling. The results indicate that common (internal) infrastructure and TQM has a positive relationship with AM specifically in the apparel export firms in a third world economy where the industrial sector is in a nascent state. Whereas, JIT relationship is positively mediated through external infrastructure, TQM and JIT did not seem to contribute directly in operational performance. However, this relationship is significant when it is mediated through AM. Market performance positively mediates the relationship between operational performance and financial performance of the firm. The implications of the findings for researchers and practitioners, looking at the industrial sectors in the developing world, are discussed and research directions offered.

1. Introduction

The dynamic nature of competition is primarily due to globalization, social infrastructures, customer preferences sophisticated demand and market changes, rapid technological progression, and the organizations' will to stay competitive and to expand. Manufacturers are adopting new improvement initiatives like Agile Manufacturing (AM), Total Quality Management (TQM) and Just in Time (JIT) to remain competitive in this dynamic environment (Inman et al., 2011; Paranitharan et al., 2017; Zelbst et al., 2010). Lean and agile improvement initiatives have emerged as 21st century manufacturing paradigms (Shah and Ward, 2003; Yusuf and Adeleye, 2002). Extant literature indicates progression towards verifying the relationship between lean bundles (TQM & JIT) and AM initiatives (Furlan et al., 2011b; Zelbst et al., 2010). However existing research is lacking and has some gaps in investigating direct and/or indirect effects of AM, TQM, and JIT on various levels of firm performance due to limitations such as non-inclusion of TQM elements (Inman et al., 2011), data analysis i.e.; correlation (Yusuf and Adeleye, 2002) and sampling limitations (Zelbst et al., 2010). Therefore, further refinement is needed in order to respond specifically to the following research questions:

- What is the relationship between AM and TQM, JIT, operational, market and financial performance specifically in the apparel export industry in Pakistan?
- How is AM, related (directly/indirectly) to TQM, JIT, operational, market and financial performance?

This research aims to explore the AM relationship building, based on theory of systems and concept of fit, with TQM and JIT and their joint impact on operational, market and financial performance. This study proposes that lean (TQM and JIT), along with management, and internal and external infrastructure enablers, are antecedent to AM (Inman et al., 2011; Narasimhan et al., 2006). The objective is to show that those findings hold true for the industrial sectors in developing economies. A conceptual 3-stage model is developed to explore the link among management, infrastructure, TQM, JIT, AM, operational, market and financial performance.

A survey of the Pakistani apparel manufacturing/export sector is conducted to obtain data to assess the proposed model. The Pakistani apparel manufacturing industry is steeped in local culture, and modernization of late has contributed to a new paradigm in the management infrastructure development. Given this paradigmatic shift, the

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study attempts to explore the impact of these new management infrastructures and test to see if the findings in Inman et al. (2011) and Narasimhan et al. (2006) hold for the Pakistani industrial sector. Findings of this research provide valuable insights for AM implementation for developing economics and industrial operations. The model is then tested by means of a structural equation methodology.

This paper is broken into five sections; the Second section provides the literature review. The Third section describes the research model and delineates the research hypotheses. The research methodology is laid out in the Fourth section and results are presented. Finally, the Fifth section provides a discussion on the contributions of this study along with the implications for practitioners and limitations. Conclusions and future research directions are also presented in this section.

2. Literature review

Lean (TQM and JIT) and AM are improvement initiatives organizations pursue to achieve their organizational objectives i.e. to improve competitiveness and enhance market share. Lean (TQM and JIT) and AM systems are often viewed in literature through the lens of isolation or joint venture (Gunasekaran, 1999). Harrison (1997) expressed his reservations over the compatibility of companies following lean initiatives and moving towards agility, whereas, Papadopoulou and Özbayrak (2005) claim that lean is a holistic approach and contains all essential elements of AM. Similarly, Gunasekaran et al. (2008) and Ramesh and Devadasan (2007) also argue that critical elements required to become agile are part of lean (TQM & JIT) manufacturing (Bortolotti et al., 2015; Inman et al., 2011; Zelbst et al., 2010). The idea that lean is antecedent to achieving agility is argued by Narasimhan et al. (2006), who stated "pursuit of agility might presume leanness, pursuit of leanness might not presume agility". Principally AM roots are deeply interconnected with other systems, such as lean (Womack et al., 1990), Flexible Manufacturing Systems (Sarkis, 2001), and time-based competition (Dröge et al., 2004). Sarkis (2001) defined AM as a conjoint set of flexible manufacturing systems (FMS) and lean production (LP). Yusuf et al. (1999), argued that AM is a set of synthesized practices and technologies, and is fully compatible with TQM, Computer Integrated Manufacturing (CIM) and JIT. Sharp et al. (1999) acknowledged that World Class Manufacturing (WCM) is in a state of progression towards best in class of AM, to address competitive priorities more efficiently than previously conceived (Cheng et al., 1998). Hormozi (2001) called AM the "next logical step" towards a production revolution stating that its roots are deeply linked with its predecessor like lean (JIT) and mass production. Jin-Hai et al. (2003) proposed an agile evolutionary production paradigm that evolved from synthesis of a previous set of management initiatives such as TQM, JIT, and CIM.

Lean focuses on waste elimination in the process and continuously works to improve it (Womack et al., 1990). Agility is a business wide capability that rests on four pillars (1) "virtual enterprise"; (2) "flexible systems"; (3) "technology advancement"; and (4) "skilled and an empowered workforce". There is significant research which shows that implementation of these improvement initiatives have a positive impact on organizational performance (Fullerton et al., 2003; Matsui, 2007). Conversely, a few failures have also been documented (Biggart and Gargeya, 2002; Jayaram et al., 2008). Lean and Agile both pursue the same competitive capabilities i.e; cost, quality service, and lead-time optimization.

Theoretical foundation of this research is built on the Theory of Systems (Skyttner, 2005) and Concept of Fit (Venkatraman, 1989). The Theory of Systems explains that systems and sub-systems integrate and depart from other sub-systems, (as per organizational requirements), and their fit leads to higher organizational results, which cannot be obtained in isolation (Jayaram and Xu, 2013). The extant available literature has been reviewed to identify management practices, infrastructure (internal and external), core AM, TQM and JIT practices and are summarized in Table 1.

From the above discussion, it is apparent that the findings in the literature are inconsistent. Some researchers assert (Narasimhan et al., 2006; Zelbst et al., 2010) these relationships as given, while others oppose (Inman et al., 2011; Yusuf and Adeleye, 2002) this assertion, and some claim them to be universally constant (Yusuf and Adeleye, 2002). Conversely, a few researchers have declared these to be context dependent (Goldman et al., 1995). Therefore, integrating lean (TQM and JIT) with AM, incorporating context (internal and external), structure (internal organization operations), and performance capabilities, is deemed necessary.

Given the discourse and lack of consensus in literature, this research proposes a locus that bears out the relationships between lean, management, infrastructure (both internal and external) as antecedent to AM. We expect that the results of the analysis will show that the hypothesized relationships are significantly strong with correlation between lean and management, Lean and infrastructure, Lean and AM, Management and infrastructure, Management and AM, Infrastructure and AM. Moreover, literature does not report any work that clearly spells out what common internal and external set of practices are required to enable core TQM, core JIT and core AM in a single framework to achieve a successful agile working environment. This research strives to establish this as well.

3. Research model and proposed hypotheses

A 3-stage theoretical model based on theory of systems and literature review of lean (TQM & JIT) and AM paradigms as proposed is depicted in Fig. 1. The model proposes a relationship among management, infrastructure (internal and external), lean (TQM & JIT), AM, operational, market and business performance. The proposed three stages are (1) organization culture; (2) core manufacturing practices; and (3) outcomes as suggested by Flynn et al. (1994) and Jayaram et al. (2010). Each stage acts as an input to the next stage to form a complete system including the socio-technical practices (Top management commitment and common (internal and external) infrastructure practices). Proposed hypotheses pertaining to the relationships suggested in the research model are labeled accordingly. We will delineate the hypotheses in the following sections.

3.1. Top management commitment

Top management commitment is the foremost element for implementation of any improvement program (TQM, JIT, AM, TPM, etc.) irrespective of type of (manufacturing or service) industry (Kaynak, 2003; Kim et al., 2012). For effective implementation of any improvement program, top management has to establish a sound internal infrastructure. A learning environment is created (Narasimhan et al., 2006) and resources are arranged for the workforce to improve their skills (Flynn et al., 1995a; Jayaram et al., 2010) through cross training (Cua et al., 2001; Kim et al., 2012) and encouraging them to share new knowledge (Gunasekaran et al., 2008; Vázquez-Bustelo et al., 2007). Empowered teams are developed that are capable and can undertake independent decision making (Narasimhan et al., 2006), like planning and readjusting production schedules, and directly interact with suppliers and customers to improve product quality (Kaynak, 2003). An organization-wide feedback based information system is developed (Flynn et al., 1994), to share quality, productivity and other important strategic data with employees (Cua et al., 2001; Fynes and Voss, 2002). Employees are trained on plant maintenance (Flynn et al., 1994, 1995a), to keep their plant in optimal operational condition (Shah and Ward, 2007). The above discussion leads to the following hypothesis:

H1. Top management commitment is significantly (positively) associated with CII practices.

Top management takes necessary measures to establish an open relationship with customers. Customers' requirements are transformed

Table 1
Management, Infrastructure (internal and external), TQM, JIT and agile manufacturing practices.

Concept	Practice	TQM Literature												JIT Literature											AM Literature											
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Core TQM Practices	Product design(PD)	✓	✓	✓	✓	✓	✓	✓			✓			✓	✓	✓			✓	✓		✓					✓	✓		✓	✓	✓	✓		✓	
	Process management(SPC)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		✓	
	Continuous improvement (CI)		✓		✓	✓				✓	✓	✓	✓		✓						✓			✓	✓	✓	✓			✓	✓		✓	✓	✓	
Core JIT Practices	Set-up time reduction(STR)																✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓	✓	✓			
	Pull system production(PSP)																✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		✓	
	Lot size reduction(LSR)																✓			✓	✓			✓	✓		✓			✓	✓	✓	✓			
	JIT scheduling(JS)															✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓		✓	
Core Agile Manufacturing Practices																																				
	Knowledge management(KM)																											✓	✓	✓	✓			✓	✓	
	Change proficiency(CP)																												✓	✓	✓	✓	✓	✓	✓	✓
	Advance manufacturing technology (AMT)																										✓	✓	✓		✓	✓	✓	✓	✓	
Management practices	Top management commitment (TMC)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓	✓		✓		✓	✓				✓	
Common Internal Infrastructure Practices(CII)	Cross training(CT)	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓	✓	✓
	Empowered Teams(ET)	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
	Information system(IS)	✓	✓	✓	✓		✓	✓			✓			✓	✓	✓		✓	✓	✓		✓	✓		✓			✓		✓	✓			✓	✓	✓
	Strategic vision and planning(SVP)	✓	✓		✓	✓		✓	✓			✓		✓	✓		✓		✓						✓	✓		✓		✓	✓			✓	✓	
	Plant environment(PE)	✓	✓	✓												✓	✓	✓	✓		✓		✓	✓	✓	✓							✓			
Common External Infrastructure Practices(CEI)	Relationship with customers(RWC)		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Relationship with suppliers(RWS)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Outcomes	Operational performance			✓	✓		✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓				✓	✓	✓	✓	✓
	Market performance												✓		✓	✓									✓			✓					✓			✓
	Financial performance											✓	✓		✓	✓									✓			✓					✓			✓

1. Saraph et al. (1989)
2. Flynn et al. (1994)
3. Flynn et al. (1995a)
4. Anderson et al. (1994)
5. Powell (1995)
6. Ahire et al. (1996)
7. Black and Porter (1996)
8. Samson and Terziovski (1999)
9. Rungtusanatham et al. (1998)
10. Forza and Filippini (1998)
11. Douglas and Jr (2001)
12. Curkovic et al. (2000)
13. Ravichandran and Rai (2000)
14. Sila and Ebrahimpour (2005)
15. Zu et al. (2008)
16. Mehra and Inman (1992)
17. McKone et al. (1999)
18. Cua et al. (2001)
19. McLachlin (1997)
20. Shah and Ward (2003)
21. Ahmad et al. (2003)
22. Shah and Ward (2007)
23. Furlan et al. (2011b)
24. Yang et al. (2011)
25. Bortolotti et al. (2015)
26. Narasimhan et al. (2006)
27. Vázquez-Bustelo et al. (2007)
28. Dove (1999)
29. Gunasekaran (1998)
30. Zhang and Sharifi (2000)
31. Zelbst et al. (2010)
32. Inman et al. (2011)
33. Sharp et al. (1999)
34. Zhang (2011); Zhang and Sharifi (2007)
35. Yusuf et al. (2014)

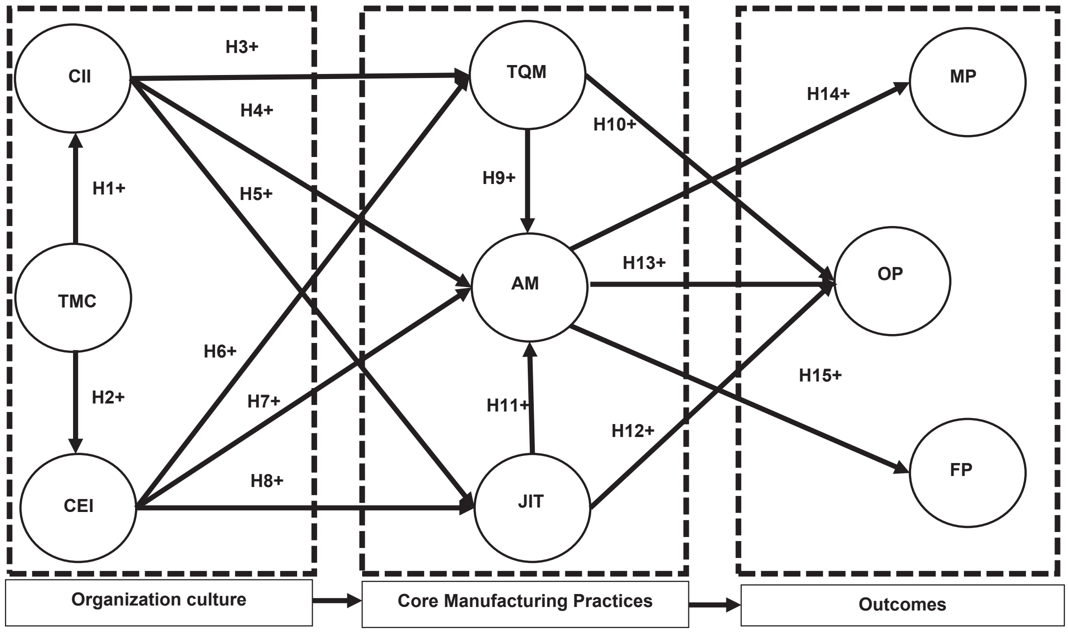

Fig. 1. Proposed theoretical model.

into acceptable products (Kim et al., 2012; Zu et al., 2008). Long-term relationships with suppliers give the organization a competitive edge. Suppliers' contribution can be enhanced by maintaining a few reliable suppliers and by involving them in the product design stage (Kim et al., 2012; Zu et al., 2008). The above discussion leads to the following hypothesis:

H2. Top management commitment is significantly (positively) associated with CEI practices.

3.2. Common internal infrastructure (CII)

CII practices are the precursor for effective execution of TQM, JIT and AM practices. Proper CII establishment lays a solid foundation for effective implementation of ensuing TQM, JIT and AM practices (Flynn et al., 1995b). Quality policies establish quality goals, appropriately trained and empowered employees participate in robust product design processes and organization-wide information system provides quality and productivity data for improvement. A clean and operationally ready plant helps to produce non-defective products (Rahul Sindhwani, 2017). Studies have also found a statistically significant positive relationship between CII and TQM practices such as; product design, process management through statistical process control (SPC) and continuous improvement (Jayaram et al., 2010; Lakhal et al., 2006; Zu et al., 2008). Similarly, studies have also found statistically significant relationship between CII practices and ensuing JIT practices like set-up time reduction, JIT scheduling, lot size reduction and pull production systems (Ahmad et al., 2003; Flynn et al., 1995a). The literature is replete with theoretical support for relationship between CII and ensuing AM, such as change proficiency, knowledge management and advanced manufacturing practices (Gunasekaran, 1998; Sharifi and Zhang, 1999), but empirical evidences are rare (Inman et al., 2011; Narasimhan et al., 2006). This discussion, lead us to the following three hypotheses:

H3. The effective establishment of CII practices are significantly (positively) associated with ensuing TQM practices.

H4. The effective establishment of CII practices are significantly (positively) associated with ensuing AM practices.

H5. The effective establishment of CII practices are significantly (positively) associated with ensuing JIT practices.

3.3. Common external infrastructure (CEI)

Supplier and customer relationship building processes provide a concrete base for smooth execution of subsequent TQM, JIT and AM. This link is deep-rooted in highly synchronized inter-firm relations, i.e; the firm's functional area relationships with suppliers and customers (Jayaram and Xu, 2013). A number of studies have empirically linked supplier and customer relationships with TQM (Kim et al., 2012; Zu et al., 2008). Suppliers support JIT implementation through timely delivery, whereas, customers contribute by furnishing timely and accurate demands (Schonberger and Brown, 2017). Empirical evidence is available to support the relationship between external infrastructure and subsequent JIT performance (Jayaram et al., 2008; Narasimhan et al., 2006). Similarly, suppliers and customer relationships are precursors to acquire Agility milestones (Inman et al., 2011; Narasimhan et al., 2006). This discussion leads to the following hypotheses:

H6. The effective establishment of CEI practices are significantly (positively) associated with ensuing TQM practices.

H7. The effective establishment of CEI practices are significantly (positively) associated with ensuing AM practices.

H8. The effective establishment of CEI practices are significantly (positively) associated with ensuing JIT practices.

3.4. Total Quality Management (TQM)

TQM is a customer focused approach that seeks to continuously improve process and product quality to customers' ever changing requirements (Anderson et al., 1994). Advanced manufacturing provides leverage to organizations to beat competitors and launch quality products in the market (Inman et al., 2011; Narasimhan et al., 2006). Sharp et al. (1999) empirically established that agility builds on a strong lean foundation. Similarly (Goldman and Nagel, 1993) noted that "agile manufacturing assimilates the full range of flexible production technologies, along with the lessons learned from TQM, JIT, and lean production". Narasimhan et al. (2006), found that agile players were better at TQM culture implementation, primarily due to the continuous improvement philosophy, as compared to lean players, and provided justification that AM execution requires effective establishment of

TQM. Similarly, Bottani (2010) classified TQM as one of the enablers of agility. Zelbst et al. (2010) found a significant positive relationship between TQM and AM. TQM positively contributes to organizational competitiveness capabilities (Bortolotti et al., 2015; Cua et al., 2006) through manufacturing excellence (Grandzol and Gershon, 1998; Zu et al., 2008). Forza and Filippini (1998) found TQM as a positive contributor to customer satisfaction and quality conformance. Curkovic et al. (2000) found that TQM positively affects quality performance of the organization through quality improvement. The discussion above leads us to hypotheses 9 and 10:

H9. The effective establishment of TQM practices are positively associated with ensuing AM practices.

H10. TQM practices are positively associated with operational performance.

3.5. Just-in-time (JIT)

AM is theoretically well accepted as an advanced stage of lean production (Hormozi, 2001; Jin-Hai et al., 2003). Shah and Ward (2003) identified JIT as one of four important lean bundles for accomplishing lean production. Narasimhan et al. (2006) found that agile groups are at par with lean players on JIT flow and JIT supply, which are prime elements for JIT implementation and provide a strong justification for JIT as precursor to AM (Vázquez-Bustelo et al., 2007). Inman et al. (2011) empirically found an indirect relationship between JIT production and AM. Similarly, Zelbst et al. (2010) found an indirect positive relationship between JIT and AM. JIT also helps to improve delivery reliability and enhances efficiency (Bortolotti et al., 2015; Danese et al., 2012) by reducing buffer inventory through lot size reduction (Flynn et al., 1995a), pull production (Shah and Ward, 2007), shortened cycle time through set-up time reduction (Cua et al., 2001; Shah and Ward, 2003), eliminating non-value added activities (Claycomb et al., 1999a, 1999b), and capability to meet master schedule timelines (Zelbst et al., 2010). Similarly, Dal Pont et al. (2008) and Furlan et al. (2011b) found a positive association between aggregate JIT and firm competitiveness. Moreover, Furlan et al. (2011a) found that internal and external JIT complementarity effects have positive impact on performance. The above discussion leads to following two hypotheses:

H11. The effective establishment of JIT Practices are positively associated with ensuing AM Practices.

H12. JIT Practices are positively associated with operational performance.

3.6. Agile manufacturing (AM)

AM is a manufacturing paradigm with special emphasis on organizational flexibility and enhanced responsiveness (Gunasekaran, 1998; Zhang, 2011). AM focuses on flexibility and responsiveness along with quality and delivery reliability (Hallgren and Olhager, 2009; Vázquez-Bustelo et al., 2007). Theoretical support for integrated AM relationship with operational, and market and financial performance (Gunasekaran, 1998; Yusuf et al., 1999) are abundant in the literature but sufficiently large scale empirical evidence is rare (Yusuf and Adeleye, 2002). Yusuf and Adeleye (2002) reported a positive correlation of aggregate agility drivers with operational, market and business performance. Vázquez-Bustelo et al. (2007), developed and validated a strong link between aggregate agility with overall business performance through significant manufacturing strength. Zelbst et al. (2010), purports that AM, supported by TQM and JIT, leads to better operational and logistics performance. Similarly, Inman et al. (2011) found that AM, in association with JIT manufacturing, leads to operational performance, marketing performance and financial performance. This discussion leads to the following three hypotheses:

H13. AM practices, supported by TQM and JIT are positively associated with operational performance.

H14. AM practices, supported by TQM and JIT are positively associated with market performance.

H15. AM practices, supported by TQM practices and JIT practices are positively associated with financial performance.

In this section, we developed 15 hypotheses that propose a relationship between management, infrastructure (internal and external), lean (TQM & JIT), AM, operational, market and business performance. In section 4 we will present the research methodology used to test these hypotheses.

4. Research methodology

In order to test the hypotheses developed in section 3, we conducted a survey and collected data. The survey instrument was tested and validated externally from survey data and internally from existing literature and studies. The survey questionnaire is available upon request.

4.1. Research sample and data collection

Pakistan's Textile and Clothing industry ranges between 50 and 65% of the country's export shares, accounts for 38% of the manufacturing labor force and has a contribution of 8.5% to the country's gross domestic production (GDP) (Pakistan Economic Survey, 2016–17). Due to its importance in the Pakistani economy the apparel export sector was selected as the targeted population, as it accounts for a large percentage of the export income of the Pakistan's industrial sector and employs a substantial portion of the workforce. Data was collected from member firms of export chapter HS code 61 (knitwear and hosiery) and export chapter HS code 62 (readymade garments). Export associations (PHMA[1] and PRGMEA[2]), were asked to encourage firm participation. Five operational plants (1-small, 2-medium and 2-large) were also studied (as case studies) to better understand the production dynamics of the export apparel industry. A survey instrument was developed to examine our research objectives (see Appendix B). Feedback from industry consultants were also solicited on the questionnaire and their feedback was incorporated. An internet-based e-mail questionnaire was developed using *Qualtrics* (www.qualtrics.com) to collect the data (Dillman, 2007). A total of 1546 firms were identified and the questionnaire was sent to 950 firms. Two reminders were also send, first after the 4th week and the second after the 6th week. Out of the 950 firms, 261 firms responded, a response rate of 27.5%. After accounting for missing data and incomplete surveys, the final tally of usable questionnaires comprised of 248 (26.1% response rate) firms. Table 2 presents the profile of the respondents. The sample includes small (19.8%), medium (40.7%) and large firms (38.5%) from both chapters HS-61(60.9%) and HS-62 (39.1%).

4.2. Measurement model assessment

Analysis of a correlated measurement model, with first order factors, including organizational culture, core practices and performance measures was carried out. The model fit well with fit statistics, $\chi^2/df = 1.217$, CFI = 0.95, NNFI = 0.95 and RMSEA = 0.03 (Hair et al., 2010). Except for top management commitment and performance measures, all other constructs are treated as higher order factors. Second order CFA (Confirmatory Factor Analysis) is performed to

[1] Pakistan Hosiery Manufacturers Association (PHMA) is the premier trade organization representing the hosiery and knitwear industry in Pakistan.

[2] PRGMEA is the premier trade organization representing the readymade garment industry in Pakistan. Pakistan readymade garments manufacturers and exporters association.

Table 2
Respondent profile.

Category	Respondent Group	Count (NOs)	Percentage (%)	Cumulative Percentage (%)
Job position	CEO	32	12.9	12.9
	GM	49	19.8	32.7
	Production Manager	60	24.2	56.9
	Quality Manager	45	18.1	75.0
	Export Manager	40	16.1	91.1
	Supervisor	22	8.9	100.0
Job experience (years)	< 3	6	2.4	2.4
	3–5	39	15.7	18.1
	6–10	101	40.7	58.9
	11–20	71	28.6	87.5
	20+	31	12.5	100.0
Firm major export business	Readymade garments	97	39.1	39.1
	Knitwear and hosiery	151	60.9	100.0
Firm size (number of employees)	1-50 (small)	49	19.8	19.8
	51-250 (medium)	101	40.7	60.5
	> 250 (large)	98	39.5	100.0

Table 3
Results of second order confirmatory factor analysis.

Construct	First Order Items	Unidimensionality				Convergent Validity			Reliability	
		χ^2/df	CFI	GFI	RMSEA	SFL (min-max)	t-value (min-max)	AVE	CR	α
Criteria		< 3	> 0.95	> 0.95	< 0.08	> 0.5	> 1.95	> 0.5	> 0.6	> 0.7
Core TQM Practices	3	1.21	0.99	0.97	0.029	0.76–0.79	8.10–8.20	0.58	0.81	0.78
Core JIT Practices	3	1.64	0.98	0.94	0.051	0.69–0.77	7.64–7.84	0.52	0.81	0.79
Core Agile manufacturing Practices	3	1.27	0.99	0.94	0.033	0.64–0.80	6.02–6.03	0.51	0.76	0.72
Common Internal Infrastructure	5	1.16	0.99	0.93	0.026	0.77–0.80	9.45–9.91	0.62	0.89	0.86
Common External Infrastructure	2	–	–	–	–	–	–	0.51	0.73	0.71

Finally, analysis of a full-scale measurement model with composite scales is performed. The model fit well with fit statistics as, χ^2/df = 1.114, CFI = 0.98, NNFI = 0.98 and RMSEA = 0.02.

evaluate the unidimensionality, reliability, convergence, discriminant and nomological validity for TQM, JIT, AM, CII and CEI. First order dimensions converge well to make second order factors. CFA for CEI cannot be performed as it comprises of only two first order dimensions and we have insufficient information to perform confirmatory factor analysis (CFA) (Hair et al., 2010). However, a correlated measurement model was tested for psychometric properties of this high order factor. Second order CFA results are presented in Table 3.

Hair et al. (2010), emphasized that a second-order factor should pass nomological validity assessment to eliminate any chance of confounding explanations that are likely to occur for a higher-order factor. All second order factors meet the threshold criteria (Table 3). First order factor loadings on respective second order factor are significant at $p < 0.01 (t > 2.58)$. The core AM super-scale fit especially well with fit indices as; $\chi^2/df < 1.64$, $CFI > 0.99$, $GFI > 0.94$, and $RMSEA < 0.033$. First order dimensions of each second order factor are significantly correlated with each other at $p < 0.01$. Furthermore, 17 first order factors, are transformed into composite measures by taking averages of these scales. A composite measure scale is formed by combining several individual variables into a single composite measure. For example, four items of cross training (CT1, CT2, CT3, CT4) are summed and then divided by the number of items, i.e.; four.

4.3. Discriminant validity

Before performing structural equation modelling (with composite measures), we assessed discriminant validity using two methods (Bagozzi et al., 1991; Fornell and Larcker, 1981). The first based on two constructs, is said to be distinct if the square root of the average variance extracted (AVE) of a construct is greater than its correlation with the other construct ($\sqrt{AVE} > \gamma$) (Fornell and Larcker, 1981). The second method involved correlating constructs in pairs. Constructs are correlated twice (as nested models). First, constructs are allowed to correlate freely. Secondly, the construct's correlation is constrained to "1" and a significant chi-square difference for a difference of one degree of freedom indicate discriminant validity (Bagozzi et al., 1991). A total of 36 models (based on possible pairs of nine constructs – Table 4) was assessed. Two runs of the models are undertaken. The first set with no restrictions placed on correlation and the second with correlation between each pair restricted to 1. The model is run and their chi-square difference is assessed for the discriminant validity analysis. Chi-square difference at one degree of freedom for all pair-wise unconstrained and constrained models are performed. All the results are significant at $p < 0.001$ and confirm discriminant validity (Bagozzi et al., 1991). Descriptive statistics, correlations and discriminant validity results are presented in Table 4.

4.4. Structural equation modelling results

Byrne (2010) stated that "Structural equation modelling is a statistical methodology that takes a confirmatory (i.e., hypothesis-testing) approach to the analysis of a structural theory". Structural equation modelling represents a series of causal relationships generating observations among multiple variables simultaneously (Bentler, 1988) and is preferred over other multivariate techniques like correlation and regression. Structural equation modelling (SME) using AMOS 20 was employed to empirically explore the fit of the proposed theoretical model-(A). The model fit well with statistics; $\chi^2/df = 1.23$, CFI = 0.97, NNFI = 0.96, and RMSEA = 0.03. Results are shown in Table 5. All the hypotheses, except hypotheses (H10, H11 and H12), are significant at $p < 0.01$. Hypotheses $H10_{TQM\rightarrow OP}$ with $\beta_{TQM\rightarrow OP} = 0.010$, $H11_{JIT\rightarrow AM}$ with $\beta_{JIT\rightarrow AM} = 0.09$, and $H12_{JIT\rightarrow OP}$ with $\beta_{JIT\rightarrow OP} = 0.09$ were not

Table 4
Descriptive statistics, correlations and discriminant validity results.

	Mean	SD	TMC		CII		CEI		TQM		JIT		AM		OP		MP		FP
Top management commitment	5.25	0.67	***0.81***[a]																
Common internal infrastructure	5.47	0.56	.363***[b]	333.3[c]	***0.79***														
Common external infrastructure	5.11	0.64	.428***	56.2	.222***	78.8	***0.76***												
Total quality management	5.13	0.51	.310***	174.6	.404***	147.2	.441***	47.1	***0.77***										
Just-in-time	5.48	0.59	.240***	154.8	.306***	143.3	.334***	58.4	.208***	157.2	***0.73***								
Agile manufacturing	5.04	0.54	.265***	132.6	.341***	116.7	.372***	55.7	.437***	78	.320***	105.4	***0.72***						
Operational performance	5.23	0.77	.224***	383.6	.227***	489.6	.225***	79.9	.188***	198.8	.206***	163.8	.231***	129.8	***0.80***				
Market performance	4.82	1.05	.281***	413	.278***	410.2	.256***	77.1	.216***	193.7	0.115*	169.6	.256***	125.3	.280***	423	***0.86***		
Financial performance	4.89	0.95	.213***	300.6	.299***	265.8	.195***	80.8	.186***	197.7	0.064	175	.189***	132.1	.196***	302.3	.490***	207.7	***0.81***

***. $p < 0.01$ (2-tailed), **. $p < 0.05$, *$p < 0$.
[a] Values on the diagonal are the square root of AVE.
[b] Values represent bivariate correlation for the factors.
[c] Values represent x^2 differences between each unconstrained and constrained model.

confirmed at the same level, $p < 0.01$. These results, suggested by modification indices in AMOS, led us to reassess the model. Based on modification indices (Table 5), employing the competitive model approach in exploratory study, the model is re-arranged to assess if underlying theory supports the alternative model construction (Hair et al., 2010; Inman et al., 2011) (see Table 6).

Before re-specification of path from JIT→CEI, and removal of paths JIT→OP, and TQM→OP, a nested model was tested against the initially proposed model. In the nested model, three paths from JIT→AM, JIT→OP and TQM→OP were removed (constrained to zero). A chi-square difference test indicates that the more simplified (constrained) model was a better fit ($\Delta\chi^2 = 2.8$, $\Delta df = 3$ at $p < 0.05$) than less restrictive (unconstrained) model (Hair et al., 2010). Two paths TQM→OP and JIT→OP were removed, whereas, path from JIT→AM is redirected through CEI as an indirect (mediation), making JIT antecedent to CEI, instead of direct path. Model-(B) model fit statistics are $\chi^2/df = 1.24$, CFI = 0.97, NNFI = 0.96, and RMSEA = 0.03.CEI positively mediates the path between JIT→AM and model-(B) results are shown in Fig. 2.

Additionally, a review of the modification indices, ensuing from assessment of the theorized model, suggests that two additional paths from OP→MP and MP→FP be added, and direct path from AM→MP be removed. Inclusion of the additional paths is in line with the results of studies by Vázquez-Bustelo et al. (2007) and Inman et al. (2011) which stated that operational performance is an antecedent to firm performance, i.e., market performance and financial performance. Moreover, Green et al. (2006) and Inman et al. (2011) also reported a positive relationship between market performance and financial performance.

This alternative model and associated SME results are shown in Fig. 3 (model C). Model-C fit statistics are $\chi^2/df = 1.17$, CFI = 0.97 NNFI = 0.97, and RMSEA = 0.02. Summary of statistics for all 3 models is given in Table 7. Market performance positively mediates path between OP→FP. However, path OP→FP is insignificant with standardized estimate value of $\beta_{OP\rightarrow FP} = 0.06$.

Finally, Total, direct and indirect effects for model (C) are calculated and results are presented in Table 8.

5. Summary and discussion

The basic objectives of this study were to explore:

1. AM's direct and/or indirect relationship with management (internal and external infrastructure), TQM, and JIT practices.
2 And AM's impact on firm performance.

Based on the literature review, the study assumed that lean (TQM and JIT) along with internal and external infrastructure was antecedent to enable AM. A 3-stage model was developed based on literature review and testing data that was collected from Pakistani apparel exporting firms.

A system perspective was assumed and the proposed model was validated using concept of fit. Structural equation modelling results showed all but 3 of the 15 hypotheses were well supported. The 3 hypotheses that did not confirm (for the Pakistani apparel export industry data) were: JIT to AM; TQM to operational performance; and JIT to operational performance.

CEI contributes to enable AM. It supports the argument that strong supplier's relationship and customer involvement is the essence of apparel export industry The apparel industry is highly unpredictable and due to its inherent volatile demand characteristics, shorter product life cycle and seasonality merit a strong relationship with customers and suppliers (Wagner et al., 2012). However, JIT production's non-significant direct relationship with AM is somewhat troublesome. JIT (supply and production) is assumed to be a precursor to acquiring agility (Narasimhan et al., 2006). The results indicate that JIT supply significantly contributes to enable AM, whereas, JIT alone does not contribute to AM, contrary to the belief that all JIT related activities are

Table 5
Model reassessed based on modification indices.

Unconstrained Model [a]		Constrained Model [b]		χ2 Statistics			Remarks
χ^2	*df*	χ^2	*df*	$\Delta\chi^2$	Δ*df*	Significance	
622.1	502	624.9	505	2.8	3	ns	Constrained model is accepted

ns: $\Delta\chi^2$ value is less than 7.81 and 11.34 for a Δdf of 3 at $p < 0.05$ and $p < 0.01$ respectively.
[a] In Un-constrained model paths from JIT to AM and OP, and path from TQM to OP are freely estimated.
[b] In constrained model paths from JIT to AM and OP, and path from TQM to OP are constrained to zero.

Table 6
Proposed model (A) results.

Hypotheses	Paths	Standardized path estimate	t-value	Significance	Results
H1	TMC → CII	0.428	5.66	***	H1 supported
H2	TMC → CEI	0.533	6.42	***	H2 supported
H3	CII → TQM	0.372	4.92	***	H3 supported
H4	CII → AM	0.243	2.752	***	H4 supported
H5	CII → JIT	0.284	3.59	***	H5 supported
H6	CEI → TQM	0.469	5.43	***	H6 supported
H7	CEI → AM	0.287	2.60	***	H7 supported
H8	CEI → JIT	0.398	4.38	***	H8 supported
H9	TQM → AM	0.304	2.75	***	H9 supported
H10	TQM → OP	0.019	0.18	*0.854*	H10 *not-supported*
H11	JIT → AM	0.099	1.10	*0.27*	H11 *not-supported*
H12	JIT → OP	0.099	1.16	*0.242*	H12 *not-supported*
H13	AM → OP	0.306	2.58	***	H13 supported
H14	AM → MP	0.447	5.45	***	H14 supported
H15	AM → FP	0.390	4.63	***	H15 supported

***$p < 0.01$.

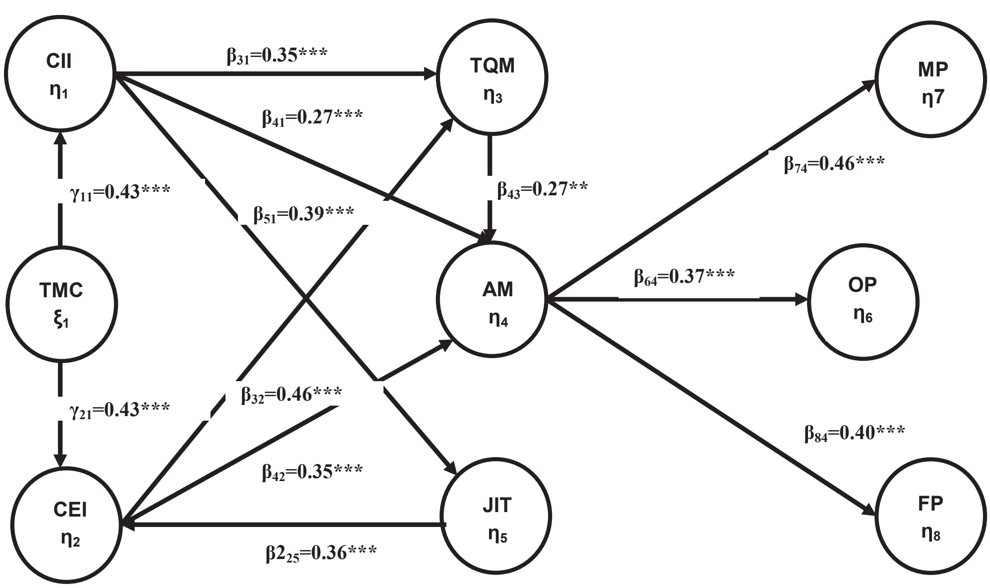

Fig. 2. Model (B).

precursor to AM (Narasimhan et al., 2006). Our results do not confirm the notion that core JIT production is antecedent to AM. One plausible cause may be that AM is enabled once JIT production, being part of AM is already functioning and it may get difficult to separate it from AM (Inman et al., 2011; McCullen and Towill, 2001).

It is assumed that once JIT production is in place in combination with CEI (suppliers and customer relationship) it helps to generate synergistic effects consistent with arcs of integration. Firms that are outward facing with strong relationships with customers and suppliers enjoy superior business performance (Frohlich and Westbrook, 2001). Furthermore JIT production and JIT supply are the precursors to AM. The JIT production path is re-specified through CEI, and this relationship was positively mediated through CEI (Frohlich and Westbrook, 2001; Inman et al., 2011). The results indicate that JIT production and JIT supply generate synergistic effects to help a firm in enhancing their AM capability as demonstrated by Inman et al. (2011). A positive association between internal lean (e.g.; pull system, set-up time reduction) and external lean (e.g.; relationship with customers and suppliers) helps to acquire better organizational excellence (Hofer et al., 2012). Our results conform to Furlan et al. (2011a) findings, indicating that upstream JIT (suppliers' relationship) and downstream JIT (customers' relationship) has synergistic effects in strengthening internal JIT (JIT

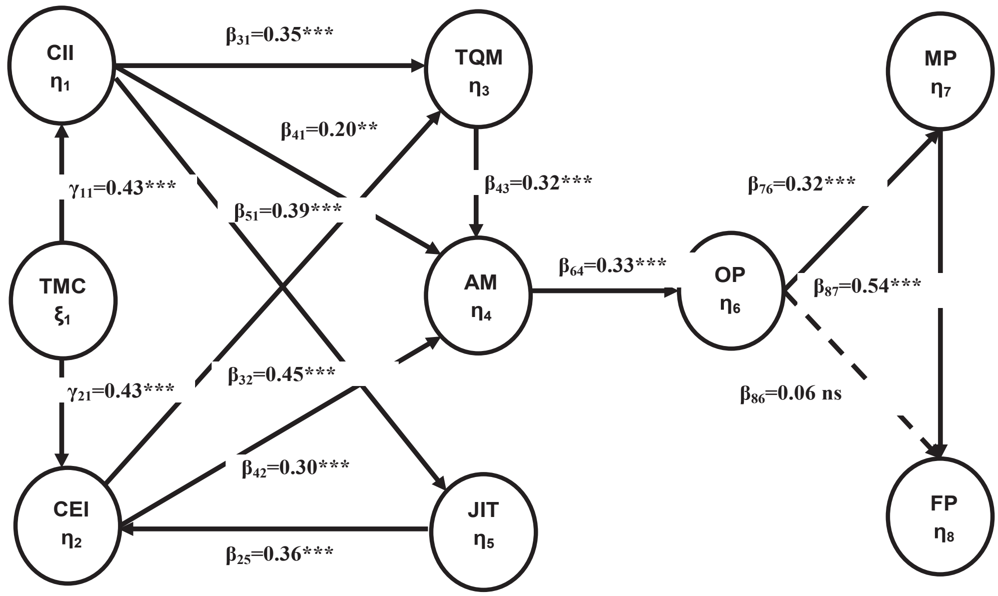

Fig. 3. Model (C).

Table 7
Models A, B and C results.

	χ2/df	CFI	TLI or NNFI	RMSEA
Criteria	< 3	> 0.95	> 0.95	< 0.08
Model A	1.23	0.97	0.96	0.03
Model B	1.24	0.97	0.96	0.03
Model C	1.17	0.97	0.97	0.02

production), and helps in outperforming firms lacking in upstream or downstream JIT.

Similarly, TQM's and JIT's non-significant relationship with operational performance is in line with earlier research (Green et al., 2014; Zelbst et al., 2010). Although TQM and JIT are performance improvement initiatives (Bortolotti et al., 2015; Cua et al., 2001), in an AM environment, however, these performance improvement programs alone are not sufficient to improve operational performance (Zelbst et al., 2010). Nevertheless, the same are positively mediated through

Table 8
Total, direct and indirect effects of model (C).

	Independent Variables	TMC	CII	CEI	TQM	JIT	AM	OP	MP
Dependent Variables	Effects type								
Common internal infrastructure	Total	0.43***							
	Direct	0.43***							
	Indirect								
Common external infrastructure	Total	0.50***	0.15***			0.36***			
	Direct	0.43***				0.36***			
	Indirect	0.06***	0.15***						
Total quality management	Total	0.38***	0.42***	0.46***		0.17***			
	Direct		0.35***	0.46***					
	Indirect	0.38***	0.07***			0.17***			
Just-in-time	Total	0.18***	0.41***						
	Direct		0.41***						
	Indirect	0.18***							
Agile manufacturing	Total	0.36***	0.39***	0.45***	0.32**	0.17***			
	Direct		0.21***	0.31**	0.32**				
	Indirect	0.36***	0.18***	0.15**		0.17***			
Operational performance	Total	0.12***	0.13***	0.15***	0.11**	0.06***	0.33***		
	Direct						0.33***		
	Indirect	0.12***	0.13***	0.15***	0.11**	0.06***			
Market Performance	Total	0.04***	0.04***	0.05***	0.03**	0.02***	0.11***	0.32***	
	Direct							0.32***	
	Indirect	0.04***	0.04***	0.05***	0.03**	0.02***	0.11***		
Financial Performance	Total	0.03***	0.03***	0.04***	0.03**	0.01***	0.08***	0.24***	0.55***
	Direct							*0.06*^{ns}	0.55***
	Indirect	0.03***	0.03***	0.04***	0.03**	0.01***	0.08***	0.18***	

***: $p < 0.01$, **:p < , *ns*: not supported.

AM. The results are in line with the findings of Narasimhan et al. (2012) that finds firms merely adopting lean (TQM and JIT) initiatives were not at par on performance when compared to agile firms. Similarly, Vokurka and Lummus (2000) also highlighted that future business competitive priorities will be highly oriented towards customer preferences with attributes of "low cost, high quality products in a greater variety".

This study provides a conceptually insightful and empirically validated, 3-stage strategic model for researchers and managers to understand AM implementation relationships. It identifies and segregates CII practices from CEI practices required to enable Core TQM, Core JIT and particularly Core AM bundles. This study also gives explicit clarity that AM builds on a strong foundation of infrastructure (internal/external), TQM and JIT setups. Piecemeal implementation of JIT or TQM may not result in significant positive results. This research also depicted AM direct and/or indirect relationship with management practice (internal and external infrastructure); TQM; and JIT, and its impact on firm performance.

This research is limited in scope to the Pakistani value apparel export industry, and limited in time as it provides a cross sectional view of the proposed theory. It is hoped that future work will be developed to consider other industries and consider longitudinal impacts.

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Appendix A. Acronyms used in the paper

AM	Agile manufacturing
TQM	Total quality management
JIT	Just in time
CEI	Common external infrastructure
CII	Common internal infrastructure
OP	Operation performance
FP	Financial performance
MP	Market performance
LP	Lean production
CIM	Computer integrated manufacturing
FMS	Flexible manufacturing systems
WCM	world class manufacturing
OM	Operations management
TPM	Total productive maintenance
PD	Product design
SPC	Process management
CI	Continuous improvement
STR	Set-up time reduction
PSP	Pull system production
LSR	Lot size reduction
JS	JIT scheduling
KM	Knowledge management
CP	Change proficiency
AMT	Advance manufacturing technology
TMC	Top management commitment
CT	Cross training
ET	Empowered Teams
IS	Information system
SVP	Strategic vision and planning
PE	Plant environment
RWC	Relationship with customers
RWS	Relationship with suppliers
GDP	gross domestic production
PHMA	Pakistan Hosiery Manufacturers Association
PRGMEA	Pakistan Readymade Garments Manufacturers & Exporters Association
CEO	Chief executive officer
GM	General manager
CFA	Confirmatory factor analysis
AVE	Average variance extracted
CFI	Comparative Fit Index

NNFI	Non-Normed Fit Index
RMSEA	Root mean square error of approximation
GFI	Goodness of Fit Index
χ^2/df	Chi-square/degree of freedom
$\Delta\chi^2$	chi-square difference
Δdf	Difference of degree of freedom

Appendix B. Construct measurement

Organizational culture constructs

Top Management Commitment (TMC) (Ahire et al., 1996; Flynn et al., 1994; Grandzol and Gershon, 1998; Saraph et al., 1989)

χ^2/df = 1.386, CFI = 0.99, RMR. = 009, AVE = 0.64 CR = 0.90, α = 0.905

TMC1	Top Managers anticipate change in business/market and make plans to respond (0.806)[a]
TMC2	Top Managers promote the use of quality tools & techniques in manufacturing processes (0.765, t = 15.332)
TMC3	Top Managers have received adequate training on quality tools & techniques (0.856, t = 14.675)
TMC4	Top Managers provides adequate resources for product and process quality improvement (0.792, t = 13.42)
TMC5	Top Managers are held accountable for achieving quality, innovation and improvement targets (0.798, t = 13.542)

Information System (IS) (Cua et al., 2001; Fynes and Voss, 2002; Prajogo and Olhager, 2012)

χ^2/df = *0.24*, CFI = 1, RMR. = 0.003, AVE = 0.65, CR = 0.88, α = 0.883

IS1	Information on productivity is readily available to employees (0.788)[a]
IS2	Feedback on strategic and economic information is provided to employees (0.837, t = 13.882)
IS3	Generic operational data is shared with suppliers to improve supplies (0.864, t = 14.317)
IS4	Frequent contact and communication is maintained with suppliers and customers (0.748, t = 12.191)

Empowered Teams (ET) (Ahire et al., 1996; Cua et al., 2001; Flynn et al., 1994; Jayaram et al., 2010; Narasimhan et al., 2006)

χ^2/df = *2.073*, CFI = 0.99, RMR. = 0.009, AVE = 0.69, CR = 0.91, α = 0.923

ET1	Production scheduling is handled by empowered teams (0.896)[a]
ET2	Suppliers certification and training are handled by empowered teams*
ET3	Labour scheduling/job assignment is handled by empowered teams (0.871, t = 18.784)
ET4	Independent decision-making done by empowered teams is encouraged in the firm (0.788, t = 15.727)
ET5	Performance reviews are handled by empowered teams (0.808, t = 16.327)
ET6	Empowered working teams operate together with suppliers and customers (0.79, t = 15.676)

Strategic Vision and Planning (SVP) (Cua et al., 2001, 2006)

χ^2/df = *2.655*, CFI = 0.99, RMR. = 0.009, AVE = 0.73, CR = 0.91, α = 0.917

SVP1	The management follows a formal strategic planning process resulting in written mission, long-term goals and implementation strategies (0.841)[a]
SVP2	Plant management is included in the strategic planning process (0.81, t = 15.254)
SVP3	Top management regularly reviews and updates long-range strategic plans (0.873, t = 17.152)
SVP4	Formal and well-defined strategy is implemented in the plant (0.902, t = 17.988)

Cross Training (CT) (Ahire et al., 1996; Cua et al., 2001; Flynn et al., 1995a; Saraph et al., 1989)

χ^2/df = *1*, CFI = 1, RMR. = 0.004, AVE = 0.78, CR = 0.93, α = 0.935

CT1	Employees receive different training to be capable to perform multiple tasks (0.897)[a]
CT2	Shop floor employees are rotated regularly among different jobs (0.886, t = 20.471)
CT3	Employees are rewarded for learning new skills & techniques (0.862, t = 19.283)
CT4	Employees are evaluated on continual professional development criteria (0.896, t = 20.949)

Plant Environment (PE) (Cua et al., 2001; Dröge et al., 2003; Flynn et al., 1995a; Shah and Ward, 2007)

χ^2/df = *1.398*, CFI = 0.99, RMR. = 0.003, AVE = 0.68, CR = 0.89, α = 0.904

PE1	Plant and equipment is in a high state of readiness for production at all times (0.871)[a]
PE2	Emphasis is placed on putting all tools and fixtures at their place after use (0.784, t = 14.336)
PE3	Pride is felt in keeping plant neat and clean (0.877, t = 16.725)
PE4	Maintenance department train machine operators to perform routine preventive maintenance (0.773, t = 14.033)

Relationship with Customers (RWC) (Flynn et al., 1994; Jayaram et al., 2010; Narasimhan et al., 2006; Sila, 2007)

χ^2/df = *1.187*, CFI = 1.00, RMR. = 0.006, AVE = 0.69, CR = 0.92, α = 0.917

RWC1	Close contact with customers is maintained (0.835)[a]
RWC2	Results of customer satisfaction surveys are shared with all employees (0.908, t = 16.869)
RWC3	Opportunities for employee–customer interactive sessions are created (0.808, t = 14.745)
RWC4	A systematic process exists to translate customer requirements into new/improved products/services (0.827, t = 14.06)
RWC5	Customer service employees are empowered to resolve customers' complaints quickly (0.795, t = 13.487)

Relationship with Suppliers (RWS) (Flynn et al., 1994; Narasimhan et al., 2006; Prajogo et al., 2012)

χ^2/df = *1.316*, CFI = 0.99, RMR. = 0.009, AVE = 0.73, CR = 0.93, α = 0.931

RWS1	Strives to establish long-term relationships with suppliers based on quality, price and reliability (0.843)[a]
RWS2	Suppliers are actively involved in new product development process (0.869, t = 17.215)
RWS3	Collaborates with key suppliers to improve their quality of supplies in the long-term (0.892, t = 18.445)
RWS4	Quality and reliability is priority one in selecting suppliers (0.856, t = 16.777)
RWS5	Firm relies on a few high quality and reliable suppliers (0.831, t = 16.323)

Core manufacturing practices constructs

Product Design (PD) (Cua et al., 2001; Flynn et al., 1995a; Zelbst et al., 2010)
$\chi^2/df = 0.853$, CFI = 1.00, RMR. = 0.004, AVE = 0.69, CR = 0.91, α = 0.924
PD1 There is considerable involvement of production and quality assurance people in the early design of products (0.844)[a]
PD2 Manufacturing engineers are involved to a great extent in new product design and development (0.823, t = 15.454)
PD3 Employees are involved to a great extent (teams or consultants) for introducing new products or making product changes (0.832, t = 15.799)
PD4 Composite teams are made from major functions (marketing, manufacturing, etc.) to introduce new products (0.873, t = 16.958)
PD5 Customer requirements are thoroughly analyzed/reviewed in the new product design process (0.796, t = 14.66)

Process Management Using Statistical Process Control (SPC) (Cua et al., 2001; Flynn et al., 1995a; Zelbst et al., 2010)
$\chi^2/df = 0.00$, CFI = 1.00, RMR. = 0.000, AVE = 0.79, CR = 0.92, α = 0.919
SPC1 A large number of the processes on the shop floor are controlled through statistical process control techniques (0.905)[a]
SPC2 Statistical techniques are extensively used to reduce variance in processes/supplies (0.925, t = 21.073)
SPC3 SPC charts are used to determine manufacturing processes capabilities 0.838, t = 18.08)

Continuous Improvement (CI) (Anderson et al., 1995; Curkovic et al., 2000; Rungtusanatham et al., 1998)
$\chi^2/df = 0.00$, CFI = 1.00, RMR. = 0.000, AVE = 0.75, CR = 0.90, α = 0.902
CI1 Quality improvement is the responsibility of every employee in the firm (0.858)[a]
CI2 Continuous improvement of quality is stressed in all work processes throughout the firm (0.897, t = 17.265)
CI3 All employees analyze their work to look for ways and means of improvement (0.852, t = 16.431)

Lot Size Reduction (LSR) (Flynn et al., 1995a; Zelbst et al., 2010)
$\chi^2/df = 0.00$, CFI = 1.00, RMR. = 0.000, AVE = 0.69, CR = 0.87, α = 0.870
LSR1 Small lot sizes are used in the firm (0.767)[a]
LSR2 Small lot sizes are used in master schedule (0.883, t = 13.401)
LSR3 Aggressively working to lower lot sizes in plant (0.845, t = 13.232)

Set-Up Time Reduction (STR) (Cua et al., 2001; Flynn et al., 1995a; Zelbst et al., 2010)
$\chi^2/df = 0.00$, CFI = 1.00, RMR. = 0.000, AVE = 0.70, CR = 0.87, α = 0.876
STR1 Aggressively working to reduce set-up times in the firm (0.8)[a]
STR2 Workers carryout practices to reduce set-up time (0.873, t = 14.128)
STR3 Low equipment set-up time is assured in the firm (0.841, t = 13.876)

Pull Production System (Kanban) (PPS) (Cua et al., 2001; Flynn et al., 1995a; Shah and Ward, 2007; Zelbst et al., 2010)
$\chi^2/df = 1.958$, CFI = 0.99, RMR. = 0.03, AVE = 0.73, CR = 0.91, α = 0.929
PPS1 Pull system for production control is used (0.764)[a]
PPS2 Production is pulled by the delivery of finished goods (0.804, t = 20.754)
PPS3 Production at current work station is pulled by the current demand of the next work station (0.935, t = 15.697)
PPS4 Kanban squares, containers of signals for production control are used (0.913, t = 15.476)

JIT Scheduling (JS) (Cua et al., 2001; Flynn et al., 1995a; Zelbst et al., 2010)
$\chi^2/df = 0.00$, CFI = 1.00, RMR. = 0.000, AVE = 0.78, CR = 0.91, α = 0.916
JS1 Production schedule is met each day (0.862)[a]
JS2 There is time in the schedule for machine breakdowns or production stoppages (0.936, t = 19.343)
JS3 Production schedule is designed to allow time for catching up due to production stoppages for quality problems (0.859, t = 17.572)

Change Proficiency (CP) (Inman et al., 2011; Sharifi and Zhang, 1999; Zelbst et al., 2010; Zhang and Sharifi, 2007)
$\chi^2/df = 1.994$, CFI = 0.99, RMR. = 0.011, AVE = 0.73, CR = 0.95, α = 0.952
CP1 Capabilities necessary to sense, perceive and anticipate market changes exist (0.827)[a]
CP2 Production processes are flexible in terms of product models and configurations (0.893, t = 21.767)
CP3 Immediately reacts to incorporate changes into manufacturing processes and systems (0.894, t = 17.879)
CP4 Appropriate technology capabilities exist to quickly respond to changes in customer demand (0.868, t = 17.041)
CP5 Strategic vision is used to emphasize the need for flexibility and agility to respond to market changes (0.866, t = 16.803)
CP6 The firm has the capabilities to deliver products to customers in time and quickly respond to changes in delivery requirements (0.858, t = 16.535)
CP7 Firm can quickly get new products to market 0.806, t = 16.641)

Knowledge Management (KM) (Hakala and Kohtamäki, 2011; Vázquez-Bustelo et al., 2007)
$\chi^2/df = 0.919$, CFI = 1.00, RMR. = 0.006, AVE = 0.66, CR = 0.90, α = 0.911
KM1 Employees are encouraged to learn from work experiences and share innovative ideas with each other's and management (0.81)[a]
KM2 Teams are prepared to constantly assess, apply and update knowledge of work (0.849, t = 14.997)
KM3 Databases containing organizational information are easily accessible to respective employees (0.851, t = 15.048)
KM4 Firm information system allow extensive dissemination of work knowledge throughout the organization (0.759, t = 12.884)
KM5 Employees are encouraged to share technical and work information (0.791, t = 13.61)

Advance Manufacturing Technology (AMT) (Narasimhan et al., 2006)
$\chi^2/df = 2.521$, CFI = 0.99, RMR. = 0.011, AVE = 0.61, CR = 0.88, α = 0.888)
AMT1 Firm uses Computer Aided Design (CAD) (0.754)[a]
AMT2 Firm uses Computer Aided Manufacturing (CAM) (0.645, t = 13.924)
AMT3 Firm uses Flexible Manufacturing Systems (FMS) 0.891, t = 11.961)
AMT4 Firm uses Robotics in production system (0.734, t = 12.14)
AMT5 Firm uses Rapid Prototyping for product development and design validation (0.872, 11.703)

Firm performance constructs

Operational Performance (1 = Well Below Average & 7 = Well Above Average) (Ahmad et al., 2003; Cua et al., 2001, 2006; Furlan et al., 2011b; Hallgren and Olhager, 2009)

$\chi^2/df = 1.674$, CFI = 0.99, RMR. = 0.015, AVE = 0.64, CR = 0.91, α = 0.916

Cost	Firm unit cost of manufacturing is lower than major competitors (0.788)[a]
Quality	Firm product quality (conformance to specification) is better than major competitors (0.806, t = 13.636)
Reliability	Firm on-time delivery performance is better than major competitors (0.805, t = 14.836)
Speed	Firm delivery speed to the customer is better than major competitors (0.848, t = 14.396)
Variety	Firm has more flexibility to change product (variety) mix as compare to major competitors (0.795, t = 13.413)
Volume	Firm has more flexibility to change product (volume) mix as compare to major competitors 0.783, t = 13.174)

Market Performance (1 = Deteriorated More Than 20% & 7 = Improved More Than 20%) (Inman et al., 2011; Sila, 2007; Sila and Ebrahimpour, 2005; Yang et al., 2011)

$\chi^2/df = 0.00$, CFI = 1.00, RMR. = 0.000, AVE = 0.74, CR = 0.89, α = 0.895

MP1	Sales growth (volume) performance of the firm for the last three years (0.891)[a]
MP2	Market share growth performance of the firm for the last three years (0.891, t = 17.484)
MP3	Sales performance of the firm for the last three years (0.801, t = 15.486)

Financial Performance (1 = Deteriorated More Than 20% & 7 = Improved More Than 20%) (Inman et al., 2011; Sila, 2007; Sila and Ebrahimpour, 2005; Yang et al., 2011)

$\chi^2/df = 0.00$, CFI = 1.00, RMR. = 0.000, AVE = 0.65, CR = 0.85, α = 0.851

FP1	Return on Asset (ROA) performance of the firm for the last three years (0.824)[a]
FP2	Return on Investment (ROI) performance of the firm for the last three years (0.807, t = 12.475)
FP3	Profitability performance of the firm for the last three years (0.797, t = 12.398)

*Items excluded from the analysis. All t-values are significant at $p < 0.01$.

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