Study of the Use of Employee Perception to Assess Lean Adoption Based on the Toyota Production System and Toyota Way Model in the Chinese Automobile Industry

by

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Abstract

In the 1980's, the world began to notice the Toyota Motor Corporation as a leader in the automotive manufacturing industry. The Toyota Production System has been researched and emulated for its business success in cost reduction and efficiency improvement over the past 30 years. However, few companies feel they have achieved significant results by adopting Lean production which describes a systematic method for waste minimization and cost reduction derived from the Toyota Production System. Failure of the inability to replicate Toyota's supportive culture has been listed as a cause for the failure to implement Lean. Many studies on assessing Lean implementation have been conducted from external points of view, only focusing on visible indicators, which may overlook the employee perception on the progress of Lean adoption. This dissertation examines how the Toyota Way culture concepts, and the difference of perception between frontline and non-frontline employees on Lean, influence the operational performance in the Chinese auto manufacturing industry. A survey instrument based on the Toyota Production System and Toyota Way culture was developed to assess Lean implementation by capturing employee perception. A survey development process and a pilot study were used to modify, finalize, and translate the survey. A full study was performed on a sample of 442 participants with Lean production experience at six auto manufacturing companies in China. The reliability and validity of the Toyota Production System and Toyota Way model-based survey were examined by reliability analysis and Confirmatory Factor Analysis. Structural Equation Modeling was used to investigate the relationships among Lean implementation, culture, and operational performance. A multigroup analysis was used to compare the influences of supportive culture within a Lean production system between organizations in the United States and China. Finally, a comparison of the perception of Lean between management and frontline employees in six plants

was conducted. According to the results, we may conjecture that the larger the difference of perception between management and frontline employees on culture, the worse the plant achieves performance objectives.

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List of Abbreviations

AGFI	Adjusted Goodness of Fit Index
ANOVA	Analysis of Variance
AVE	Average Variance Extracted
BIQ	Built-in Quality
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CI	Confidence Interval
CLF	Common Latent Factor
CR	Composite Reliability
DF	Degree of Freedom
DMAIC	Define-Measure-Analyze-Improve-Control
DWLS	Diagonally Weighted Least Squares
FAW	First Automobile Works
HTMT	Heterotrait-Monotrait Ratio
IRB	Institutional Review Board
JIT	Just-in-time
KMO	Kaiser-Meyer-Olkin Test
LESAT	Lean Enterprise Self Assessment Tool
MIT	Massachusetts Institute of Technology
ML	Maximum Likelihood
MTMM	Multitrait-Multimethod

NFI	Bentler-Bonet Normed Fit Index
P	Probability Value
PAF	Principal Axis Factor
PDCA	Plan-Do-Check-Action
RMSEA	Root Mean Square Error of Approximation
SEM	Structural Equation Modeling
SMED	Single-Minute Exchange of Dies
SME	Subject Matter Expert
SPSS	Statistical Package for Social Sciences
SRMR	Standardized Root Mean Residuals
STD	Standard
TLI	Tucker-Lewis Index
TPS	Toyota Production System
TPS-TW	Toyota Production System-Toyota Way
TPM	Total Productive Maintenance
TQM	Total Quality Management
TW	Toyota Way
VSM	Value Stream Mapping
WTO	World Trade Organization
WWII	World War II
YRS	Years

Chapter 1 Introduction

1.1 Background

Since the 1980's when the Toyota Motor Corporation became a recognized leader in the automotive manufacturing industry, the Toyota Production System (TPS) has been researched by many for its capability to significantly reduce cost and improve both quality and efficiency. The key objective of TPS is to reduce the time from customer order to delivery by eliminating all non-value-added operations (Ohno, 1988). Krafcik (1988) created the term "Lean production" to describe a systematic method for waste minimization and cost reduction derived from the TPS. In this research, the terms TPS and Lean are used interchangeably, as is done in other research on the TPS. Womack, Jones, and Roos (1990) presented the advantages of TPS over the traditional mass production methods and proposed 5 principles of Lean thinking consisting of define value, map the value stream, create flow, establish pull, and pursuit of perfection. Many manufacturing companies worldwide have attempted to implement the TPS or Lean, however, majority of them have not been able to achieve expected results (Burcher & Bhasin, 2006; Koenigsaecker, 2016; Liker & Rother, 2011; Mann, 2010; Pay, 2008; Sisson & Elshennawy, 2015; Spear & Bowen, 1999). Failures of the transition from the traditional mass production to Lean production have been attributed to poor change management, poor training, a lack of communication and mutual trust between management and workers, a lack of support from suppliers, and a lack of implementation of the Toyota's supportive culture which results in a focus on doing Lean rather than being Lean in practice (Cudney & Elrod, 2010; Herron & Hicks, 2008; Liker & Meier, 2005; Mann, 2010; McLean & Antony, 2014; Sim & Rogers, 2008; Wilson, 2009). All of these reasons are associated with the Toyota Way culture in different degrees.

Many studies on the application of Lean have been conducted. However, most of the research on assessing Lean implementation has been conducted with only emphasis on visible results or performance indicators, which may overlook what the employees think about the progress of Lean adoption (Loyd, 2017; Shetty, 2011). Having the employees who are an integral part of the Lean system in an organization assess the situation can highlight areas that need attention to improve operational performance and provide insight into the development of sustainability in the Lean implementation. Employees also have an opportunity to learn about Lean concepts and themselves in relation to the organizational objectives. Thus, the clarity of Lean objectives at all levels can be achieved.

1.2 Research Questions and Objectives

Shetty (2011) proposed an assessment approach using workers' perception based on the 5 principles of Lean Thinking promoted by Womack and Jones (2003). Building from Shetty's research, Loyd (2017) developed an assessment tool to empirically measure Lean implementation from workers' perception using the Toyota Production System-Toyota Way (TPS-TW) principles and validated it in manufacturing companies located in the US. However, Loyd's indicators, which represent the desired results of Lean adoption, were qualitative and not well-defined. The assessment tool was validated in the American manufacturing sector, so the results may not apply to operations in other countries. Additionally, no demographic information such as job role was involved in the data analysis. Considering the limitations of Loyd's research, this study attempts to answer a set of questions, "What measures of performance could be used to replace Loyd's qualitative indicators to improve the assessment tool?" "Is the TPS-TW model valid for measuring Lean production system implementation using employee perception in the manufacturing sector in China?" "How does the organizational culture affect Lean implementation and operational performance in China?" "Is there any difference in the effect of Lean culture in the Lean production system between America and China?" "Lastly, what is the difference of perception on Lean implementation and its supportive culture between management and frontline workers in the Chinese automotive industry?" Therefore, the objectives of this research include: 1) development of a TPS-TW model-based measurement instrument based on employee perception and validation of the instrument using quantifiable metrics in the automobile manufacturing sector in China; 2) investigation of the effect of TW culture on Lean deployment and operational performance in the automobile manufacturing sector in China and a comparison of how the effect of culture impacts operational performance between organizations in the US and China; and 3) comparison of the perception of Lean in the automobile manufacturing sector in China between management and frontline employees.

This research provides a validated Lean assessment tool based on employee perception. Manufacturing companies can use this assessment tool to measure their Lean implementation, identify problems in the culture, and guide decisions towards desired operational performance. This study also investigates whether the Toyota Way culture has a positive mediating effect in a Lean system in the Chinese manufacturing industry, which Loyd found in the US. This finding helps in driving manufacturing companies to move towards a supportive Lean culture for achieving performance improvement. The comparison of the effect of the Toyota Way culture between organizations in the US and China could provide valuable information about the influence of organizational and social culture in the success of achieving Lean objectives. Mutual communication and respect between management and frontline workers are fundamental principles of the Toyota Way culture and associated with failures of Lean implementation. This research examines the difference of perception of a Lean implementation between management and frontline workers and associates the difference with the actual performance metrics. The findings could help companies that have adopted Lean production have a better understanding of how to improve operational performance.

1.3 Dissertation Organization

This dissertation is comprised of five chapters. The organization of this dissertation is as follows. Chapter 1 is a traditional introduction that summarizes the background, purpose, and research objectives of this study. Chapter 2 is a comprehensive literature review of current knowledge related to TPS/Lean, the development of the Chinese automotive industry, and survey research methodologies. Chapter 3 presents the research statement and describes the research methods that were carried out in three phases: a survey development phase, a pilot study phase to test the effectiveness of the survey instrument, understand the structure of the survey, and identify appropriate statistical methods for data analysis, and a full study phase to achieve the research objectives. Chapter 4 describes the data collected in this study and reports the results of data analysis. Chapter 5 is a traditional discussion describing conclusions, assumptions, limitations, and future research. The appendices contain the survey used in this study, Internal Review Board (IRB) approval letter and consent forms, a full multigroup analysis in Structural Equation Modeling (SEM) to support the results presented in the Chapter 4, and other information to support this research.

Chapter 2 Review of the Literature

2.1 Background on Toyota

In the 1980's, the world began to take notice of the Toyota Motor Corporation as a leader in the automotive manufacturing industry. Over the decades since then, Toyota has continued to lead the industry, largely due to the continued focus on the now well documented Toyota Production System (TPS). Toyota's success has led many companies to research, investigate, and attempt to emulate the TPS.

The foundation of Toyota's success was laid by Sakichi Toyoda, who helped develop Japan's first power loom and created a successful weaving business (Toyota Industries Corporation [TIC], 2019). In 1933, the Automotive Production Division, part of Toyoda Automatic Loom Works, Ltd., was created, which would later become Toyota Motor Company in 1937 (Toyota Motor Corporation Global Website [TMCGW], 2019). The original goal for the Automotive Production Division was to produce passenger cars, which was discontinued due to World War II (WWII). Instead, the company had to change plans and produce trucks for the Japanese Army (TMCGW, 2019). After WWII, Toyota returned to commercial vehicle production for the general public (TMCGW, 2019). In 1943 Taiichi Ohno became a frontline supervisor in the engine plant, and he later assumed a leadership position at Toyota by becoming the machine shop director in 1954. Ohno (1988) realized that Toyota could not compete by adopting the mass production methods widely used in other vehicle manufacturers such as Ford, General Motors, and Chrysler, since the conventional mass production system naturally required an abundance of resources and robust customer demand. In response, Ohno began to develop a new operating philosophy, described in Taiichi Ohno's book *Toyota Production System: Beyond Large Scale*

Production (Ohno, 1988). The goal of the Toyota Production System (TPS) is to develop human ability to its fullest capacity to best enhance creativity and fruitfulness, to utilize facilities and machines well, and to eliminate all waste (Ohno, 1988). According to Ohno, the key objective of TPS is straightforward and simple: reduce the time from customer order to delivery by eliminating non-value-added operations. One of the leading experts on manufacturing practices and the TPS, Shigeo Shingo (1989), stated that the TPS is 5% Kanban -- the Japanese term for signboard which is a signaling device that gives authorization and instructions for the production or withdrawal of items in a pull system -- while the remainder is to remove all Muda, the Japanese term for waste or futility (Shook & Marchwinski, 2014). Muda includes seven types of waste: defects, overproduction, waiting, transportation, inventory, motion, and extra-processing (Alukal, 2003; Monden, 2011). Toyota credits its success to adherence to the TPS, which has propelled it to become the largest automotive manufacturer in the world and one of the most consistently successful global manufacturing enterprises (Monden, 2011).

Researchers from the Massachusetts Institute of Technology (MIT) investigated the automotive industry in the International Motor Vehicle Program, a 14 country 5 year study in the early 1980s (Womack et al., 1990). The study presented the advantages of Toyota's production methods over the conventional mass production in the book, *The Machine that Changed the World* (Womack et al. 1990). A researcher of the program, John Krafcik, created the term "Lean production" to describe Toyota's unique production system (Krafcik, 1988). Even though Womack predicted Toyota's triumph with detailed analysis, in the early 1990s U.S. automakers struggled to adopt Lean production. The U.S. automakers were used to working with the mass production strategy that was counter to Lean production (Holweg, 2007; Krafcik, 1988; Liker, 1997). Lean production was criticized by Western researchers and entrepreneurs on several aspects: lack of principles of implementation and a coherent theory (Flynn, Sakakibara, Schroeder, Bates, & Flynn, 1990), not suited for low-volume high-variety producers, inadequate sustainability (Cusumano, 1994), confusion about how to control labor cost (Williams et al., 1992), and the negative effects on the workforce (Delbridge, Turnbull, & Wilkinson, 1992; Garrahan & Stewart, 1994). In 1997, Womack and Jones issued their follow up book, *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. They defined the five principles of Lean production as 1) identify customers and value, 2) map the value stream, 3) create flow by eliminating waste, 4) respond to pull from the customer, and 5) pursue perfection (Womack & Jones, 1997). These five principles formed the foundation of a Lean implementation and provided a path to continuous improvement for manufacturing companies.

Toyota has continued utilizing the TPS tools and philosophies to lead the automotive industry. By 2003, Toyota's annual profit was greater than the combined annual profit of Ford, General Motors, and Chrysler (Liker, 2004). According to Toyota's final sales results, Toyota overtook Ford to become the world's second-largest automaker in 2004, and overtook General Motors in 2008 to become the world's largest automaker (Bunkley, 2009; Hakim, 2004). This broke the American auto producers' dominance over the global automotive industry that they had held for decades. Even though from 2009 to 2011 Toyota experienced vehicle recalls that involved approximately 5.2 million vehicles for pedal entrapment problems, 2.3 million vehicles for the accelerator pedal problem, and Japan's 2011 9.0 magnitude earthquake, Toyota overcame these setbacks to reclaim the title of the world's largest auto producer in 2012 (Bunkley, 2011; Tabuchi, 2018). In 2012, Toyota became the first company in history to produce more than 10 million automobiles in a single year (Organisation Internationale des Constructeurs d'Automobiles [OICA], 2012). In 2018's Fortune Global 500 list, Toyota was identified as the world's sixth largest company, Japan's largest company, and the world's largest manufacturer for its 265 billion dollars revenues (Fortune, 2018). All of these major accomplishments by Toyota were possible because of the TPS and Toyota's supportive culture. Toyota has surpassed its competition, as well as made its own mark worldwide, due to its strict adherence to the system it created.

2.2 The Toyota Production System, Toyota Way Culture and Various Lean Models

The original TPS model, resembling a house, was introduced by Fujio Cho and presented by Dennis and others, has a foundation of standardization and stability supporting the two pillars of just-in-time and built-in quality (Dennis, 2007; Shook & Marchwinski, 2014). The desired results of TPS which includes highest quality, lowest cost, and shortest lead time are illustrated as the roof of the house. Figure 2-1 shows the full TPS house model.

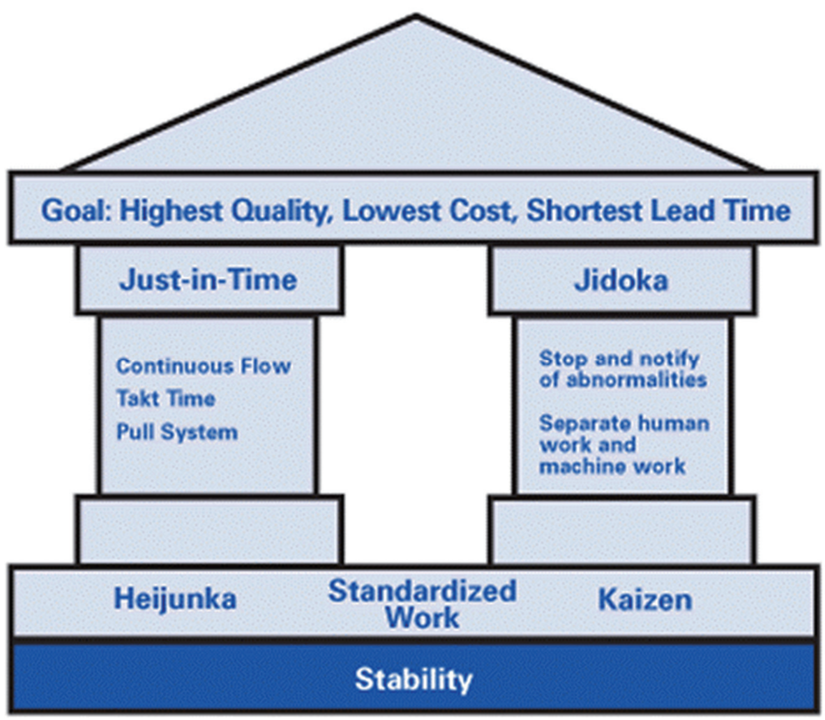

Figure 2-1 Toyota Production System House (Dennis, 2007; Shook & Marchwinski, 2014)

The foundation of stability and standardization make it possible to decrease ambiguity and uncertainty, guarantee quality, boost productivity, and maintain minimum inventories on a Just-in-time basis (Monden, 2011). Desired outcomes of standardization and stability are achieved through Heijunka, which means leveling production and controlling the variability of the job sequence to achieve better resource utilization (Hüttmeir, De Treville, Van Ackere, Monnier, & Prenninger, 2009; Matzka, Di Mascolo, & Furmans, 2012).

The first pillar, just-in-time manufacturing, facilitates smooth production flow by ensuring that the correct quantities of materials are delivered to the right place only when they are needed (Sakakibara, Flynn, Schroeder, & Morris, 1997; Sayer, 1986). In ideal conditions, material would move from process to process and piece by piece in a continuous flow without stopping. In mass production, this continuous flow is difficult to maintain since components are produced in batches which generates large inventories. The Single-Minute Exchange of Dies (SMED) technique enables equipment to be quickly changed over from producing one component to another so that it is possible to produce low batches and maintain small, or no, inventories (Ani, Norzaimi, Shafei, & Solihin, 2014; McIntosh, Culley, Mileham, & Owen, 2000). Applying Kanban philosophy, replenishment occurs only when the inventories are exhausted in the next process (Monden, 2011; Sakakibara, Flynn, Schroeder, & Morris, 1997; Sayer, 1986).

The Jidoka pillar is directly related to built-in quality and refers to a worker's authority to stop production when defects occur and quickly implement corrections (Masaaki, 1986; Monden, 1983; Standard & Davis, 1999). It ensures that quality issues are constantly identified, and processes are improved continually (Monden, 2011). To perform Jidoka effectively, skilled operators with strong problem-solving ability are needed (Monden, 2011).

Implementation of the TPS is full of problems, challenges and obstacles, especially for the companies that have utilized mass production methods for years (Ahmad, 2017). Researchers suggest that the implementation of TPS, or lean manufacturing, requires a supportive culture in the organization in addition to applications of the Lean tools and techniques (Ahmad, 2017; Burcher & Bhasin, 2006; Dahlgaard & Mi Dahlgaard-Park, 2006). The former chairman of the Toyota Motor Corporation, Fujio Cho, summarized the Lean supportive culture in Toyota and its guiding principles in a document, known as the Toyota Way (TW) (Toyota Motor Corporation [TMC], 2001).

The Toyota Way documented the values and business strategies that all employees should grasp with the goal to practice the guiding principles throughout the Toyota enterprise (Fane, Vaghefi, Deusen, & Woods, 2003; TMC, 2001). The Toyota Way is based upon two main beliefs: continuous improvement and respect for people (TMC, 2001). While the continuous improvement concept and tools such as 5S, 5 Whys, Kanban, Single-Minute Exchange of Dies (SMED), Kaizen, and the Plan-Do-Check-Act (PDCA) cycle have been widely adopted, the second pillar of the TW, respect for people, has been largely overlooked. To make engineers design and place Kanban cards, inventory flow racks, single-piece flow stations, and management boards throughout the entire manufacturing site is not the difficult aspect of a Lean implementation. Many organizations are able to implement the technical Lean tools by complying with instructions. Adopting the TW's concept of respect for people is what many companies find to be very challenging. Employees are much harder to motivate and lead if they lack basic understandings of Lean implementation and the company's long-term vision and strategy (Liker & Rother, 2011). In cases where companies did not achieve all of their objectives in a Lean implementation, it was usually associated with errors in their implementation process such as focusing only on the technical Lean tools and very little effort to enhance employee confidence (Harris et al., 2014; Hilbert, 1998). Yasuhiro Monden

(1983) systematically introduced the TPS to the United States with his book, *Toyota Production System: Practical Approach to Production Management,* in 1983. Monden (1983) suggests that the TPS methodology includes a hierarchy of concepts with each subsequent level getting closer to the shop floor level of operations. Through TPS adoption, companies have realized that the shop floor is where value is created, waste is encountered, and technical tools are employed to identify and eliminate waste (Monden, 2011). However, many manufacturing companies outside of Toyota still overlook the importance of the TW culture (Ahmed, 2013; Liker & Rother, 2011).

The principles of the TW of continuous improvement and respect for people consists of 5 components: teamwork; respect; challenge; Kaizen (the Japanese term for "change for the better") and Genchi Genbutsu (the Japanese phrase for "go to the source and see for yourself) (Liker, 2004; TMC, 2001). Figure 2-2 illustrates the principles of the Toyota Way culture.

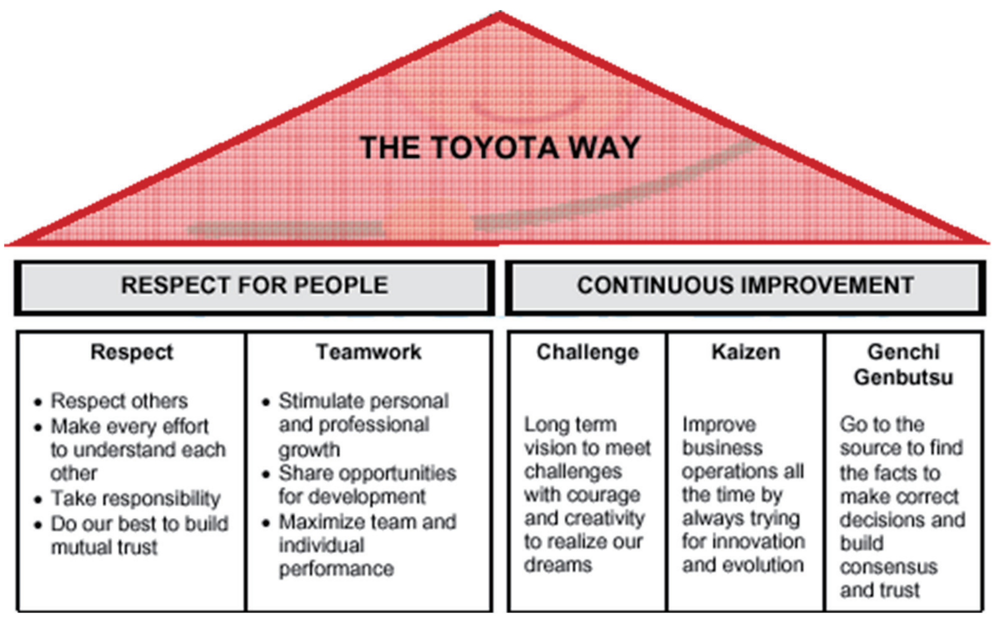

Figure 2-2 The Toyota Way Culture (Liker, 2004; TMC, 2001)

Liker (2004) proposed 14 principles of the Toyota Way in a 4P model of TPS. 4P refers to Philosophy, Process, People and Partners, and Problem Solving. Philosophy was defined as the fundamental law for every decision towards Lean production. Base management should be consistent with a long-term philosophy, and leaders should see the entire company as a vehicle for delivering value to their customers and community. To achieve the goal of waste elimination, the organization should avoid overproduction, identify problem at the beginning, level out workload, and standardize operating procedures. People and Partners involve the concept that management should value employees and suppliers by challenging them and helping them improve. Problem solving refers to the progress of how a company becomes a learning organization through continuous improvement. A requirement for management is to go and see problems at the shop floor and thoroughly understand the situation. Liker (2004) suggests that the concepts of the TPS are the engines that drive Toyota's operations, but it is the Toyota Way that provides the necessary environment for successful Lean implementation.

Hoeft (2009) combined the TPS and the TW culture adding another pillar to the TPS house. The third central pillar adds two people-oriented desired results, safety and highest morale, to the roof. Based on this configuration, Loyd (2017) developed the Toyota Production System–Toyota Way (TPS-TW) model with a central pillar that represented the TW culture and its two principles: respect for people and continuous improvement. Figure 2-3 illustrates the TPS-TW model.

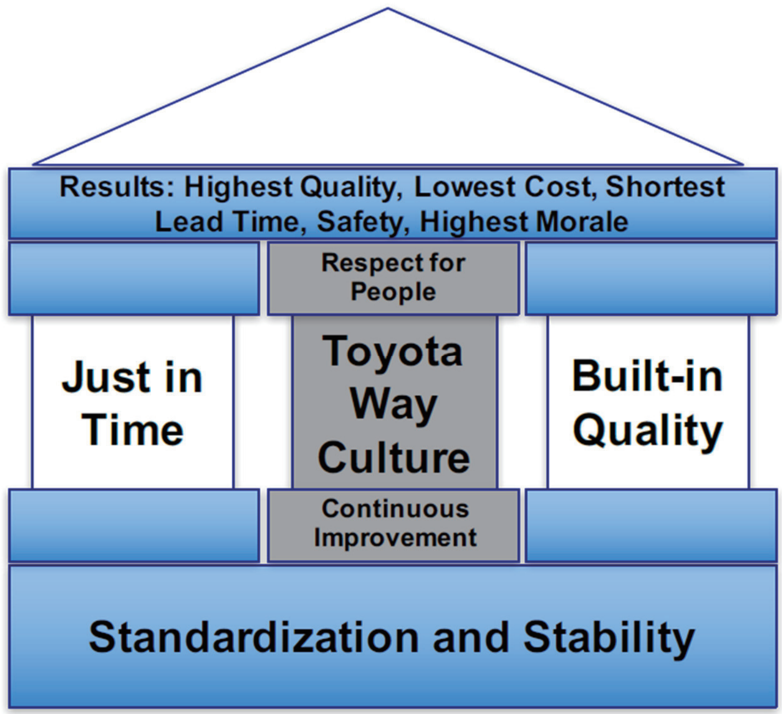

Figure 2-3 TPS-TW Model (Hoeft, 2009; Loyd, 2017)

Several other models have been developed that contain a people component of Lean. Karlsson and Ahlstrom (1996) developed a Lean model that consists of 9 principles: zero defects, JIT, continuous improvement, pull of materials, waste elimination, decentralization, integrated functions, multi-functional teams, and vertical information systems. Shah and Ward (2007) integrated internal production operations with suppliers and customers into a Lean model consisting of 10 factors: pull, flow, low setup, JIT, supplier feedback, supplier development, involved customers, involved employees, controlled processes, and productive maintenance. This study concluded that the desired objective of Lean production is to minimize the internal variability related to supply chain and customers' demands. Yu, Tweed, Al-Hussein, and Nasseri (2009) developed a Lean model based on Value Stream Mapping (VSM) with features of first-in first-out flow, leveling production, work restructuring and solid operational reliability in the house construction industry. Wahab, Mukhtar, and Sulaiman (2013) developed a conceptual Lean production model that was comprised of 7 dimensions: manufacturing process and equipment, manufacturing planning and scheduling, visual information system, product development and technology, workforce management, supplier relationship, and customer relationship. Though all of these examples involved a people factor as a component of Lean production, none captured respect for people element in their models.

Recent approaches to Lean have integrated the concepts of Lean production with other operations management philosophies in the manufacturing industry. Lean Six Sigma is a method that combines the Define-Measure-Analyze-Improve-Control (DMAIC) improvement method of Six Sigma and Lean techniques to systematically reduce variation and eliminate waste (Albliwi, Antony, Abdul Halim Lim, & van der Wiele, 2014; Cherrafi, Elfezazi, Chiarini, Mokhlis, & Benhida, 2016; Pepper & Spedding, 2010). Cherrafi et al. (2016) presented an analysis based on literature review and proposed an integrated model consisting of Lean production concepts, Six Sigma, and sustainability. Dettmer (2011) proposed an integrated model that consists of Lean and the Theory of Constraints (TOC) for evoking efficiency and minimizing non-value added costs. Yang and Yang (2013) proposed an integrated model of TPS, Human Resources Management (HRM), Total Quality Management (TQM), and “people factors.” The study concluded that the inclusion of people-related factors significantly enhanced the benefits associated with Lean adoption. Some researchers integrated Lean and agile concepts to form the “leagile” strategies within supply chain management to balance long lead times with unpredictable demands (Krishnamurthy & Yauch, 2007; Mason-Jones, Naylor, & Towill, 2000; Purvis, Gosling, & Naim, 2014). The waste elimination from Lean and flexibility from agile are mutually supportive in the leagile system.

2.3 TPS Adoption Issues

Since Toyota's success, many manufacturing companies have attempted to implement Lean production. However, only 24% of non-Japanese companies implementing Lean consider that they have achieved the significant, sustained, results they expected, and just 2% have accomplished their full Lean objectives (Pay, 2008; Sisson & Elshennawy, 2015). Many reasons have been presented to explain the failures of Lean implementation in the manufacturing industry. These include a lack of true understanding of the philosophy by senior management (Spear & Bowen, 1999), ethnic culture difference (Cudney & Elrod, 2010; Herron & Hicks, 2008), poor change management (Mann, 2010; Sirkin, Keenan, & Jackson, 2005), a lack of communication and mutual trust between management and employees (Sim & Rogers, 2008; Staudacher & Tantardini, 2008), a lack of support from suppliers (Liker & Meier, 2005; Salaheldin, 2005; Wilson, 2009), a lack of Lean training (McLean & Antony, 2014; Sim & Rogers, 2008), fundamental misunderstanding of the TPS in practice by focusing on doing Lean rather than being Lean (Liker & Rother, 2011), and a lack of implementation of the Lean supportive culture (Spear & Bowen, 1999). All of these reasons for the failure of Lean adoption are associated with the Toyota Way culture in different degrees.

Considering the fact that the majority of manufacturing companies trying to adopt Lean production have not been able to achieve expected results (Burcher & Bhasin, 2006; Koenigsaecker, 2016; Liker & Rother, 2011; Mann, 2010; Pay, 2008; Sisson & Elshennawy, 2015; Spear & Bowen, 1999), it is apparent that the transition from mass production to Lean can be very difficult (Sirkin et al., 2005). Liker and Rother (2011) indicate that all employees working at Toyota in Japan at all levels conduct TPS as their primary way to work every day with the goal of creating value and minimizing non-value-added activity (waste), while in other companies, managers and engineers tend to lead and employ Lean tools only as their tasks require. So the question begging to be answered is: Does the Toyota Way culture really have an effect on Lean implementation and operational performance?

2.4 The Role of Culture

Acceptance of a Lean implementation may have varied results in different countries based upon how the culture of a country is supportive of change (Hofstede, Hofstede, & Minkov, 2010; Kull, Yan, Liu, & Wacker, 2014; Lagrosen, 2003; Newman & Nollen, 1996; Ralston, Holt, Terpstra, & Kai-Cheng, 2008; Sousa & Voss, 2008). Many automobile producers outside of Japan experience difficulty in successfully implementing Lean and realizing the benefits of costs reduction from JIT and zero-inventory which lure most automotive producers to establish their JIT management and Kanban system at the beginning of Lean adoption (Liu, 2005; Pay, 2008; Sisson & Elshennawy, 2015). Some researchers argued that it is easier to adopt Lean production in countries with generally collectivist cultures such as Japan, China, and South Korea than it is in individualistic culture countries such as the U.S., Germany, and the United Kingdom (Naor, Linderman, & Schroeder, 2010; Pakdil & Leonard, 2017; Power, Klassen, Kull, & Simpson, 2015; Power, Schoenherr, & Samson, 2010; Wiengarten, Fynes, Pagell, & de Búrca, 2011). Araujo Calarge, Loureiro Junior, Damasceno Calado, and Cezar Lucato (2014) found that multinational companies had better Lean implementation than national companies in Brazil.

Chinese culture, as one of the world's oldest cultures, is a representation of Confucianism. The culture can result in barriers, such as a conservative view, a lack of initiative, and a lack of communication between management and operators that affect Lean transformation and has its own impact on operational performance. Ralston et al. (2008) performed a study of managers from the United States, Russia, Japan, and China. The result suggests that the Chinese managers are less open in terms of individualism, change, and self-enhancement than managers in the other countries. Brown and O'Rourke (2007), Oliver, Delbridge, and Lowe (1998), Paolini, Leu, and Chinn (2005) found that many Chinese factories tend to hire poorly educated workers from rural areas, lacking basic cost saving knowledge. The tolerance the Chinese employees have for a disorganized workplace contradicts the application of the 5S tool. Aoki (2008) describes a lack of initiative among Chinese frontline employees in a Sino-Japanese joint venture in routine continuous improvement activities. Only employees above team leader levels showed enthusiasm for Kaizen (Aoki, 2008). Chin and Pun (2002) reported that some Chinese frontline workers and supervisors were seen to be unwilling to participate in continuous improvement. Taj and Morosan (2011) performed a survey in Chinese manufacturing sectors with results indicating that 10% of enterprises have an annual employee turnover rate of more than 30%. The high employee turnover makes it difficult to train front-line operators on Lean concepts and tools. Aminpour and Woetzel (2006) suggest that the strict hierarchy of organization in China impedes the collaboration between managers and workers in problem-solving. Similarly, Paolini et al. (2005) reported that some managers are afraid of losing authority when empowering frontline workers plays a part in Lean adoption. The clash between Chinese and Lean culture can inhibit the success of the Lean adoption.

2.5 Lean Measurement Methods

The manufacturing enterprises that have adopted Lean production require an effective measurement method for assessing the organization's level of Lean implementation. Also, a reliable and appropriate measurement method can guide and drive a company's Lean implementation towards desired results. An inappropriate measurement method may inhibit an organization's long-term strategy and vision, and lead to the unsuitable strategies in the Lean adoption (Bhamu & Sangwan, 2014).

Researchers have developed various “leanness” measurement methods for the manufacturing industry. The Shingo Prize for Operational Excellence was named after the prominent TPS expert, Shigeo Shingo, and is one of the earliest Lean measurement systems. This system measures the Lean capabilities of an organization based on its 10 guiding principles of operational excellence that consists of respect every individual, lead with humility, seek perfection, embrace scientific thinking, focus on process, assure quality at the source, flow and pull value, think systemically, create constancy of purpose, and create value for the customers (Shingo Institute, 2018). The criticism of such operational excellence awards and prizes was that the measurement process is extensive and lumbering (Dahlgaard, Pettersen, & Dahlgaard-Park, 2011). The Shingo Institute seems to merely support organizations in doing Lean to apply for the awards rather than driving sustainable excellence leading to a situation where “some companies can look great and win awards, yet find themselves in bankruptcy court” (Meyer & Waddell, 2007).

The Lean Enterprise Self-Assessment Tool (LESAT) Version 2.0 developed by the Massachusetts Institute of Technology and the University of Warwick is one of the most popular self-evaluation techniques for Lean measurement. The LESAT 2.0 utilizes a capability maturity model with a five-degree maturity scale and surveys 68 enterprise practices in three dimensions: Lean Transformation and Leadership, Lifecycle Processes, and Enabling Infrastructure. The LESAT 2.0 assesses Lean implementation in an organization only by having management self-report at the enterprise level and perception from employee level is not directly captured (Lean Advancement Initiative [LAI], 2012).

Several operational performance frameworks have been developed to drive and monitor Lean implementation. Mishra and Chakraborty (2014) proposed eight main factors contributing to successful Lean implementation that were comprised of perpetual evolution, employee's willingness of the shift to Lean production, leadership skills of the management, supplier management, employee development, organizational culture, communication, and employee empowerment. Vinodh and Chintha (2011) proposed a conceptual model for Lean manufacturing that consisted of five leanness categories: responsibility leanness, manufacturing management leanness, workforce leanness, technology leanness and strategy leanness. Gao and Low (2014) developed an implementation framework based on the Toyota Way model consisting of 14 factors: long-term perspective, one-piece flow, Kanban, level out the workload, build-in quality, standardization, visual management, reliability, leadership, people management, partner relationships, on-site problem solving, decision-making, and Kaizen. Omogbai and Salonitis (2016) proposed a Lean assessment tool that consists of 4 dimensions: lead time performance, TQM performance, employee morale performance, and total productive maintenance (TPM) performance. However, there is a complexity and diversity in Lean implementation throughout the manufacturing industry. Using an inappropriate or incomplete framework to assess Lean implementation may lead to inaccurate results and misallocations of future resources, and thus hurt an employee's confidence in the system.

Fuzzy logic theory is widely used in developing Lean assessment tools. Fuzzy logic is a multi-valued logic approach to assess based on "degrees of truth" between 0 and 1 rather than the exact "true or false" of Boolean logic (Klir & Yuan, 1995; Ross, 2004; Zadeh, 1988). It is utilized to deal with the condition of partial truth, where the value may be located in the middle of absolutely true and absolutely false (Ross, 2004). Bayou and De Korvin (2008) employed a fuzzy logic approach to measure and compare the degrees of leanness between Ford, General Motors, and Honda serving as benchmarked firms. Three dimensions were included in Bayou and De

Korvin's assessment tool: JIT, continuous improvement, and total quality management. Bayou and De Korvin (2008) collected benchmark data from Honda's records, but did not capture employees' perception.

Behrouzi and Wong (2011), Vinodh and Vimal (2012), Anvari, Zulkifli, and Yusuff (2013), Pakdil and Leonard (2014), Susilawati, Tan, Bell, and Sarwar (2015) and Abreu and Calado (2017) also developed Lean measurement tools based on fuzzy logic and were mainly in the form of self-assessment. Behrouzi and Wong's (2011) tool measured eight metrics: scrap, customer complaints, inventory, transportation cost, non-value added time, setup time, late delivery, and lead time across four performance categories of quality, cost, time and delivery. Vinodh and Vimal's (2012) tool measured nine leanness enablers consisting of management responsibility, leadership, culture, communication and coordination, general management, process management, continuous improvement, hiring policies, and planning based on thirty criteria. Anvari et al.'s (2013) assessment tool focused on four basic attributes to leanness: lead time, costs, defects, and customer satisfaction. Pakdil and Leonard's (2014) tool measured eight quantitative dimensions including time effectiveness, quality, process, cost, human resources, delivery, customer and inventory via 62 indicators based on seven types of wastes. Susilawati et al. (2015) identified 66 lean practice factors that were divided into 6 impact areas including customer issues, supplier issues, manufacturing and internal business, research and development, learning perspectives and investment priority through a study in the Indonesian manufacturing industry. Abreu and Calado (2017) developed their Lean measurement tool based on thirteen criteria that consist of customers' focus, continuous improvement, employee involvement, process management, quality, visual management, production flow, pull system, standardized work, setup time, TPM, suppliers relationship, and suppliers development. In these studies, the primary participants were engineers and management.

Research suggests that it would be difficult to adopt Lean in an organization without understanding the employee perception, and the employee perception determines the degree of "leanness" in the organization (Jayamaha, Wagner, Grigg, Campbell-Allen, & Harvie, 2014; Losonci, Demeter, & Jenei, 2011; Loyd, 2017; Oon, 2013; Shadur, Rodwell, & Bamber, 1995; Shetty, 2011). Employees within an organization usually have different demographics. Losonci et al. (2011) identify that belief, commitment to company, communication, and work method were main contributors to Lean success from the standpoint of employee perception via a case study and a survey at a Hungarian auto parts plant. Losonci et al. (2011) argued that male workers are more affected by commitment and work method, whereas female employees tend to be influenced more by belief and communication. Oon (2013) conducted a survey to study the difference of employee perception in a Japanese semiconductor company located in Malaysia and found a significant difference between the workers who had significant exposure to Lean production and those with low exposure to Lean. This research found that no significant difference of perception existed in terms of gender, job role, length of service, age, or education level. Lodgaard, Ingvaldsen, Gamme, and Aschehoug (2016) conducted a two-year single case study in a Norway manufacturing company with about 300 employees. Lodgaard et al. (2016) identified the difference of perceptions on existing barriers to continuous improvement success were between different hierarchical levels of employees. The frontline workers tend to see limited support and commitment from management, as well as a lack of involvement, motivation, and teamwork as the main existing barriers to continuous improvement; the top managers instead tend to think shortcomings of information systems and improvement methods are more critical (Lodgaard et al., 2016). Engineers and mid-level managers acknowledge both groups of barriers, but tend to agree more with the frontline employees' view (Lodgaard et al., 2016). The authors argued that the different opinions at different hierarchical levels may misguide the Lean implementation. Shadur et al. (1995) studied the predicting factors on employees' acceptance of Lean adoption in a Japanese-owned automotive plant in Australia and found that commitment to the company, work speed, and age were significant predictors. Jayamaha et al. (2014) conducted a study using data obtained from Toyota's logistics, sales, and marketing functions across 27 countries to test the TW model. The study assessed the theoretical TW model using Structural Equation Modeling (SEM) technique and concluded that continuous improvement was a direct indicator of successful deployment of TW whereas respect of people serves as a direct predictor of continuous improvement and has an indirect effect on TW (Jayamaha et al., 2014). Through the process of the adaptation of the TPS in western manufacturing industry, researchers (Bhasin, 2012; Burcher & Bhasin, 2006; Lee & Jo, 2007; Niepce & Molleman, 1998; Shetty, 2011) suggest that while companies outside of Japan usually have more concern for designing and making jobs desirable and safe for the workers, Toyota's production system focuses more on respect and involvement in continuous improvement, which motivates employees to minimize waste and improve product output efficiency.

Shetty (2011) affirmed that it would be hard to completely understand how Lean is being adopted without understanding the employee perspective. Shetty developed a Lean assessment tool based on the five principles of Lean thinking. His survey-based tool assessed Lean adoption through a direct employee-centric approach that quickly and effectively captured employee perception via 29 questions. The five-degree Likert scale (strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree) with an additional option of "I don't know" was used in his questionnaire. Sarantopoulos, Min, Calado, & Componation (2013) implemented Shetty's survey-based tool at both Lean and non-Lean companies in the Brazilian manufacturing industry. The result suggests that employees working at Lean companies have a better understanding and a less dispersion in each survey item, than employees from companies without Lean (Sarantopoulos et al., 2013).

Based on the success of Shetty's assessment approach, Loyd (2017) developed an assessment tool to empirically measure Lean adoption from employees' perception using the TPS-TW model. Loyd's (2017) tool measures four dimensions: standardization, just-in-time, built-in quality, and the Toyota Way culture. Loyd's tool also includes three items representing the desired results of Lean implementation for assisting in validation. The result validated his tool and proved that the TW culture has a mediating effect between Lean implementation and the desired results of Lean (Loyd, 2017). Loyd's research is limited in several ways. First, the survey items representing the desired results of Lean adoption were qualitative and not well defined. Second, the assessment instrument was created and tested in relation to the manufacturing sector in the U.S. and the results may not apply to other countries. And third, no demographic information such as job role was involved in analysis. Table 2-1 summarizes the literature review on Lean assessment.

Table 2-1 Summary of Lean Assessment Literature Review

Lean Assessment Research	Toyota Production System / Toyota Way Constructs					Assessment Methodology		
	STD and Stability	Just-In-Time	Built-In-Quality	Continuous Improvement	Respect for People	Employee Perception	Validation in Research	Validation Method
Shingo Prize (1988)	○	●	○	●	○			
Shah and Ward (2007)		●	●		○		●	SEM
Bayou and De Korvin (2008)		●	●	●				Fuzzy
Shetty (2011)		○		●		●	●	SEM
Behrouzi and Wang (2011)		●	●					Fuzzy
LESAT 2.0 (2012)	○	●		●	○			
Vinodh and Vimal (2012)				○	○		●	Fuzzy
Anvari et al. (2013)	●	●	●				●	Fuzzy
Yang (2013)		●	●	●			●	SEM
Sarantopoulos et al (2013)		○		●		●	●	SEM
Jayamaha et al. (2014)				●	●	●	●	SEM.
Pakdil and Leonard (2014)	○	○	●	●	○			Fuzzy
Mishra and Chakraborty (2014)		○		○	○			
Low (2014)	●	○	●	●	○			
Susilawati et al. (2015)				●	●	●	●	Fuzzy
Omogbai et al. (2016)		●	●	○	○			
Abreu and Calado (2017)	○	●	●	○	○			Fuzzy
Loyd (2017)	●	●	●	●	●	●	●	SEM

●	Completely Covered
○	Partially Covered
	Not Covered

2.6 Lean in the Chinese Auto Industry

The history of China's automobile industry begins in the mid-1950s, under the leadership of the Central Committee of the Chinese Communist Party and the assistance of the former Soviet Union (Holweg, Luo, & Oliver, 2005; Tang, 2009, 2012). The First Automobile Works (FAW) located in Changchun, Jilin Province produced the first Chinese self-made vehicle in 1956, a commercial truck called the Jiefang (Holweg et al., 2005; Xinhua, 2013). For the next two decades, China produced less than 150,000 cars per year, and only 2% were passenger vehicles (Holweg et al., 2005). In 1978, China started the "Reform and Opening" program of economic reforms and trade liberalization, which accelerated the modernization of the Chinese automobile sector (Harwit, 2016; Vause, 1988). Since the 1980s, government policies permitting foreign direct investment and global automakers to undertake joint ventures with domestic companies activated the rapid development of the Chinese automobile industry (Harwit, 2016; McGrattan, 2016; Tang, 2012). In 1983, the first automobile manufacturing joint venture in China, Beijing Jeep Corporation, was established between American Motors Corporation and Beijing Auto Works (Mann, 2018). Beijing Jeep Corporation was followed in 1984 by the foundation of Shanghai Volkswagen between Volkswagen Group and Shanghai Automotive Industry Corporation (Harwit, 2016).

Chinese automobile manufacturing companies faced many problems that stemmed from being a developing country in the 1980s and 1990s, including inadequate energy and power supplies, poor transportation infrastructure, and unreliable material supply chains (Vause, 1988). In spite of all these issues, Chinese automakers overcame and made significant progress with rapid economic growth (Holweg et al., 2005; Tang, 2009). In 1985, China produced a total of 5,207 passenger vehicle as shown in Figure 2-4 (China Council for the Promotion of International Trade [CCPIT], 2011; Chen, 2002; State Council, 2019). The annual output of passenger cars reached

487,695 in 1997 and first time surpassed the annual output of trucks as shown in Figure 2-5 (State Council, 2019; CCPIT, 2011).

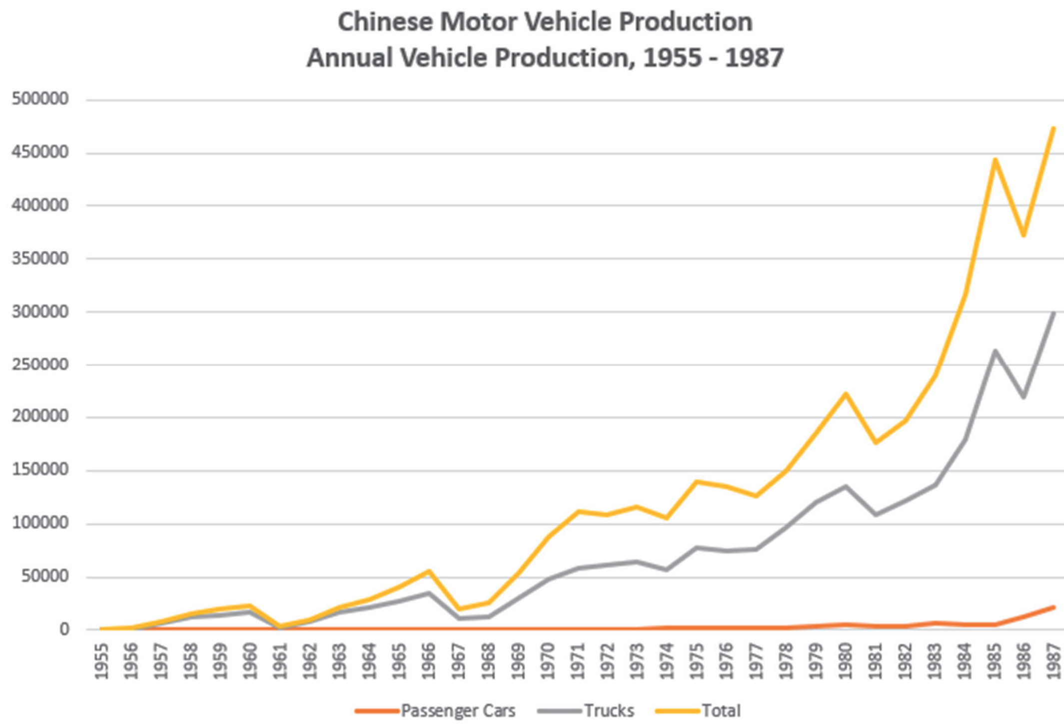

Figure 2-4 Chinese Motor Vehicle Production 1955 - 1987 (State Council, 2019)

After China became a member of the World Trade Organization (WTO) in 2001 as a developing country, the government began liberalizing foreign investment in China's automobile industry, as well as making efforts to improve internal laws and regulations (Holweg et al., 2005; Harwit, 2016). The potential market attracted most of the major global automakers to expand operations and create new plants in China (Harwit, 2016). In the 2000s, China's low labor cost, strong supply base, high investment in transportation infrastructure, and solid fundamental education of engineering have provided a good platform for automotive manufacturing (Eloot, Huang, & Lehnich, 2013). With an annual production of 13.7 million vehicles, China became the largest automobile market, both in terms of demand and supply in 2009 (Cox, 2017; Tang, 2012;

The Guardian, 2010; Xinhua, 2010). In 2018, Chinese automobile industry produced approximately 23.5 million passenger cars and 4.3 million commercial vehicles as shown in Figure 2-6 (OICA, 2018). The number of registered vehicles on the road in China reached 240 million by December 2018 (The Ministry of Public Security of China [MPSC], 2019). The foreign brands produced by joint ventures, such as Volkswagen, General Motors, Nissan, Toyota, Honda, and Hyundai-Kia, occupied more than half of the Chinese automotive market, see Figure 2-7 (State Council, 2019).

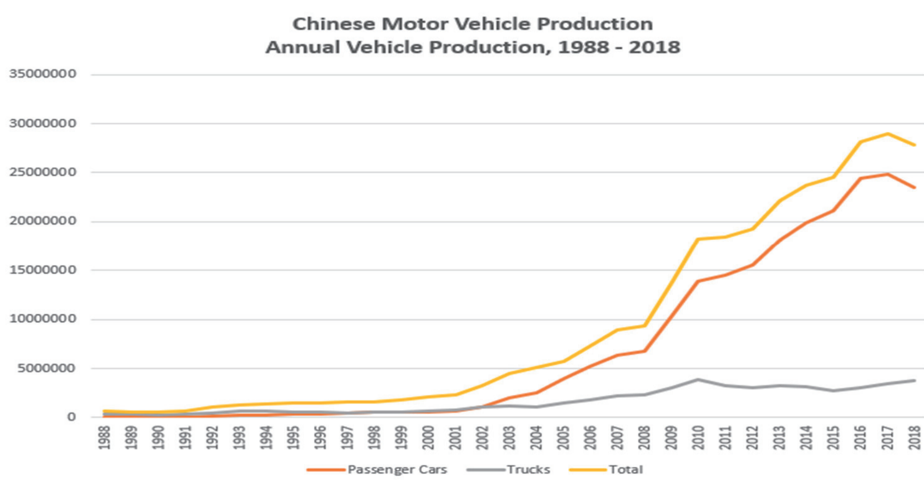

Figure 2-5 Chinese Motor Vehicle Production 1988 - 2018 (State Council, 2019)

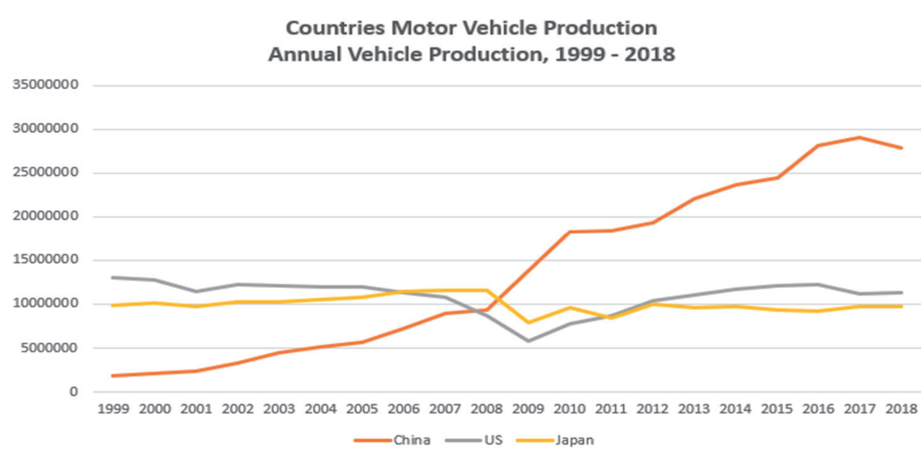

Figure 2-6 Countries Motor Vehicle Production 1999 - 2018 (OICA, 2019)

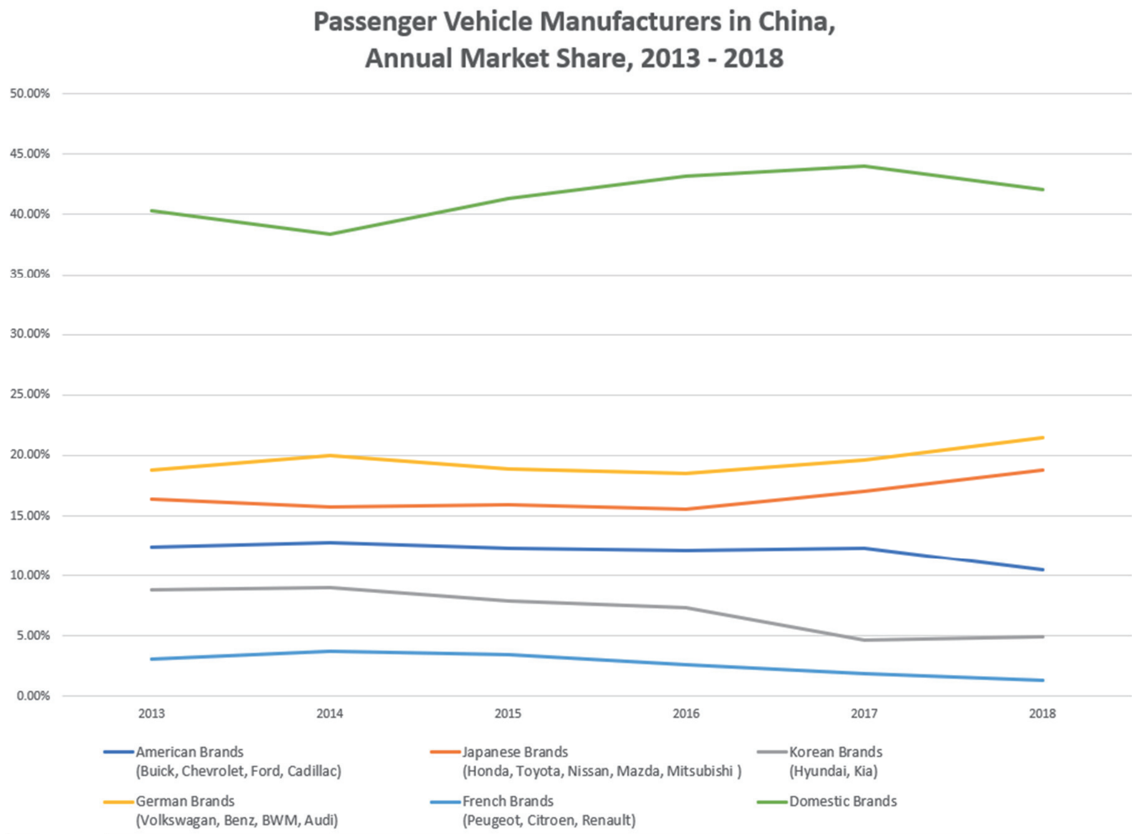

Figure 2-7 Passenger Vehicle Manufacturers in China 2013 - 2018 (State Council, 2019)

To meet customer's requirement and maintain manufacturing competitiveness in terms of product design, quality, safety, cost, and delivery time, the Chinese automobile producers adopted the technological and management expertise from their foreign partners (Holweg et al., 2005; Vause, 1988). As early as 1978, a delegation of twenty professionals from China's First Automobile Works (FAW) visited Toyota in Japan and stayed for 5 months to learn the TPS (Lee, 1998; Ning, 2006). After the delegation returned to China, they began to teach what they learned about the TPS to senior managers at FAW. In 1981, FAW invited Taiichi Ohno to teach TPS to managers and engineers in China. Ohno gave guidance on the adoption of TPS and assisted in building two TPS sample lines at FAW (Ning, 2006). This was the first time that a Chinese auto producer implemented the TPS (Ning, 2006). In 1994, Yasuhiro Monden, a well-known management educator and the director of the Japanese Production and Operations Management Society, visited FAW for two weeks to teach Lean production and cost improvement in manufacturing (Ershi, 1997). During the 1990s, FAW reduced work-in-process inventory 70% by adopting one-piece flow manufacturing (Chen, Lee, & Fujimoto, 1997; Lee, 1998; Liu, 2005). Other automobile producers in China were encouraged by FAW's successful adoption of Lean and learned from Sino-foreign joint ventures in terms of quality improvement and cost reduction. In response to the success of FAW and Toyota, many Lean training organizations were established in China. The top management in other Chinese companies gradually accepted Lean thinking and were willing to deploy Lean production to achieve their profit targets (Ning, 2006; Lee, 1998). Lean production spread in the Chinese automobile industry quickly.

Though some Chinese automobile producers demonstrate benefits from Lean production, most of them have not achieved their expected goals (Chen & Meng, 2010; Ershi, 1997). Some enterprises build solid competitiveness through Lean (Ershi, 1997; Ning, 2006). Many frustrations occur in the process of adopting Lean that create doubt in the minds of managers about whether Lean is suitable for their plants (Chen & Meng, 2010; Ershi, 1997). The lack of a continuous improvement culture was identified as one of the main reasons for Lean implementation failures (Chen & Meng, 2010; Ershi, 1997; Gao & Low, 2014; Liu, 2005). Many employees only consider Lean a set of technical tools. The employees only "do" Lean rather than "be" Lean. These issues found in the Chinese industry are the same as those found in American manufacturing companies (Harris et al., 2014; Liker & Rother, 2011; Spear & Bowen, 1999). Without a culture to support Lean implementation, many employees do not understand how what they do affects the company's business vision and strategy (Chen & Meng, 2010).

As with American companies, another difficult aspect of implementing Lean is measuring the progress of the effort. There is not currently a reliable tool to successfully measure the progress achieved in the implementation of Lean production in Chinese companies (Ershi, 1997; Liu, 2005). Moreover, some enterprises broadly copy the successful system of their foreign partners or others without tailoring the system to their own situation (Chen & Meng, 2010). Simply mimicking a successful system does not work because companies have different situations and backgrounds. The successful adoption of a Lean approach is closely related to the culture of the enterprise (Liker & Rother, 2011; Mann, 2010; Spear & Bowen, 1999). In addition, some enterprises hope to achieve desired results by applying Lean quickly (Chen & Meng, 2010; Liu, 2005). When the managers find they are not able to successfully implement Lean quickly, they become doubtful and give up. Toyota has spent more than thirty years developing the TPS and they work to improve it each day. Lean transformation is a revolution, one that requires an entire cultural transformation to be successful (Ahmed, 2013; Koenigsaecker, 2016; Sisson & Elshennawy, 2015).

2.7 Survey Research

Survey research refers to a method used to collect data from a population to obtain information and perspectives on various subjects of concern through their responses to questions (Check & Schutt, 2011). Surveys have been used in social and psychological studies to collect data from predefined individuals and groups for more than two hundred years. As early as 1790, the first United States Census was taken to collect information including the number of family members, the name of head of family, and categorized inhabitants throughout the thirteen original US colonies and the Southwest Territory (US Census Bureau, 2019). In the 1830s, the Statistical Society of London organized a committee to investigate industrial and social conditions by written questionnaires (Gault, 1907). Survey research has been developed into a systematic methodology in the research of human subjects with a variety of scientifically tested approaches involving respondent recruitment, question design, and data collection. Survey research can use a quantitative approach to collect structured facts, a qualitative approach to collect information on a topic more than measure it, or a mixed approach (Cohen, Manion, & Morrison, 2002).

The first step in a survey investigation is to select a sampling strategy (Henry, 2009; Kalton & Graham, 1983; Kish, 1965). The objective of sampling is to achieve sufficient samples that are representative of the entire target population (Henry, 2009; Kalton & Graham, 1983; Kish, 1965). Researchers have to consider their key factors before determining the final sampling strategy that consists of the sample size, representativeness and characteristics of the sample, and access to the sample (Cohen et al., 2002). There are two general types of sampling strategies: probability sampling and non-probability sampling. Probability sampling refers to a procedure in which samples are randomly selected from the population of interest while non-probability sampling refers to samples that are not randomly selected from the population (Visser, Krosnick, & Lavrakas, 2000). Adopting a probability sampling strategy provides a better chance that the selected sample is representative of the larger population, and allows for precise estimation of variance due to sampling error in a given dataset to construct confidence intervals (Visser et al., 2000). There are various probability sampling methods such as simple random sampling, systematic sampling, stratified sampling, cluster sampling, stage sampling, and multi-phase sampling (Cohen et al., 2002; Gundersen, Jensen, Kieu, & Nielsen, 1999; Henderson & Sundaresan, 1982; Neyman, 1934; Thompson, 1990).

Non-probability sampling strategy is viewed as an inferior alternative to probability sampling and is often adopted in small-scale or exploratory research because it is more convenient and less expensive to set up. However, non-probability sampling can sometimes be the only possible option, such as when the population is very large and the researcher has limited resources, where it is better to conduct non-probability sampling rather than no research at all (Cohen et al., 2002; Etikan, Musa, & Alkassim, 2016). Typical non-probability sampling methods include convenience sampling, quota sampling, purposive sampling, dimensional sampling, volunteer sampling, snowball sampling, and theoretical sampling (Etikan et al., 2016; Morse, 1991; Arnold, 1970; Goodman, 1961; Biernacki & Waldorf, 1981; Coyne, 1997; Draucker, Martsolf, Ross, & Rusk, 2007).

The next step in survey research is questionnaire design. The objective of questionnaire design is to assist in maximizing the reliability and validity of the data to be collected (Visser et al., 2000). At the preliminary stage of designing questions, the researchers have to make several decisions:

- Will the question be qualitative open-ended or quantitative closed-ended?
- If it is a closed-ended question, will it use rating or ranking scale?
- If adopt a rating scale, how many points should be on the scale and how should these points be labeled with words?
- Should "I don't know" be explicitly offered in response options or omitted?
- How should the question item be precisely worded?
- In what order should the questions will be asked?

A closed-ended question confines answers to the predefined alternatives, and it is convenient and quick for respondents to answer. Also, researchers could easily code and compare the answers of different respondents. However, a closed-ended question can only be useful when it offers comprehensive answer choices, otherwise respondents may be confused or frustrated because their desired answer is not offered (Boynton & Greenhalgh, 2004; Houtkoop-Steenstra & Houtkoop-Steenstra, 2000). An open-ended question allows the respondents to answer in their own words without being limited by multiple choice or “yes or no” option. Even though open-ended questions could provide original and unique answers with details, the answers must be classified into a relatively small number of categories for analysis. This requires a well-defined coding criteria for each of the questions, careful transcription of answers, consistent judging standard, and plenty of time for analysis (Cohen et al., 2002; Visser et al., 2000).

Rank order questions ask respondents to indicate preferences or priorities among different items. Rating questions ask respondents to assess different items using a common scale. Ranking scale questions are preferable when researchers want respondents to choose among several options and provide that each option has a unique value. However, ranking questions typically require more time making respondents less interested in participating (Alwin & Krosnick, 1985; Visser et al., 2000). Wilson and McLean (1994) suggests that asking respondents to identify priorities where there are more than five items should be avoided. Furthermore, ranking questions force respondents to differentiate between items which could introduce bias (Visser et al., 2000). Using scales such as Likert, semantic differential, Thurstone, and Guttman, provides a degree of sensitivity and differentiation of responses numerically. The Likert scale (named after its creator, Rensis Likert) has been one of the most widely used psychometric rating scales in survey research based on attitude and perception measurement (Likert, 1932; Norman, 2010). A Likert scale offers respondents a range of ordered points reflecting levels of agreement to a given statement (Likert, 1932; Norman, 2010) and should measure only one thing at a time (Oppenheim, 1992). While plenty of psychological studies based on survey research have been conducted with different types of Likert scales, the general agreement is that reliability and validity of scales will increase from two-points to seven-points, and tends to level out beyond that (Krosnick, 2018). Krosnick (1991) suggest that rating questions are tedious and thus lead to a non-differentiation where respondents tend to choose what appears to be a reasonable point to rate most items on the scale and select that point over and over again, rather than thinking carefully about each statement and rating differently.

Questionnaire designers often provide respondents the “I don’t know” option based on a concern about the possibility that respondents may not be sure what a question is asking or what a response alternative means (Cohen et al., 2002; Visser et al., 2000). According to literature on survey research, there are generally three types of respondents who would opt for “I don’t know” option (Feick, 1989; Krosnick et al., 2002; Oppenheim, 1992). First, respondents who do not completely understand the meaning of a question (Feick, 1989). Second, respondents who face a question that exceeds their motivations or abilities (Krosnick, 1991). Third, respondents who avoid thinking or committing to a question (Oppenheim, 1992). The latter two types of respondents tend to waste some potentially useful data if given “I don’t know” option otherwise they would have selected a substantial response. Some researchers argue that the quality of data collected is not higher whether or not an “I don’t know” option is provided (Krosnick et al., 2002; McClendon & Alwin, 1993). The decision to offer an “I don’t know” in a questionnaire depends on the sample size, the nature of the questions and the profile of the respondents. According to Bradburn, Sudman, and Wansink (2004), and Krosnick and Petty (1995), a questionnaire designer can manage to obtain substantive data from respondents that opted for the “I don’t know” by asking them a follow-up question to determine their attitudes on the survey.

The questionnaire based survey research requires all respondents reply to the same question, to ensure the variation in responses are due to differences between the human subjects (Visser et al., 2000). Therefore, the descriptions or statements of a question should avoid ambiguity.

Moreover, short and simple question wording could enable respondents to understand survey items quickly and easily with minimum fatigue. Krosnick, Presser, and Building (2009) summarized eight valuable suggestions on question wording as follows:

1) Use simple and familiar words and phrases, and avoid technical terms, jargon, and slang (when these must be used, define them explicitly).
2) Use simple syntax.
3) Avoid ambiguous descriptions.
4) Use specific and concrete words as opposed to abstract.
5) Make response alternatives exhaustive and exclusive.
6) Avoid leading descriptions that may push respondents to a certain answer.
7) Avoid double-barreled questions, and only ask about one thing at a time.
8) Avoid statements with single or double negations.

Proper question order could help respondents build motivation and comfort to provide high-quality data (Visser et al., 2000). Krosnick et al. (2009) suggest six rules on how to optimize question order as follows:

1) Begin with easy questions and build rapport between the respondent and the researcher.
2) Questions at the very beginning of a questionnaire should explicitly address the topic of the survey.
3) Group questions on the same topic.
4) Order question from general to specific within a same topic question group.
5) Sensitive questions that may make respondents uncomfortable should be placed at the end of the questionnaire.
6) Use filter questions to avoid respondents who are not supposed to take part.

Data collection is the final step of survey research. The questionnaire could be in paper form and mailed to respondents, in electronic format delivered by email, an online program such as Qualtrics and Google Forms, or a mixed approach allowing for respondents to choose their preferred option and maximizing sample coverage (Dillman, Smyth, & Christian, 2014). Questionnaire based survey research can utilize several data collection modes including self-administered, post, face-to-face, telephone, and Internet (Bradburn et al., 2004; Cohen et al., 2002; Dillman et al., 2014; Fowler, 2013). Cohen et al. (2002) suggests that a data collection procedure with the presence of the researcher could enable uncertainties or issues from respondents to be addressed immediately, while data collection without the presence of the questionnaire designer could allow participants to answer questions in private with sufficient time, and thus avoid potential pressure caused by the researcher's presence. An interview is another data collection method widely used in survey research. Interviews help in obtaining more information by requesting a clarification of an unclear answer instantly. However, an interviewing is more expensive than questionnaires and is relatively impractical for a large-scale study (Cohen et al., 2002; Ponto, 2015; Szolnoki & Hoffmann, 2013). The choice of data collection method depends on costs, time, the profiles of participants, sampling strategy, the characteristics of the questionnaire, and availability of staff and facilities (Visser et al., 2000).

Ideally survey research with a proper sampling strategy, excellent questionnaire design, and well researched data collection procedure, would accurately measure particular constructs within a sample of respondents who are randomly selected representatives of the target population. In practice, however, bias in survey research is inevitable. The cumulative result of several sources of survey errors leads to the overall bias from the ideal (Visser et al. 2000). Ponto (2015) summarized four types of common errors in survey research, along with the sources of error and strategies for reducing bias shown in Table 2-2.

Table 2-2 Summary of Errors in Survey Research Summarized by Ponto (2015)

Types of Error	Source of Error	Strategies to Reduce Error
Sampling	Individuals included in the sample do not represent the population	Clearly identified population of interest; Diverse participant recruitment strategies; Random sampling
Coverage	Unknown or zero chance of individuals in the population being included in the sample	Multimode design
Measurement	Questions do not reflect the topic of interest; Questionnaires do not evoke truthful answers	Valid, reliable instrument; Pretest questions; User-friendly graphics and characteristics
Nonresponse	Lack of response from all individuals	Provide rewards; User-friendly survey design; Follow-up procedures for nonresponse
Note: Information from Dillman et al. (2014), Singleton and Straits (2009), and Check and Schutt (2011)		

A survey should measure the variables it is intended to measure accurately. Better survey instruments lead to more accurate results which would enhance the scientific quality of the research. Hence, the researcher always needs to assess the goodness of the model or instruments. Validity and reliability are the two critical characteristics for assessing the quality of the model or survey instrument adopted in research. Figure 2-8 shows the goodness of measures established through different types of validity and reliability analysis, summarized by Sekaran and Bougie (2016).

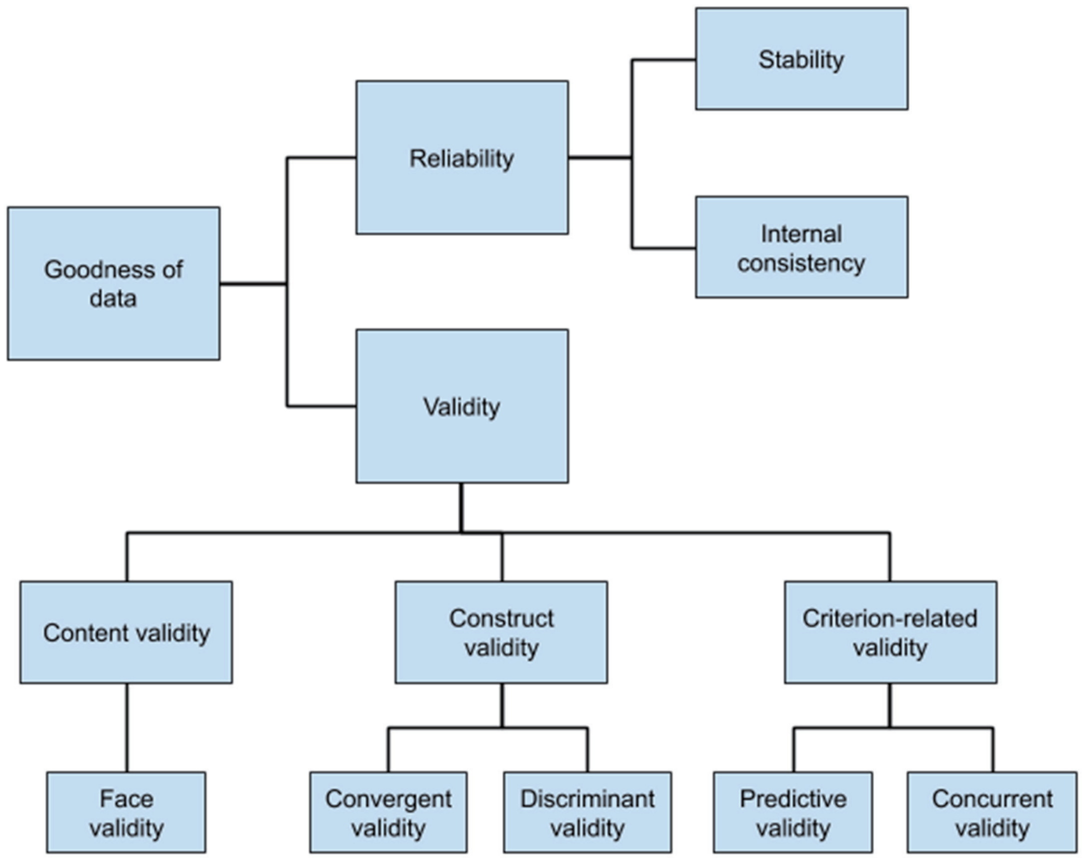

Figure 2-8 Testing Goodness of Measures: Forms of Reliability and Validity (Sekaran & Bougie, 2016)

Reliability is concerned with how consistently an instrument measures the various items in the instrument (Sekaran & Bougie, 2016). In other words, reliability refers to consistency and stability of the measuring instrument over a variety of conditions (Bollen, 1989; Nunnally & Bernstein, 1994). Internal consistency of a measuring instrument is an indicator of the homogeneity of a set of survey items designed to measure a particular concept (Drost, 2011; Sekaran & Bougie, 2016). The most commonly used test of internal consistency for rating survey items is Cronbach’s coefficient alpha (Cronbach, 1951), and for dichotomous items the Kuder–Richardson formulas are used (Kuder & Richardson, 1937). Evidence of stability can be achieved by repeating the same measuring instrument to the same respondents on a second occasion (Drost, 2011; Sekaran & Bougie, 2016).

Validity reflects the meaningfulness of survey-based research. A variety of validity tests have been developed to examine the goodness of measures. According to Sekaran and Bougie (2016), validity evidence can be categorized into three groups: content validity, criterion-related validity, and construct validity.

Content validity is a qualitative type of validity and it refers to the extent to which a measure represents an adequate and representative set of items of a given content (Bollen, 1989; Sekaran & Bougie, 2016). The more the items representing the domain of content being measured, the better the content validity. In other words, content validity concerns about how well the dimensions and elements of a concept are measured. Drost (2011) suggests that asking the opinion of experts in the same research field on the survey instrument is a basic way of assessing content validity. Face validity is a basic and minimum index of content validity, and it is a subjective judgement (Drost, 2011; Sekaran & Bougie, 2016). A measuring instrument could be seen to have face validity if it appears to measure what it is designed to measure (Cohen et al., 2002).

Construct validity refers to the extent to which the results obtained from a measuring instrument fit the concepts around which the survey is designed (Sekaran & Bougie, 2016). Campbell and Fiske (1959) proposed to assess construct validity by assessing their convergent and discriminant validity. Convergent validity refers to the extent to which two different measures on the same concept that are supposed to be correlated are in fact correlated, while discriminant validity is established when two measures are predicted to be uncorrelated are indeed uncorrelated (Sekaran & Bougie, 2016; Trochim & Donnelly, 2006). According to literature, factor analysis and structural equation modeling are useful techniques for examining convergent and discriminant validity (Garver & Mentzer, 1999; Henseler, Ringle, & Sarstedt, 2015; Kline, 2015; Sekaran & Bougie, 2016).

Criterion-related validity refers to the extent to which a respondent's answers on a measure are correlated with one or more external criteria that the question designer would expect them to be correlated with (Cohen et al., 2002; Drost, 2011). Criterion-related validity can be assessed by establishing concurrent validity or predictive validity (Sekaran & Bougie, 2016). Concurrent validity is established when the external criterion exists at the same time as the measure, while predictive validity is established when the external criterion occurs in the future (Drost, 2011). Drost (2011) suggests that concurrent validity or predictive validity can be assessed by obtaining actual records to compare with the results of survey instrument.

Chapter 3 Research Statement and Methodology

3.1 Research Statement

A method for Lean adoption that is both reliable and appropriate can guide an organization's operational activities toward desired objectives. Research supports that a manufacturing organization is only as Lean as its employees perceive it to (Jayamaha et al., 2014; Losonci, Demeter, & Jenei, 2011; Loyd, 2017; Oon, 2013; Shadur, Rodwell, & Bamber, 1995; Shetty, 2011). Loyd (2017) created a validated Lean assessment tool based on employee perception in American manufacturing companies. Loyd found that the Toyota Way culture has a mediating effect between Lean and operational performance (Loyd, 2017). However, Loyd's indicators representing the desired results of Lean adoption were qualitative and not well-defined. Loyd's research did not validate his assessment tool in other countries and lacked demographic information of participants, such as job role. Considering the limitations of Loyd's (2017) research, the following questions arise:

- What measures of performance could be used to replace Loyd's qualitative items to improve the assessment tool?
- Is the TPS-TW model valid for measuring Lean production systems using employee perception in the manufacturing sector in China?
- Does the culture of an organization have a mediation effect between Lean implementations and actual operational performance in China? Is there any difference of effect of TW culture on Lean implementation and actual operational performance between organizations in America and China?
- Is there a difference of agreement between management and frontline employees in the adoption of Lean in the Chinese automotive industry?

The achievement of following objectives in this research will provide answers to the questions posed above.

- Development and validation of a survey instrument based on the TPS-TW model and employee perception using quantifiable metrics in the automobile manufacturing sector in China;
- Investigation of the effect of TW culture on Lean deployment and operational performance in the automobile manufacturing sector in China and comparison of how culture impacts operational performance between organizations in the US and China;
- Comparison between management and frontline employees in the perception of Lean implementation in the automobile manufacturing sector in China.

An improved assessment tool based on employee perception and validation of the TPS-TW model would provide companies in the Chinese automobile sector with a valid, accurate, and effective tool to measure the level of Lean adoption. The use of quantifiable performance metrics that represent desired operational outcomes with comparisons between management and frontline employees in Lean perception would provide robust and valuable information to understand the relationship between employee perception of Lean systems and the degree of implementation in the organization, the effect of TW culture, and insight into barriers to Lean adoption in auto manufacturing companies other than Toyota.

The primary objective of this research is to validate the TPS-TW model as an effective method to assess the degree of Lean adoption through employee perception in the Chinese automobile manufacturing sector. This study adopts Loyd's (2017) survey tool, which was created based on the TPS-TW model, as a basis to develop an improved assessment instrument. The improved survey instrument retains the constructs of Loyd's survey tool that consists of the foundation and pillars of TPS: standardization and stability, built-in quality, and just-in-time, and the Toyota Way culture. The Toyota Way culture is comprised of two main components: continuous improvement and respect for people. Adjustments to the survey items were made based on review of a panel of Subject Matter Experts (SMEs) who had more than 10 years of Lean experience as engineers or managers in the Chinese auto manufacturing industry. The questionnaire was translated by Lean experts in China who were native Chinese speakers and able to read, speak and write English fluently. A pilot study was conducted to test the effectiveness of the survey and provide information for survey item modification. Reliability analysis was used to analyze the data of the pilot study to quantitatively strengthen the content validity of the survey instrument. Based on the pilot study and expert review, the survey tool was finalized and distributed to employees who had worked at least three months for a manufacturing organization that had been implementing Lean production for at least one year in the Chinese automobile sector. After data collection, reliability analysis was used to assess the structural integrity of the assessment instrument. Confirmatory Factor Analysis (CFA) was used to study the goodness of fit of the TPW-TW model and provide evidence of construct validation. A comparison between the results of the survey and recorded performance of six plants was used to examine the criterion-related validity. Structural Equation Modeling (SEM) was used to study the mediation effect of the Toyota Way culture on the relationship between Lean implementation and operational performance. Additionally, a multi-group analysis in SEM was used to compare the effect of culture on operational performance between organizations in the US and China. Finally, Mann-Whitney U test and divergent stacked bar chart were utilized to compare management and frontline employees in the perception of Lean adoption.

3.2 Survey Development

3.2.1 Scale and Item Development

Loyd's survey instrument was the first and only measurement of Lean based on the TPS-TW model (Loyd, 2017). The survey instrument was developed through a thorough literature review, an assortment of recommendations from a panel of experts who all had experience working at Toyota, and an exploratory factor analysis process based on a pilot study. Loyd's survey instrument was based on a TPS-TW model and comprised of the foundation and two pillars of the house model of TPS, the Toyota Way culture, and three qualitative questions representing the desired performance of Lean implementation. This research retained the constructs of TPS-TW model and improved Loyd's assessment tool to overcome limitations in terms of ambiguous descriptions for survey questions and weak conclusions generated from using qualitative questions to represent performance (Loyd, 2017). The theoretical TPS-TW structural model is shown in Figure 3-1.

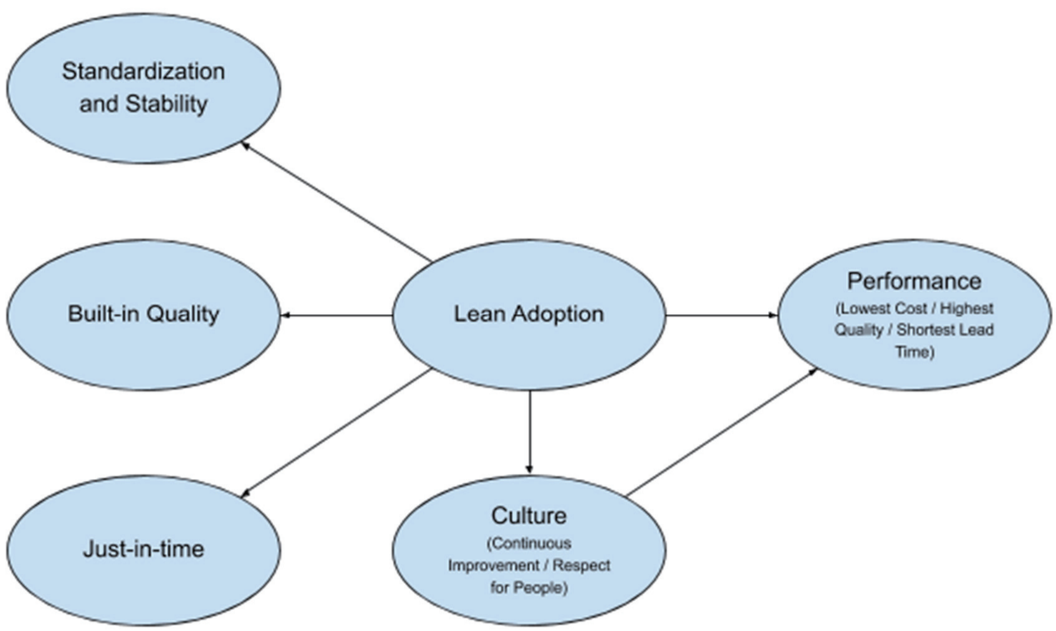

Figure 3-1 Theoretical Structural Model of TPS-TW

Loyd (2017) validated the TPS-TW model by utilizing his survey instrument, consisting of 30 questions, in the American manufacturing sector. Quantitative statistical methods such as reliability analysis, Exploratory Factor Analysis, and Confirmatory Factor Analysis (CFA), were used to examine the content validity and construct validity of the TPS-TW model (Loyd, 2017). Additionally, Loyd found the Toyota Way culture had a positive mediating effect on the relationship between Lean implementation and desired performance by using SEM. However, this conclusion was based on three qualitative questions representing the desired results of Lean deployment in his survey instrument. More accurate and well-defined quantitative metrics under the "performance" construct are needed to provide a more robust survey instrument. The improvement could provide more information to understand the relationship between Lean adoption, culture, and operational performance in the Chinese automobile manufacturing sector.

A panel of SMEs assisted in determining quantitative metrics under "performance" construct. The panel was made up of eight native Chinese Lean experts who had more than 10 years of Lean implementation experience as managers or engineers in the Chinese auto manufacturing industry. The qualifications of this panel are shown in Table 3-1.

Table 3-1 Information of Subject Matter Experts

No.	Job Title	Age (yrs)	Lean Experience (yrs)	Employer	Location (in China)
1	Chief Engineer of Manufacturing	50	17	Dongfeng Motor	Wuhan, Hubei
2	Deputy Manager of General Assembly Plant	53	15	Dongfeng Motor	Wuhan, Hubei
3	Industrial Engineer and Lean Production Trainer	35	13	Honda China	Wuhan, Hubei
4	Continuous Improvement Manager	44	15	Nissan China	Guangzhou, Guangdong
5	Deputy Quality Manager	39	15	Nissan China	Guangzhou, Guangdong
6	Industrial Engineer and Lean Production Trainer	37	15	Nissan China	Guangzhou, Guangdong
7	Industrial Engineering Manager	44	17	Volvo Trucks	Shiyan, Hubei
8	Assembly Engineer and Lean Production Trainer	40	12	Volvo Trucks	Shiyan, Hubei

Based on their personal experience of Lean adoption in China and online discussions, the panel of SMEs suggested the use of three quantitative metrics that widely applied in manufacturing companies that had adopted Lean in China: process downtime, first-pass-yield, and on-time delivery. These three metrics are representative of lowest cost, highest quality, and shortest lead time respectively under the “performance” construct. This suggestion was incorporated in a pilot study. Table 3-2 shows a comparison between Loyd’s qualitative items and the improved quantifiable metrics.

Table 3-2 Original Loyd's Measures and Improved Metrics Under "Performance"

Loyd's Measure	Construct	Desired Result	Updated Metric
My company strives to provide the lowest possible cost to our customers	Standardization and Stability	Lowest Cost	Process Downtime
My company strives to provide the highest quality	Built-in Quality	Highest Quality	First Pass Yield (%)
My company strives to provide the shortest lead time	Just-in-time	Shortest Lead Time	On-time Delivery (%)

Process downtime is a commonly used metric to assess availability in the companies that have implemented Lean. Some manufacturing plants use the opposite metrics of "process downtime" such as "uptime," "net available time," "utilization," or "reliability." "Process downtime" refers to a period of time in which a process or equipment is not in an operable or committable state at the point in time when it is needed (Katukoori, 1995). This definition covers operable and committable factors contributing to the equipment, the process, and the surrounding facilities and operations. During process downtime, the manufacturing process is stopped and not adding value to its products and customers. Standardization and stability of Lean aim to reduce variability, simplify training for new employees, document the processes for all shifts, and facilitate continuous improvement efforts that directly contribute to minimizing process downtime. The better standardization and stability are achieved, the lower process downtime.

First-pass-yield is the percentage of products that are produced to specification and can pass quality inspections the first time without any rework or scraping of the product (Mohan et al., 2012). It can be calculated as the number of acceptable products exiting the process divided by the total amount of units entering the same process over a period of time (Mohan et al., 2012). First-pass-yield is a typical metric for assessing built-in quality and production performance in the manufacturing sector.

On-time delivery refers to the percentage of acceptable products delivered to customers, or downstream process at the designated, agreed upon, time (Martin, Givens, & Kuttler, 1998). It is a commonly used metric in plants to measure how the process meet customer demand or agreed delivery time. Just-in-time manufacturing aims to produce goods only according to what is needed. The key features of just-in-time, such as one piece flow, small batch processing, flexible production planning, and rapid machine setup and die change, are all crucial for on-time delivery (Sakakibara et al., 1997).

For the purpose of content validity determination, the experts were asked to provide feedback on the following questions in their review:

- Is this measuring instrument fit for a Chinese manufacturing company?
- Is this measuring instrument focused in the correct category?
- Are there any questions that are unclear or may lead to misunderstanding?
- Was there any key concept of TPS or Lean that has not been captured in the questionnaire?
- How long did it take you to complete the survey?
- Do you have any additional suggestions?

Two professors from the Department of Industrial and Systems Engineering at Auburn University, with extensive research experience in the field of Lean production and survey development, also reviewed the survey instrument. These reviewers provided adjustment suggestions on the wording of the survey questions and demographic information part of the survey. The list of wording changes can be found in Appendix-B. One option that "I don't understand the question," or "I don't know what the terminology is," was added to each of the survey items in the categories of standardization and stability, built-in quality, just-in-time, and TW culture to minimize potential confusion. Two options, "I don't know what the indicator means," and "I don't know the value of the indicator," were added to each of the survey items under the “performance” construct, to improve accuracy. Table 3-3 shows the breakdown of survey items by category.

Table 3-3 Breakdown of Survey Items

	Construct	**Number of Items**
Toyota Production System	Standardization and Stability	5
	Built-in Quality	7
	Just-in-time	6
Toyota Way	Culture	9
Desired Results of Lean Deployment	Performance	3
	Total:	30

A seven-point Likert scale was chosen to measure how strongly participants agree or disagree with the description of each survey item. Thus, employee perception on Lean adoption could be captured on a scale ranging from 1 (strongly disagree) to 7 (strongly agree). The scale definitions used in this study were created to help participants rate each item. These definitions are shown in Table 3-4.

Table 3-4 Rating Scale Definitions for Survey Participants

Rating	Description	Instruction
1	Strongly Disagree	This concept has not appeared at my company as I know
2	Disagree	I could find little to no evidence of this concept in practice
3	Somewhat Disagree	This concept was practiced before, but is no longer in use
4	Neither Agree or Disagree	I am neutral
5	Somewhat Agree	Parts of this concept exist at my company, but not all
6	Agree	This concept exists in many areas of my company, but not all areas
7	Strongly Agree	This concept completely exists in all areas of my company

3.2.2 Questionnaire Translation

Beaton, Bombardier, Guillemin, and Ferraz (2000) suggested a guideline with the procedures for cross-cultural adaptation of self-report measures which consists of five steps: translation from the original language to target language, synthesis of translations, back-translation to the original language, expert evaluation and the pretest of translated version.

As suggested in the guideline, two independent Lean experts who were native Chinese speakers, able to read, speak, and write English fluently, served as translators for the questionnaire from English to Simplified Chinese. The two independent translators conducted a joint review to meet and agree on the translation. Then, the initial Chinese version was back translated to English by a native English speaker who was working at a Chinese automotive company as a manufacturing engineer. A review of the original version, Chinese language version, and back-translated version was conducted by the three translators and the researcher to reach a consensus on the final Chinese language version of the questionnaire. Any issues with the translation were addressed with the help of the panel of SMEs. The finalized Chinese language version of the questionnaire was pre-tested in a pilot study.

3.2.3 Summary of Survey Development Phase

The survey development phase of the research resulted in the creation of a Chinese language version survey instrument to measure an organization's Lean adoption from employee perception based on the TPS-TW model. The items under the constructs of standardization and stability, built-in quality, and just-in-time, based on Loyd's validated survey instrument were used with wording adjustments and response options added to obtain more accurate results. The three quantitative metrics under the construct representing the desired operational performance of Lean adoption were developed based on the suggestions from a panel of SMEs in the Chinese automobile manufacturing sector. Three independent Lean experts helped in translation of the questionnaire from English to Simplified Chinese. Then a pilot study was used to test the survey instrument before the full study.

3.3 Pilot study

It is suggested that pilot study with a smaller sample size should be conducted before the full study to provide valuable information and check for unexpected issues (Van Teijlingen & Hundley, 2001). In scientific research, pilot studies are more often conducted for the purpose of examining the feasibility of a proposed study rather than checking any statistical significance from the results and making conclusions. Therefore, the feasibility objectives of a pilot study should be clearly identified before conducting the actual survey to help researchers fully understand the survey research (Thabane et al., 2010). The objectives of the pilot study in this research included:

- A pre-test of the effectiveness of the survey instrument and delivery method of the survey, leading to adjustments based on the results;
- An understanding of the structural behavior of the survey instrument;
- Identification of the appropriate statistical analysis procedures to be used in the full study and to develop a subsequent familiarity with the tools.

3.3.1 Pilot Survey Delivery

Because the Great Firewall of China blocks many online survey software providers whose servers are located outside of China, such as Qualtrics and Google Forms, the Tencent Survey was chosen to create and distribute questionnaires electronically in the pilot study. Tencent Survey is a free Chinese online application that allows users to create, disseminate, and analyze questionnaires conveniently.

The target population consisted of adults over the age of 18, the youngest age for human subjects research permitted by the Institutional Review Boards (IRB), who had worked at least three months for a manufacturing organization in China that had been implementing Lean for at least one year. There were no exclusions based on race, gender and other factors. The link of the electronic questionnaire (Chinese Version) was delivered to 40 individuals by WeChat on the researcher’s personal contact list. The 40 participants were from more than 10 plants and volunteered to take the survey. To understand the structural behavior of the survey instrument and obtain more information for content validation, every participant in the pilot study was asked to provide feedback on the time it took to complete the survey, as well as potential confusion about survey items. Thirty-One valid survey responses were received in four weeks after online questionnaire distribution. The length of time to complete the survey was stated as less than 5 minutes by 7 respondents (22.6%), between 5-10 minutes by 12 respondents (38.7%), between 10-15 minutes by 10 respondents (32.3%), and more than 15 minutes by the remaining 2 respondents (6.4%). Subjects from production frontline stated that they prefer manually filling out the questionnaires rather than using a web application. Based on this request, a paper version of the questionnaire was added as another survey distribution method to complement the online Tencent Survey application. Some minor wording changes of survey items were made based on respondent feedback to reduce ambiguity. Decisions on the recruitment method, conciseness, and efficiency of the survey instrument were made. The pilot study successfully pre-tested the effectiveness and delivery method of the survey instrument, and thus fulfilled the primary feasibility objective.

3.3.2 Analysis of the Results from the Pilot Study

Reliability analysis was used as the main statistical method to learn about the structure of the survey instrument and evaluate its internal consistency. In statistics research, the internal consistency measures whether the survey items that propose to measure the same general construct could generate similar results (Streiner, 2003). Cronbach's coefficient alpha is the most commonly used measure of internal consistency in survey-based research using Likert scales (Cortina, 1993; Cronbach, 1951). The general consensus is that an alpha of greater than or equal to 0.7 could be considered acceptable while greater than or equal to 0.8 implies good internal consistency (George & Mallery, 2016; Gliem & Gliem, 2003). The IBM SPSS Statistics Version 24 software was used to calculate the Cronbach coefficient alpha for each construct of the TPS-TW based survey instrument. Table 3-5 shows the Cronbach's alpha for each construct of the survey. With all the

Cronbach's coefficient alpha values at 0.8 or greater, confidence was obtained for the internal consistency and scale reliability of the survey.

Table 3-5 Cronbach's Coefficient Alpha in the Pilot Study

Construct	Cronbach's alpha	Status
Standardization	0.836	Good
Built-in Quality	0.864	Good
Just-in-time	0.874	Good
Culture	0.820	Good

Common method bias is variance in responses of a survey due to the measurement method or instrument itself rather than the predilections of the respondents, and is a common occurrence in survey-based research (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Podsakoff et al. (2003) suggested that Harman's single factor test is one of the most widely used methods to measure the common method bias on the survey data. Harman's single factor test examines if the majority of the variance in responses of a survey can be explained by a single factor. If one single factor would account for over 50% of the covariance based on Principal Axis Factoring (PAF) extraction method, then it implies that a significant common method bias is present. The IBM SPSS Statistics Version 24 software program was used to conduct Harman's single factor test using PAF as the extraction method on the data of the pilot study. The result shows the largest factor accounts for 39.75% of the overall covariance, which is better than the threshold value of 50%. Six factors were proved to be significant contributors to the overall covariance with Eigenvalues greater than 1. Therefore, the result of the initial Harman's single factor test shows that significant common method bias is not present for the TPS-TW model-based survey instrument.

Podsakoff et al. (2003) suggested that the Common Latent Factor (CLF) test should supplement Harman's single factor test to fully examine the existence of common method bias. However, larger sample sizes were required to conduct a CLF test. Common method bias was evaluated by a deeper level of testing in the full study phase of this research to ensure reliability.

3.3.3 Identification of Statistical Analysis Techniques

The last objective of the pilot study was to identify and become familiar with the appropriate statistical analysis procedures to be used in the full study phase. Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM) are powerful tools for construct validation of theoretical models and study of relationships among constructs (Anderson & Gerbing, 1988; Bollen, 2005; Brown, 2015; Kline, 2015). A survey based on a Likert scale is likely to generate non-Gaussian data. Non-parametric statistical approaches such as Kendall's Tau and Mann-Whitney U test are useful methods to analyze the data measured on an ordinal scale (Agresti, 2010). The Kendall's Tau could be used to measure the association between survey results and actual performance metrics to examine the criterion-related validity in this study. Additionally, the Mann-Whitney U test can be used to compare two groups in survey research where response is in a Likert scale (Bertram, 2007; Jamieson, 2004; McCrum-Gardner, 2008). A more in-depth description of these methods is provided in the full study portion of this section.

3.4.3.1 Confirmatory Factor Analysis (CFA)

In 1969, Jöreskog (1969) first developed Confirmatory Factor Analysis to evaluate goodness-of-fit for a hypothesized measurement model. Plenty of social research has utilized CFA to test whether measures of constructs are consistent with the researchers' a priori measurement models. CFA has become the most commonly used statistical tool for construct validation of a measurement instrument (Brown, 2015; Brown & Moore, 2012; Schreiber et al., 2006; Strauss & Smith, 2009). In contrast to Exploratory Factor Analysis, which does not involve a presumption of factor structure, CFA tests the constructs of a survey tool that are predefined by a priori on a theoretical model. In this case, those constructs are the dimensions of the TPS-TW model including standardization and stability, built-in quality, just-in-time, TW culture, and operational performance (Hurley et al., 1997; Loyd, 2017; Thompson, 2004). CFA serves as the first step of SEM to provide a measurement model with the relationships between each latent variable and their observed variables (Anderson & Gerbing, 1988; Bollen, 2005; Brown & Moore, 2012). The fundamental statistics of CFA are to estimate a population covariance matrix that is compared with the observed covariance matrix (Kline, 2015; Schreiber et al., 2006). CFA and SEM techniques involve two types of variables: observed variables and latent variables. Observed variables refer to measures and indicators that are actually measured and recorded in a study (Bollen, 2005; Kline, 2015; Schreiber et al., 2006). The response to a Likert seven-point scale is a typical example of an observed variable. Latent variables are also termed unobserved variables, factors, latent factors, or constructs. Latent variables are hidden, therefore cannot be recorded directly but are inferred from other observed variables (Bollen, 2005; Kline, 2015; Schreiber et al., 2006). In CFA and SEM studies, models are developed with observed variables graphically designated by squares or rectangles, and latent variables depicted by circles or ovals (Schreiber et al., 2006). Figure 3-2 shows a generic example of a CFA model. The two ovals at the top are latent variables, the rectangles at the middle are observed variables, and the circles at the bottom are the measurement errors that only associate with observed variables. The straight line pointing from a latent variable to the three observed variables associated with it indicates the causal effect of the latent variable on the observed variables. The curved arrow between two latent variables indicates a covariance between the two variables with no implied direction of effect. If using a straight one-headed arrow between two latent factors instead of the curved two-headed arrow, a direct relationship between the two latent variables would be hypothesized (Schreiber et al., 2006; Ullman & Bentler, 2003).

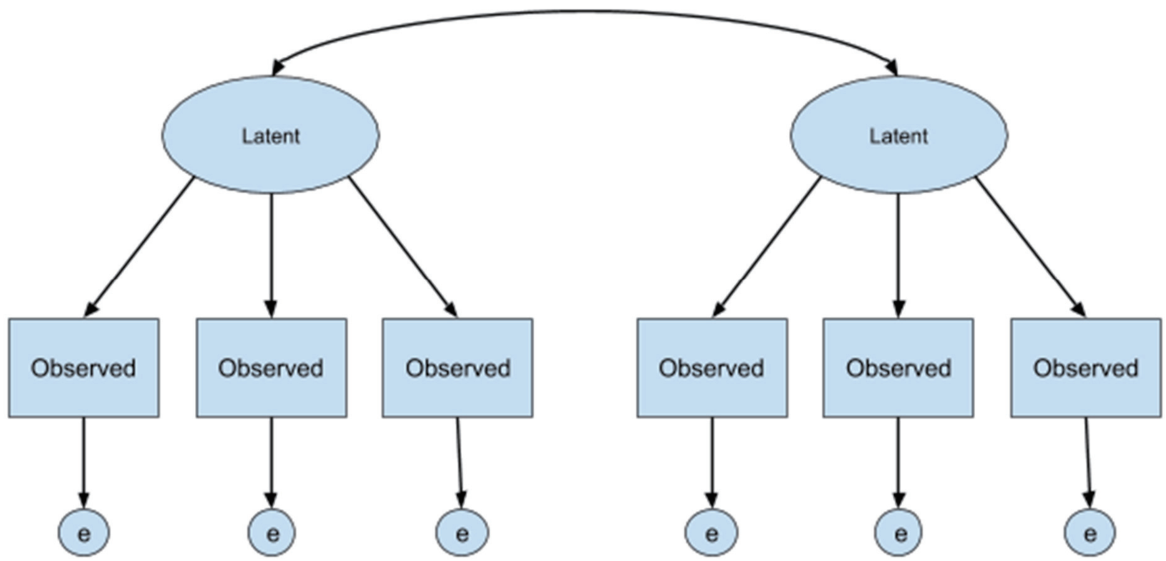

Figure 3-2 A Generic Example of Confirmatory Factor Analysis

CFA is considered as an improvement of the Multitrait-Multimethod (MTMM) approach developed by Campbell and Fiske (1959) for convergent and discriminant validation to provide quantitative information on the degree of construct validity in a study (Kenny, 1976; Kenny & Kashy, 1992; Marsh & Hocevar, 1988). Convergent validity refers to the extent to which two different measures of the same concept that are supposed to be correlated are in fact correlated, while discriminant validity is established when two measures are predicted to be uncorrelated are uncorrelated (Sekaran & Bougie, 2016; Trochim & Donnelly, 2006). Convergent and discriminant validity are subcategories of construct validity, along with criterion-related validity and content validity, and are keys in this study to determine whether the TPS-TW model-based measurement instrument using employee perception is applicable to the Chinese automobile manufacturing sector.

3.4.3.2 Structural Equation Modeling (SEM)

SEM is a family of multivariate statistical tools including factor analysis and multiple regression (Schreiber et al., 2006; Ullman & Bentler, 2003). SEM has been commonly adopted in social research to establish a structural model based on the measurement model generated in CFA (Kline, 2015). The measurement model defines the relationships between various observed variables to their corresponding latent variables whereas the structural model shows how constructs are related to others (Bollen, 2005; Brown, 2015; Kline, 2015). The measurement model is used to examine the reliability of the observed variables, the correlation (not causation) and covariation among variables before testing the structural model. The structural model exhibits the causal and correlational links among observed variables and latent factors in the proposed model as a series of structural equations (Ullman & Bentler, 2003). There are two new types of variables associated with SEM: exogenous variables and endogenous variables. Exogenous variables, which are similar to independent variables, represent the factors that have an effect on other latent factors but are not influenced by other factors in the structural model (Schreiber et al., 2006; Ullman & Bentler, 2003). Endogenous variables, which are similar to dependent variables, refer to those factors affected by exogenous variables or other endogenous variables in the structural model (Schreiber et al., 2006; Ullman & Bentler, 2003). In SEM, a direct effect refers to the effect of an exogenous variable on an endogenous variable, while an indirect effect refers to the effect of an exogenous variable on an endogenous variable through a mediating variable (Baron & Kenny, 1986; Schreiber et al., 2006). Figure 3-3 shows a generic type of a SEM model that was adopted in this study. The exogenous variable has a direct and an indirect effect (through the mediator) on the endogenous variable. The total effect of the exogenous variable is the summation of the direct and indirect effects of this variable on the endogenous variable (Baron & Kenny, 1986). Lavaan, a package for SEM in the R environment developed by Rosseel, was used for data analysis of CFA and SEM in this study (Rosseel, 2012).

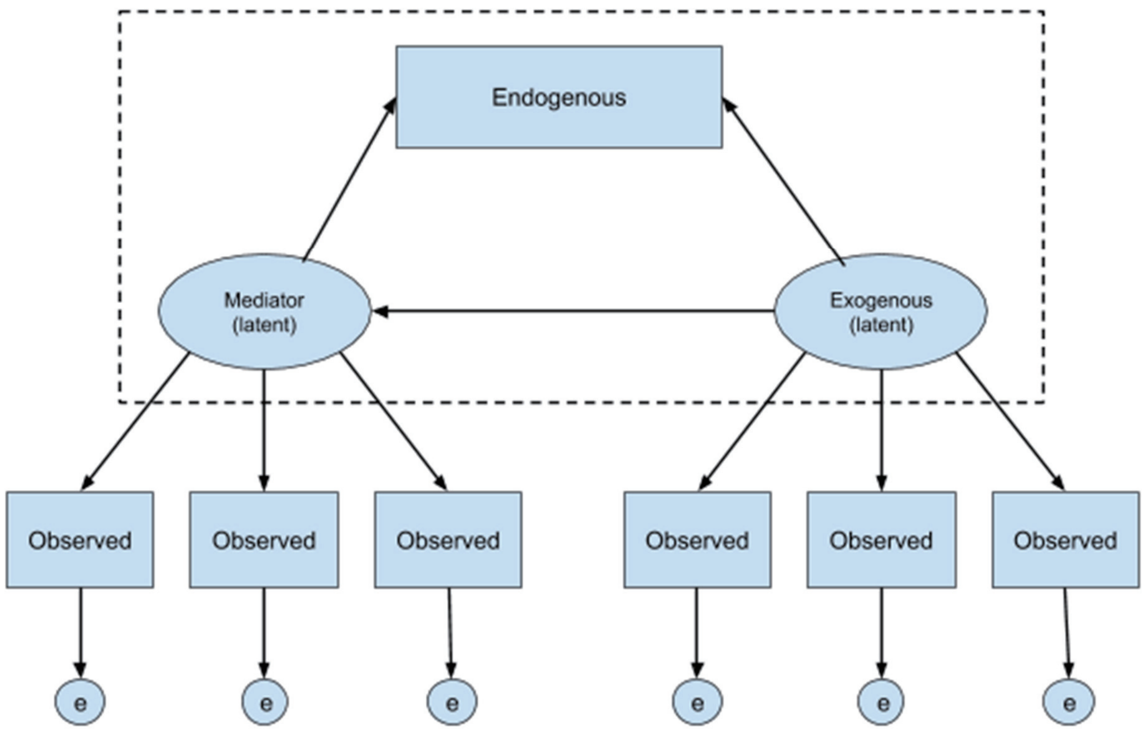

Figure 3-3 A Generic Example of Structural Equation Modeling

3.4.3.3 Non-Parametric Approach

The data collected in the pilot study shows that the score distribution in Likert seven-point scale is non-Gaussian. The patterns of data distribution violate the assumption of normality in parametric statistical tests such as Student's T test and Analysis of Variance (ANOVA). Considering that it is difficult to obtain normally distributed samples in the full study, the non-parametric statistical approaches are indispensable tools for data analysis. The Kendall rank correlation coefficient, also known as Kendall's Tau, is a non-parametric statistic used to measure the strength and direction of association between two variables measured on an ordinal scale (Agresti, 2010; Kendall, 1948). The Mann-Whitney U test is a commonly used non-parametric method for comparing two independent samples generated from a Likert scale (Bertram, 2007; Jamieson, 2004; McCrum-Gardner, 2008). Thus, the Kendall's Tau was used to assess the similarity between survey results and actual metrics to examine the criterion-related validity in this study. The Mann-Whitney U test was selected to test for the equality of the population means between frontline and non-frontline employees in the perception of Lean adoption. Each construct of the TPS-TW measurement model was considered.

3.3.4 Summary of Pilot Study

The pilot study phase of this research had three objectives: 1) pre-test the effectiveness of the survey instrument and delivery method of the survey, leading to adjustments based on the results; 2) study the structure of the survey instrument; 3) identify the appropriate statistical analysis procedures to be used in the full study. To address the first objective, the survey was delivered to a sample population. Based on the respondents' feedback, conciseness and efficiency of the survey instrument, some minor wording changes of survey items and decisions on the survey distribution method were made. To address the second objective, reliability analysis was used to understand internal consistency of the measurement scales. Results from the reliability analysis showed that ideal internal consistency was obtained. To address the last objective, research was performed to identify CFA, SEM, and non-parametric methods that would be used as the main statistical tools in full study phase.

3.4 Full Study

The survey development phase and the pilot study demonstrated good content validity and reliability of the measurement scales. However, to achieve the objectives of validating the TPS-TW model, investigating the relationships among the constructs, and understanding the difference of perception on Lean between management and front-line employees in the Chinese automotive industry, a thorough overall validation and non-parametric analysis is required (Zumbo & Chan, 2014). The full study phase of this research employs reliability analysis, CFA, SEM, Kendall's Tau, and Mann-Whitney U test to examine the construct validity and the criterion-related validity of the TPS-TW model, the relationship among latent factors, and the statistical differences between sub-demographic groups. A summary of research methods for each research objective which were identified in the pilot study phase is shown in Table 3-6.

Table 3-6 Summary of Research Methods

Objectives	Items			Methods	Criteria
Validation of the assessment instrument	Reliability	Internal consistency	-	Reliability analysis	• Cronbach's Coefficient Alpha • Harman's single factor test • Common Latent Factor test
	Validity	Content validity	Face validity	Expert review	• Consensus
		Construct validity	Convergent validity	Confirmatory Factor Analysis	• Factor loading • Composite reliability • Average Variance Extracted (AVE)
			Discriminant validity		• The heterotrait-monotrait ratio of correlations • Square root of AVE vs. correlation
		Criterion-related validity	Concurrent validity	Comparison between survey results and actual metrics	• Kendall rank correlation coefficient
Investigation of the effect of TW	Mediating effect	-	-	Structural Equation Modeling	• Mediating effect • Multigroup analysis
Comparison between management and frontline employees	-	-	-	Comparison of survey response between 2 groups	• Mann-Whitney U test

3.4.1 Survey Delivery

The TPS-TW model-based survey tool was modified, translated, and finalized according to feedback from expert reviewers and respondents recruited in the pilot study phase. The finalized measurement instrument can be found in Appendix-C (English Version) and Appendix-D (Chinese Version). The target population for the full study remained the same as in the pilot study: adults over the age of 18, who have worked at least three months at a manufacturing company in China that has implemented Lean for at least one year. There were no exclusions based on race, gender and other factors. Additional demographic information such as age, job role, length of service, and company size was collected along with the questionnaire.

The seven-point Likert scale that was used in the pilot study phase was kept to measure how strongly respondents agree or disagree with the concept of each survey item in the full study stage. Several minor wording changes and two major changes were made to the survey before performing the full study phase to provide more accurate and well-defined items. First, the quantitative metric “process downtime,” representing the lowest costs of desired results of Lean adoption, was replaced by “process downtime %” because in the pilot study some respondents wrote down daily values of process downtime while others wrote monthly values. The “process downtime %” can be calculated by equation (III.1).

$$\text{process downtime } \% = (1 - \frac{\text{operating time}}{\text{planned time}}) \ *100\% \qquad \text{(III.1)}$$

Using “process downtime %” minimized the misunderstandings on this quantitative metric. Second, the full study adopted the suggestions on survey options from the researcher’s advisors. One option that "I don't understand the question,” or "I don't know what the terminology is" was added to each of the questions in the construct standardization and stability, built-in quality, just-in-time, and Toyota Way culture to minimize respondents’ possible confusion. Two options, "I don't know what the indicator means," and "I don't know the value of the indicator," were added to each of the questions in the "performance" construct in order to obtain a more accurate result. These modifications to the survey were approved by IRB, shown in Appendix-E.

According to the feedback from respondents in the pilot study, the frontline employee prefers to answer the survey manually rather than using an online survey tool. The finalized survey was distributed electronically by using Tencent Survey and manually by paper versions simultaneously. Approximately 300 individuals who meet the criteria of the target population on the China Association of Automobile Manufacturers' contact list and the researcher's personal contact list received the Tencent Survey link to have access to the online survey. Meanwhile, for the purpose of investigating the difference between frontline employees and management, the researcher visited six plants that had been implementing Lean production in the Chinese auto manufacturing sector to distribute hardcopies of the survey and collect data in person. The actual values of the measures on their overall operational performance including "process downtime %," "first-pass-yield," and "on-time delivery" in the most recent 3 years were also collected from plant management. Table 3-7 presents the demographic information of the six plants. No identifiable personal data was collected directly or indirectly in this study from respondents and all of responses were kept strictly confidential. All participants were informed that their participation in this research was voluntary and they were free to decline to answer any question or exit the research for any reason without penalty.

Table 3-7 Demographic Information of the Lean Plants Where the Researcher Collected Data

Plant	Product	Employees	Lean Adoption Yrs
1	Sedan Assembly	101 - 200	16
2	Engine Parts	51 - 100	13
3	Axle	201 - 300	9
4	Truck Assembly	201 - 300	10
5	Seat	101 - 200	7
6	Body	101 - 200	10

3.4.2 Sample Size

While CFA and SEM approaches have been used for decades, there is no established standard for requisite sample size. The universal agreement is the larger the better. There are various recommendations of acceptable sample size based on respective concerns such as model convergence, the ratio of sample size to enable parameter estimation, adequate statistical power of the model, and the ratio of indicators per latent variable.

Anderson and Gerbing (1988) suggested that N = 150 was adequate to obtain a convergent or proper solution for most cases. Kline (2015) suggested N = 200 was a typically acceptable sample size in a SEM study. Bentler and Chou (1987) suggested a ratio as low as 5 cases per observed variable would be sufficient when latent variables have multiple indicators for normally distributed data, and a ratio of 10:1 for non-normally distributed data. Muthen and Muthen (2002) were concerned about sufficient statistical power of the model in a SEM, and used a Monte Carlo study to conclude that the minimum sample size should be no less than 265 to achieve a statistical power of the test of 0.8, which is generally acceptable in statistical research, whether the data is normally distributed or non-normally distributed. Marsh, Hau, Balla, & Grayson (1998) considered the construct reliability and stated that the minimum sample size for a SEM should be at least 200, and a large ratio of observed variables to latent factors could compensate for a small sample size. Boomsma and Hoogland (2001) suggested that the acceptable sample size for normally distributed data should be greater than 200, while $N \geq 300$ for non-normally distributed data in a SEM study. Based on the same concern of observed variables per latent variable, Westland (2010) consolidated Marsh et al.'s (1998) and Boomsma and Hoogland's (2001) results, and suggested an equation (III.2) to determine minimum sample size required in SEM, with r = the ratio of observed variables to latent factors:

$$N \geq 50r^2 - 450r + 1100 \qquad \text{(III.2)}$$

In this study, 5 latent factors and 30 observed variables result in $r = 6$ and $N \geq 200$. Thus, the target of sample size in full study phase of this research was determined to be at least 300. Table 3-8 summarizes the various recommendations of minimum sample size for SEM study.

Table 3-8 Summary of Minimum Sample Size Recommendations for CFA and SEM

Source	Suggestion
Gerbing and Anderson (1988)	$N \geq 150$
Kline (2015)	$N \geq 200$
Bentler and Chou (1987)	5:1 ratio for normally distributed data 10:1 ratio for non-normally distributed data
Muthen and Muthen (2002)	$N \geq 265$
Marsh et al. (1998)	$N \geq 200$
Boomsma and Hoogland (2001)	$N \geq 300$
Westland (2010)	$N \geq 50r^2 - 450r + 1100$ with r = the ratio of observed variables per latent variable In this study, $r = 6$ and $N \geq 200$

3.4.3 Objective 1: Validation of the TPS-TW Model-Based Assessment Tool

3.4.3.1 Reliability Analysis

Cronbach's coefficient alpha was used to test each measurement scale for internal consistency of the survey instrument. In this study, a Cronbach's alpha of greater than or equal to 0.7 was considered as acceptable, and greater than 0.8 as ideal internal consistency (George & Mallery, 2016). The IBM SPSS Statistics Version 24 program was used to calculate the Cronbach's coefficient alpha for each construct of the TPS-TW based measurement instrument. SPSS provides a function that recalculates the value of Cronbach's alpha with each item deleted to help in determining if any items should be removed for further analysis.

Harman's single factor test was used to measure the common method bias. Harman's single factor test determines if the majority of the variance in responses in a survey can be explained by a single factor. If a single factor would account for over 50% of the covariance, then it implies that a significant common method bias exists and should be avoided (Podsakoff et al., 2003). The IBM SPSS Statistics Version 24 program was used to conduct Harman's single factor test with recruiting Principal Axis Factoring (PAF) as the extraction method on the data of the full study.

In addition to Harman's single factor test, the Common Latent Factor (CLF) test was used to detect common method variance. The CLF test adds a separate latent factor named "common" to the model, to measure the common variance among all observed variables. A common variance of 50% or more indicates that common method bias presents in the survey tool (Podsakoff et al., 2003).

Assuming the results of the Cronbach's alpha, the Harman's single factor test, and the CLF test that lead to a good internal consistency, there is strong evidence that reliability has been achieved (Haynes, Richard, & Kubany, 1995).

3.4.3.2 Validity

Validity can be categorized into three groups: content validity, construct validity, and criterion-related validity (Sekaran & Bougie, 2016). Content validity is qualitative and it refers to the degree to which a measure represents an adequate set of items of a given content (Bollen, 1989; Sekaran & Bougie, 2016). Face validity is a subjective judgement and a basic indicator of content validity (Drost, 2011; Sekaran & Bougie, 2016). The panel of SMEs reached a consensus in the survey development phase of this study which provides strong evidence of face validity.

Construct validity refers to the extent to which the data obtained from a survey fits the concepts around which the survey is designed (Sekaran & Bougie, 2016). CFA was adopted as the first step of a two-step covariance analysis to examine the correlations (not causation) and covariation among variables in the TPS-TW model for the evidence of construct validity. The statistics of CFA tests whether the data fits a hypothesized measurement model which indicates the relationship between a set of observed variables to their corresponding latent variables (Bollen, 2005; Brown, 2015; Kline, 2015). In this study, the constructs of standardization and stability, built-in quality, just-in-time, and TW culture serve as latent variables, while the survey items related to each of these constructs are the observed variables in the TPS-TW measurement model. The hypothesized measurement model must be tested by CFA before a study of the causal relationships between latent factors in a subsequent following SEM analysis can be conducted (Schreiber et al., 2006; Ullman & Bentler, 2003).

The Kaiser-Meyer-Olkin (KMO) Test was utilized in this study to examine sampling adequacy for each variable and the entire TPS-TW measurement model. KMO measures the extent to which the data is suited to CFA by evaluating the proportion of common variance among variables (Kaiser, 1974). KMO returns values ranging from 0 to 1. The lower the KMO values, the larger the widespread correlations compare to the sum of correlations which should be avoided in factor analysis. The consensus is that KMO values less than 0.5 indicate the sampling adequacy is not acceptable and KMO values greater than 0.8 are ideal (Cerny & Kaiser, 1977; Field, 2013). The equation for KMO can be found in Equation III.3, where r_{ij} is the simple correlation coefficient between variables i and j, and a_{ij} is the partial correlation coefficient between variables i and j (Hutcheson & Sofroniou, 1999).

$$KMO = \frac{\sum_{i \neq j} r_{ij}^2}{\sum_{i \neq j} r_{ij}^2 + \sum_{i \neq j} a_{ij}^2} \qquad \text{(III.3)}$$

Bartlett's test for Sphericity was employed to check if there is a redundancy between variables that can be summarized with some factors in this study (Armstrong & Soelberg, 1968; Snedecor & Cochran, 1989). Bartlett's test for Sphericity tests the hypothesis that the Pearson-type correlation matrix is an identity matrix and returns a Chi-square value (Tobias & Carlson, 1969). Bartlett's test for Sphericity states that values that are greater than 0.05 indicate that the variables have a chance to be unrelated, and therefore unsuitable for CFA (Snedecor & Cochran, 1989). The IBM SPSS Statistics Version 24 software program was used to perform KMO test and Bartlett's test for Sphericity prior to CFA.

Kline (2015) summarized the four steps in CFA including model specification, model identification, parameter estimation, and model evaluation. Model specification is the representation of latent factors and their corresponding observed variables. In CFA and SEM studies, observed variables are graphically presented with squares or rectangles, whereas latent variables are commonly presented with circles or ovals (Schreiber et al., 2006). A latent factor and its corresponding observed variables are connected with straight one-head arrow to present the directional effect between them. The CFA distinguishes two types of measurement models with very different causal structures: reflective and formative (Edwards & Bagozzi, 2000). A reflective model refers to a model that the latent factors impact on the observed variables, while a formative model refers to a model that the observed variables impact on the latent factors (Edwards & Bagozzi, 2000). Considering the nature of Lean implementation and that standardization, built-in quality, just-in-time, and TW culture work as the principles of Lean, the TPS-TW model can be defined as a reflective model. Each latent factor is also connected to other latent factors with a curved double-ended arrow, representing an unconstrained covariance among the latent variables with no implied direction of effect. The covariance is supposed to indicate the degree of discriminant validity of the model (Bollen, 2005; Brown, 2015; Kline, 2015). Figure 3-4 illustrates the proposed measurement model of the TPS-TW model-based survey tool in CFA.

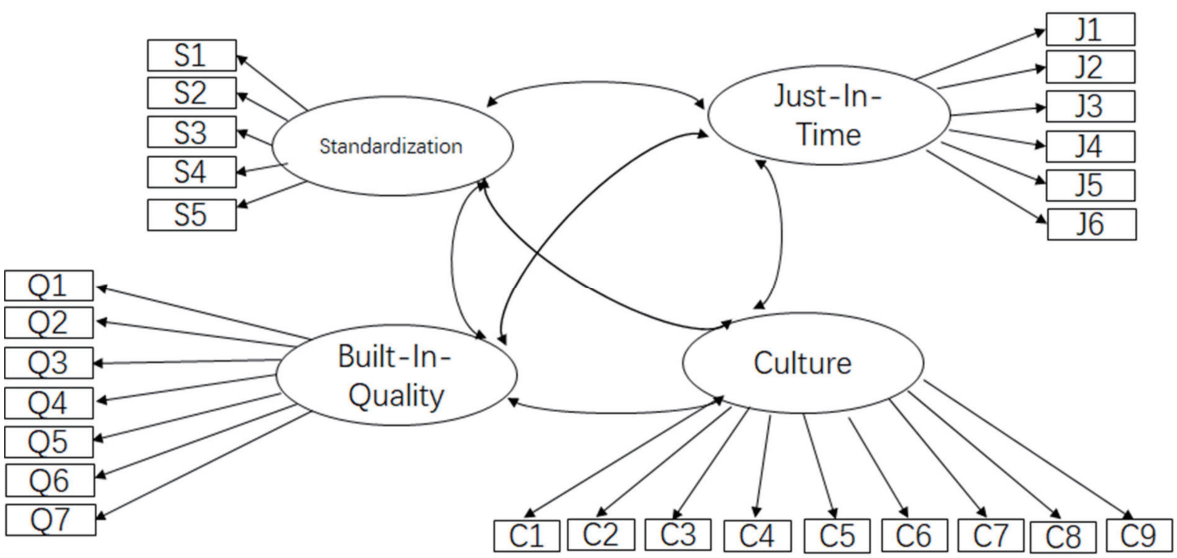

Figure 3-4 TPS-TW Measurement Model in CFA

Model identification occurs when the known information including variances and covariances about the data allows for a unique solution in the parameter estimation process (Kline, 2015). Model identification requires that known parameters must be more than unknown parameters. In other words, the degrees of freedom must be positive. A negative degree of freedom would result in an under-identified model and indicates that a unique solution does not exist. When the number of known parameters is equal to unknown parameters (degrees of freedom is 0), a just-identified model occurs and indicates that there would be a unique solution in parameter estimation, but no goodness-of-fit can be evaluated. Only when the measurement model has positive degrees of freedom, or is over-identified, can a unique solution be achieved and the model fitness be evaluated in the following parameter estimation process (Brown, 2015). Kline (2015) suggests that each latent factor and error variable for each endogenous variable has to be assigned a scale. The most common method in scaling latent factors in CFA is to create a marker variable with a fixed variable path constraint and assign a value of 1 to each error variable and the first observable variable for each factor (Kline, 2015). Bollen (2005) suggests that a single-factor measurement model requires at least three observed variables and a multi-factor model requires at least two observed variables for parameter estimation. In this study, the TPS-TW model has more known parameters than unknowns, at least three observed variables for one factor, and adopted marker variables and error variables with fixed path values of 1. All requirements were met for the subsequent parameter estimation.

Parameter estimation in CFA generates estimated values for each parameter of the model. The Maximum Likelihood (ML) estimation method is commonly used in traditional CFA research. However, the ML assumes that observed variables are continuous and multivariate normal distributed (Bollen, 2005; Brown, 2015; Kline, 2015). In this research, the observed variables are measured by the Likert seven-point scale which generated ordinal data that does not fit multivariate normality. Therefore, the ML was not chosen for parameter estimation in this study. Recent research suggests that the Diagonally Weighted Least Squares (DWLS) parameter estimation method can provide a more accurate parameter estimate and more robust result of model fit when dealing with ordinal data compared to the ML method (DiStefano & Morgan, 2014; Mindrila, 2010). In the full study stage, the DWLS method was adopted to estimate the parameters of the TPS-TW model such as factor loadings, factor variance and covariance, and error variances.

Model evaluation in CFA includes measurement of goodness-of-fit of the overall model and individual model parameter estimates, and therefore tests for convergent and discriminant validity. Various tests and fit indices have been developed to measure the fit of a CFA model. According to the recommendations in recent research, the Chi-square/degrees of freedom, the Root Mean Square Error of Approximation (RMSEA), the Standardized Root Mean Residuals (SRMR), the Bentler-Bonet Normed Fit Index (NFI), the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), and the Adjusted Goodness of Fit Index (AGFI), were adopted as the fit indices in the full study phase of this study (Brown, 2015; Hooper, Coughlan, & Mullen, 2008; Iacobucci, 2010; Kline, 2015). Lavaan, a package for SEM in the R environment, was used for the parameter estimation in this study (Rosseel, 2012). Table 3-9 shows the fit indices and acceptance threshold in model evaluation.

Table 3-9 Fit Indices and Acceptance Threshold in CFA

Fit Index	**Acceptable Fit Threshold**	**Good Fit Threshold**
Chi-Square/df	< 3	< 2
RMSEA	< 0.08	< 0.06
SRMR	< 0.1	< 0.08
NFI	> 0.9	> 0.95
CFI	> 0.9	> 0.95
TLI	> 0.9	> 0.95
AGFI	> 0.9	> 0.95

The last step of model evaluation is to assess construct validity for the measurement model. After evaluating the overall measurement model fit with the results that each of the model fit indices meets its corresponding requirement, some individual estimated parameters were evaluated to assess the convergent validity of the TPS-TW model. These individual estimated parameters include the factor loadings of observed variables on their corresponding latent factors, composite reliability, and Average Variance Extracted (AVE). Then the discriminant validity was assessed by Heterotrait-Monotrait Ratio (HTMT) test and comparing AVE to the squared correlation between constructs.

Factor loading is a path coefficient, like a regression coefficient, that reflects the change of an observed variable by the one-unit change in a corresponding latent factor. O'Rourke and Hatcher (2013) suggest that standardized parameter estimates suit single group analysis while unstandardized parameter estimates are preferred in multiple group analysis. Because this research only involved a single group analysis, the standardized factor loadings that set all variables' standard deviation equal to 1 were chosen to study the effect of latent factors on each of their respective observed variables (O'Rourke and Hatcher, 2013). Hair (2006) suggests a guideline for identifying significant factor loadings based on sample size which is shown in Table 3-10. Some research suggest that the factor loadings greater than 0.6 are generally considered significant regardless of sample size (Field, 2013; Guadagnoli & Velicer, 1988; MacCallum, Widaman, Preacher, & Hong, 2001). Lavaan uses the Student's t-test to test for statistical significance of factor loadings (Rosseel, 2012). The factor loadings and results of t-test were used to provide strong evidence of convergent validity and allow for computing composite reliability to measure the internal consistency of the TPS-TW model-based measurement instrument as a complement to Cronbach's coefficient alpha.

Table 3-10 Guideline for Identifying Significant Factor Loadings based on Sample Size

Sample Size	**Significant Factor Loading**
350	0.30
250	0.35
200	0.40
150	0.45
120	0.50
100	0.55
85	0.60
70	0.65
60	0.70
50	0.75

Raykov (1997a) suggests that the Cronbach's coefficient alpha is based on multiple assumptions to reflect the internal consistency of the model. Violation of these assumptions can make the Cronbach's coefficient alpha underestimate the true reliability of the data. Researchers suggest using Composite Reliability (CR) and Average Variance Extracted (AVE) in addition to Cronbach's coefficient alpha to accurately estimate the internal consistency (Anderson & Gerbing, 1988; Hair, 2006; Raykov, 1997b). CR is based on factor loadings in CFA and it measures internal consistency among the observed variables and their respective latent factor. CR estimates how much a set of latent factors share in their measurement of a construct (Hair, 2006). The equation for CR can be found in Equation III.4, where p is the number of observed variables related to one latent factor, λ_i is the standardized factor loading for that observed variable, and $V(\delta_i)$ is the error variance associated with the individual observed variable (Netemeyer, Bearden, & Sharma, 2003).

The acceptable threshold value for CR is 0.7 (preferably 0.8) and higher values indicate strong internal consistency (Hair, 2006; Nunnally & Bernstein, 1994).

$$\text{Composite Reliability} = \frac{\left(\sum_{i=1}^{p}\lambda_i\right)^2}{\left(\sum_{i=1}^{p}\lambda_i\right)^2 + \sum_{i}^{p}V(\delta_i)} \qquad \text{(III.4)}$$

The AVE for each individual construct is another important measure of convergent validity. AVE is similar to CR, and it estimates the extent to which the average amount of variances in observed variables are accounted for by their respective latent factors (Hair, 2006). The equation for AVE can be found in Equation III.5, where *p* is the number of the observed variables related to one latent factor, λ_i is the standardized factor loading for that observed variable, and $V(\delta_i)$ is the error variance associated with the individual observed variable (Fornell & Larcker, 1981). A value of AVE above 0.5 is treated as an indication of satisfactory convergent validity (Fornell & Larcker, 1981).

$$\text{AVE} = \frac{\sum_{i=1}^{p}\lambda_i^2}{\sum_{i=1}^{p}\lambda_i^2 + \sum_{i}^{p}V(\delta_i)} \qquad \text{(III.5)}$$

According to Fornell and Larcker (1981), discriminant validity can be assessed by comparing the amount of the variance captured by one construct and the covariance with other constructs. A latent factor with good discriminant validity should account for more of the variance of its respective observed variables than the variance of other factors (Hair, Hult, Ringle, & Sarstedt, 2016). This Fornell-Larcker criterion compares the square root of AVE with the correlation between latent factors (Fornell & Larcker, 1981; Hair et al., 2016). If the levels of square root of the AVE for each construct are all greater than the correlations involving the constructs, it indicates a satisfactory discriminant validity (Hair et al., 2016).

Henseler et al. (2015) proposed the Heterotrait-Monotrait Ratio of the Correlations (HTMT) approach for assessing discriminant validity in CFA. Henseler et al. (2015) suggest that HTMT has better performance for identifying a lack of discriminant validity and signaling discriminant validity if the two constructs are empirically distinct compared to the Fornell-Larcker criterion. HTMT derives from the classical Multitrait-Multimethod (MTMM) matrix, and it assesses the average correlation among observed variables across latent variables, relative to the average correlation among observed variables within the same factor (Henseler et al., 2015). The equation for of the latent variables i and j with, respectively, K_i and K_j observed variables can be formulated in Equation III.6, where $r_{ig,jh}$ is correlation of the observed variables (Henseler et al., 2015). Some research suggests that the value of HTMT greater than 0.9 indicates there is a lack of discriminant validity (Gold, Malhotra, & Segars, 2001; Teo, Srivastava, & Jiang, 2008), while others propose a cut-off value of 0.85 (Clark & Watson, 1995; Kline, 2015).

$$\mathrm{HTMT}_{ij} = \frac{\frac{1}{K_i K_j} \sum_{g=1}^{K_i} \sum_{h=1}^{K_j} r_{ig,jh}}{\sqrt{\frac{2}{K_i\left(K_j - 1\right)} * \sum_{g=1}^{K_i - 1} \sum_{h=g+1}^{K_i} r_{ig,ih} * \frac{2}{K_j\left(K_j - 1\right)} * \sum_{g=1}^{K_j - 1} \sum_{h=g+1}^{K_j} r_{jg,jh}}} \qquad \text{(III.6)}$$

Criterion-related validity refers to the degree to which survey responses are correlated with one or more external criteria of the same performance that the survey designer would expect them to be correlated with (Cohen et al., 2002; Drost, 2011). In this study, criterion-related validity was measured by comparing the survey results with the actual metrics using Kendall's Tau-b. Kendall's Tau coefficient is a non-parametric statistic commonly used to assess the strength and direction of association between two variables measured on an ordinal scale (Agresti, 2010; Kendall, 1948).

The Kendall's Tau-b measures the similarity of the rankings of the data with range from -1 (100% negative association) to +1 (100% positive association) (Agresti, 2010; Kendall, 1948). A value of 0 indicates no correlation. The statistic of Kendall's Tau-b coefficient is shown in equation III.7, where n_c is the number of concordant pairs, n_d is the number of discordant pairs, t_i and u_i are the numbers of observations tied at each rank, and n is the size of the ranks.

$$\tau_b = \frac{n_c - n_d}{\sqrt{[n(n-1)/2 - \sum_{t=1}^{t} t_i(t_i - 1)/2][n(n-1)/2 - \sum_{u=1}^{u} u_i(u_i - 1)/2]}} \qquad \text{(III.7)}$$

3.4.4 Objective 2: Understanding the Effect of the Toyota Way (TW) Culture in a Lean System

To achieve the objective of understanding the effect of the TW culture in a Lean production system, a SEM method was used to measure the directional relationships among Lean implementation, the TW culture, and the operational performance in a TPS-TW structural model. In contrast to the measurement model in CFA, two new latent variables were added to the structural model. The first is a second-order latent variable "lean" based on standardization and stability, built-in quality, and just-in-time to represent the general Lean production deployment. The other new latent variable is "performance" which represents the operational performance of Lean deployment. In the TPS-TW model-based measurement instrument, the "performance" is measured by three quantitative metrics: "process downtime %," "first-pass-yield," and "on-time delivery." Loyd (2017) suggests that the TW culture has an indirect mediating effect between "Lean adoption" and "performance" in the American manufacturing sector. A question this research is attempting to answer is if the role of TW culture in Lean deployment in the Chinese automotive industry is different from what was found for the American industry? Figure 3-5 illustrates the structural model of the TPS-TW model-based measurement instrument in SEM.

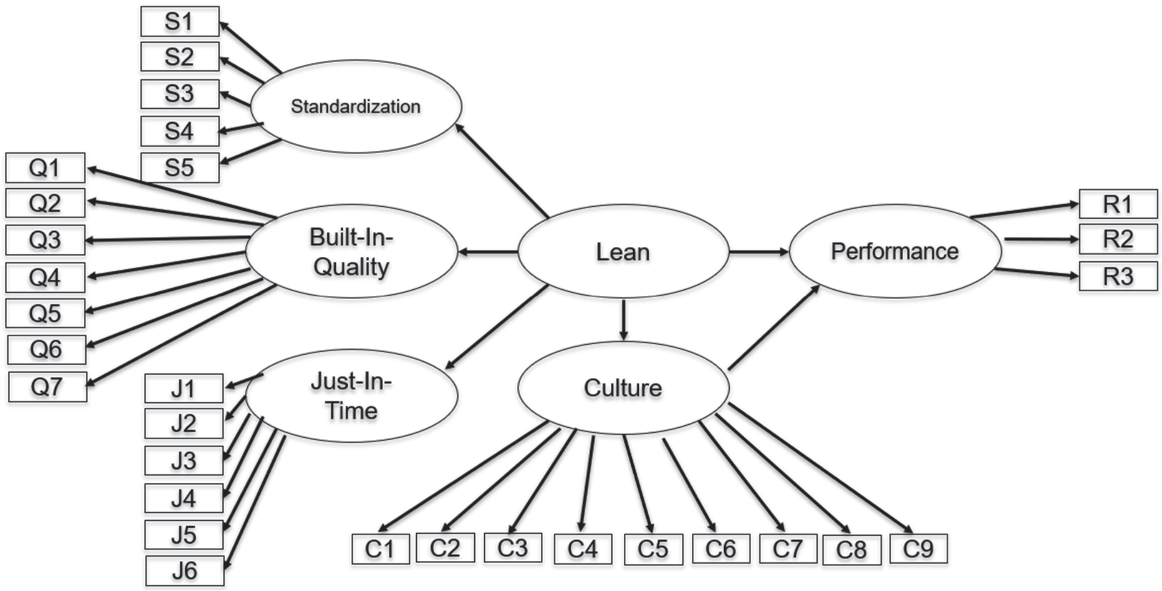

Figure 3-5 TPS-TW Structural Model in SEM

Like the measurement model in the CFA analysis, ovals represent the latent factors and rectangles represent the observed variables. Variables are connected by straight one-headed arrows representing directional effects. Each latent variable assigns a path coefficient of one to an observed variable or first order latent variable to make it scaled. The SEM analysis employed the DWLS parameter estimation method and model fit indices such as Chi-square/df, RMSEA, SRMR, NFI, CFI, TLI and AGFI, same as the CFA analysis.

Mediation indicates that the effect of an independent variable on a dependent variable passes through a third variable, known as a mediator, rather than a direct association between the independent variable and the dependent variable (Baron & Kenny, 1986; Shrout & Bolger, 2002). Figure 3-6 illustrates the pathway of a mediation process, where X denotes the independent variable, Y denotes the dependent variable, M denotes the mediator, and e_M and e_Y are uncorrelated error terms.

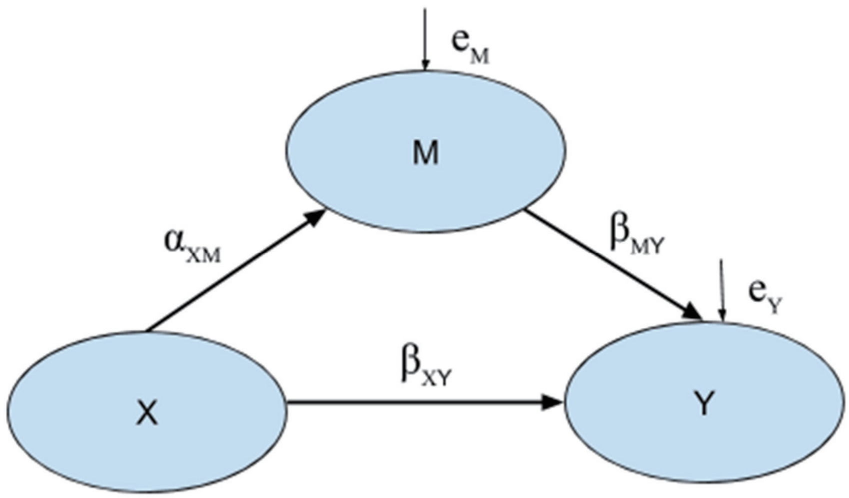

Figure 3-6 Pathway of a Mediation Process

The relationship among the variables can be tested as follows: (1) the dependent variable Y is regressed on the independent variable X, (2) the mediator M is regressed on the independent variable X, and (3) the dependent variable Y is regressed on both the independent variable X and the mediator M (Baron & Kenny, 1986; Edwards & Lambert, 2007). The SEM for this mediation process can be defined in Equations III.8 and III.9.

$$M = \alpha_0 + \alpha_{XM} X + e_M \quad \text{(III.8)}$$

$$Y = \beta_0 + \beta_{MY} M + \beta_{XY} X + e_Y \quad \text{(III.9)}$$

The direct effect refers to the path from X to Y. Therefore, β_{XY} is the direct effect in Figure 3.7. The indirect effect refers to the amount of mediation and it can be calculated as the product of α_{XM} and $\beta_{MY.}$ Finally, the total effect is the sum of the direct and indirect (Baron & Kenny, 1986; Shrout & Bolger, 2002). The primary interest in a mediation analysis is to see whether the effect of the independent variable on the dependent variable can be mediated by a change in the mediator. In a complete mediation process, the effect is 100% mediated by the mediator (β_{XY} is not significant and β_{MY} is significant). However, in most cases, a partial mediation is more common, in which case the mediator only mediates part of the effect of the independent variable on the dependent variable (β_{XY} and β_{MY} are both significant) (Gunzler et al., 2013). According to Loyd's mediation model, the second-order latent variable "lean" was treated as the independent variable, the first-order latent variable "culture" is the mediator, and the first-order latent variable "performance" is the dependent variable in this study (Loyd, 2017). By investigating the mediation processes to understand how the Lean implementation achieves operational performance in a Lean production system, we may be able to identify more efficient strategies to improve performance for the companies that have implemented Lean in the Chinese auto manufacturing industry.

Various methods for assessing indirect mediating effects have been developed such as the causal steps approach (Baron & Kenny, 1986), the Sobel test (Sobel, 1982, 1986), the distribution of products test (MacKinnon et al., 2002), and bootstrapping (Preacher & Hayes, 2008). The causal steps approach, also called a test of joint significance, is the most widely and easily used approach. However, the causal steps approach was criticized for its low power and inaccuracy (Fritz & MacKinnon, 2007). The Sobel test serves as a supplement of the causal steps approach, but it has an assumption that the indirect effect is normally distributed (Sobel, 1982, 1986). Unfortunately, the sampling distribution derived from a Likert scale rarely fits normal distribution and tends to be asymmetric with skewness, and thus brings in extra computational burden (Bollen & Stine, 1990; Preacher & Hayes, 2008). Hayes (2009) suggests that the non-parametric bootstrapping with confidence intervals is the most adaptable method for assessing indirect effects regardless of the data distribution and could provide the most accurate result. The bootstrapping method reports a bootstrap confidence interval based on percentile. If the 95% bootstrap confidence interval does not include the value of 0, then the conclusion that the indirect mediating effect exists with 95% confidence could be made. In other words, the null hypothesis, that the TW culture does not have an indirect mediating effect between “lean” and “performance” in the Chinese automobile manufacturing sector, would be rejected at the significant level of 0.05 (Hayes, 2009). The parameter estimation, model fit tests, and the non-parametric bootstrapping method for testing mediating effect was conducted in an R environment.

A multigroup analysis in SEM is a powerful tool to compare the effects of “culture” in the mediation model between the US and China. A multigroup analysis focuses on the interaction applied across a structural equation model by a single variable, that is, it asks if any regression coefficient is different between groups (Lefcheck, 2016). Multigroup modeling begins with the estimation of two models: one in which all parameters are allowed to vary between groups, called the “free” model, and one in which all parameters are constrained to fixed values determined by the entire data set between groups, called the “full constrained” model. If the two models are not significantly different by a Chi-squared difference test, then one can assume the absence of variation in the path coefficients by group. If the two models are significantly different, then a subsequent modeling process by constraining the coefficient of each path one at a time and re-fitting the model is needed (Lefcheck, 2016). When a “single constrained” model that is not significantly different from the “free” model is found, we can study the parameter estimations and draw conclusions (Lefcheck, 2016). The multigroup analysis in SEM employed the DWLS parameter estimation method and model fit indices such as Chi-square/df, RMSEA, SRMR, NFI, CFI, TLI and AGFI in an R environment.

3.4.5 Objective 3: Comparison of Conceptions on Lean between Frontline and Non-Frontline Employees

The Mann-Whitney U test in the R environment was utilized to test for the equality of the population means between frontline and non-frontline employees in the perception of Lean implementation. Each survey item associated with the constructs of the TPS-TW measurement model including standardization and stability, built-in quality, just-in-time, and TW culture was considered. The null hypothesis is that there is no significant difference in agreement on each of the constructs between frontline and non-frontline employees in the same plant.

Chapter 4 Results

The questionnaires in the full study phase were disseminated in both paper version and the electronic Tencent Survey web application. The target population remained adults over the age of 18, who had worked at least three months at an auto manufacturing company in China that had been implementing Lean for at least one year. There were no exclusions based on race, gender and other factors. 350 valid survey responses from 6 plants in the Chinese auto manufacturing sector via paper questionnaire and 92 valid survey responses via electronic questionnaire were received. The total 442 valid responses meet the minimum required sample size of 300. Table 4-1 shows the sample in the full study.

Table 4-1 Sample in the Full Study

	Paper Version Survey						**Electronic Survey**	**Sum**
	Plant #1	**Plant #2**	**Plant #3**	**Plant #4**	**Plant #5**	**Plant #6**		
Frontline	35	22	67	53	27	31	4	239
Supervisor	5	4	7	6	6	4	6	38
Management	6	3	4	5	5	4	31	58
Administration	0	1	1	0	0	2	2	6
Quality	5	3	3	4	3	6	19	43
Engineering	3	4	7	4	2	5	27	52
Finance	1	0	1	1	0	0	3	6
Sum (Frontline : Non-frontline)	55 (35 : 20)	37 (22:15)	90 (67 : 23)	73 (53 : 20)	43 (27 : 16)	52 (31 : 21)	92 (4 : 88)	442 (239 : 203)

4.1 Objective 1: Validation of the TPS-TW Model-Based Tool

4.1.1 Reliability

As in the pilot study, the IBM SPSS Statistics 24 software program was used to calculate Cronbach's coefficient alpha to evaluate the internal consistency and scale reliability of the survey instrument. Table 4-2 shows the Cronbach’s alpha for each construct in the survey. All of the Cronbach’s coefficient alpha values are greater than 0.8. Additionally, the alpha score for each scale decreased if any item was removed, thus no survey items need to be deleted. The result indicated each survey construct was considered to have good internal consistency.

Table 4-2 Cronbach’s Coefficient Alpha in the Full Study

Construct	Value	Good Fit	Status
Standardization	0.862	> 0.8	Good
Built-in Quality	0.892	> 0.8	Good
Just-in-time	0.868	> 0.8	Good
Culture	0.899	> 0.8	Good

Harman’s single factor test and Common Latent Factor (CLF) test were used to examine for common method bias in the survey responses. The IBM SPSS Statistics 24 software program was used to conduct Harman’s single factor test adopting PAF as the extraction method. The result shows the most significant factor extracting 23.92% of the total variance, which satisfied Harman’s single factor test since no single factor extracts over 50% of variance. Additionally, five factors with Eigenvalues greater than 1 were considered to be significant contributors to the overall covariance. The IBM SPSS AMOS 26 software was used to perform a CLF test. A separate latent factor named “common” was added to the TPS-TW measurement model and linked to all observed variables. The factor loadings from each observed variable were constrained to be equal and the variance of “common” latent variable was set to 1. The common factor loading was 0.351, and the square of the factor loading was 0.123. The value was less than the 0.5 threshold and satisfied the CLF test. Therefore, the results of Harman’s single factor test and the CLF test suggested that the TPS-TW measurement model was free of common method bias.

4.1.2 Validity

The Confirmatory Factor Analysis (CFA) was used to evaluate the construct validity of the survey instrument. The first step in CFA for the full study was to test for sample adequacy. Kaiser-Meyer-Olkin (KMO) Test and Bartlett’s Test of Sphericity were used to measure if the data suits a CFA. The IBM SPSS Statistics 24 software was used to perform the KMO test and Bartlett’s Test of Sphericity, and Table 4-3 shows the result in the full study. The 0.890 KMO value suggested that sampling adequacy of the data was ideal for CFA, and the small value (less than 0.05) of Bartlett’s Test of Sphericity indicated that CFA was likely to be useful with the data.

Table 4-3 KMO and Bartlett’s Test in the Full Study

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.890
Bartlett's Test of Sphericity	Approx. Chi-Square	6297.378
	df	351
	Sig.	.000

The first step of data analysis was to assess the fit of the TPS-TW Measurement Model which was described in section 3.4.3.2 and shown in Figure 3.4. The Diagonally Weighted Least Squares (DWLS) parameter estimation method was utilized to estimate the parameters. The Chi-Square per degree of freedom, the Root Mean Square Error of Approximation (RMSEA), the Standardized Root Mean Residuals (SRMR), the Bentler-Bonet Normed Fit Index (NFI), the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), and the Adjusted Goodness-of-Fit

Index (AGFI), were selected as fit indices and calculated in an R environment using the Lavaan package. Table 4-4 shows the summary of the TPS-TW measurement model's various fit indices compared to their respective acceptance values. The model showed evidence of good fit according to all measures, so the study proceeded to evaluate the construct validity of the survey instrument.

Table 4-4 TPS-TW Measurement Model's Fit Indices Compared to Acceptance Values

Fit Index	Value	Acceptable Fit	Good Fit	Status
Chi-Square	407.08			
Chi-Square/df	1.28	< 3	< 2	Good
RMSEA	0.025	< 0.08	< 0.06	Good
SRMR	0.051	< 0.1	< 0.08	Good
NFI	0.968	> 0.9	> 0.95	Good
CFI	0.993	> 0.9	> 0.95	Good
TLI	0.992	> 0.9	> 0.95	Good
AGFI	0.978	> 0.9	> 0.95	Good

The standardized factor loadings for each observed variable to its corresponding latent variable was examined in R for the evidence of convergent validity. According to Hair's (2006) guideline, an acceptable significant factor loading with a sample size of 350 should be greater than 0.3. Several research papers suggest that the factor loadings greater than 0.6 are generally considered significant regardless of sample size (Field, 2013; Guadagnoli & Velicer, 1988; MacCallum et al., 2001). For the TPS-TW measurement model, all factor loadings exceeded 0.6 and were significant ($p < 0.05$). Table 4-5 shows the summary of the standardized factor loadings compared to the acceptance criterion. The results indicate that each observed variable has a strong relationship with its respective latent variable which provides strong evidence of convergent validity.

Table 4-5 Summary of Standardized Factor Loadings in CFA

Observed Variable	Std Factor Loading	Acceptable Value	Good Value	Status
Standardization = ~				
S1	0.736	> 0.3	> 0.6	Good
S2	0.796	> 0.3	> 0.6	Good
S3	0.794	> 0.3	> 0.6	Good
S4	0.743	> 0.3	> 0.6	Good
S5	0.644	> 0.3	> 0.6	Good
Built-in Quality =~				
Q1	0.626	> 0.3	> 0.6	Good
Q2	0.742	> 0.3	> 0.6	Good
Q3	0.797	> 0.3	> 0.6	Good
Q4	0.775	> 0.3	> 0.6	Good
Q5	0.798	> 0.3	> 0.6	Good
Q6	0.719	> 0.3	> 0.6	Good
Q7	0.685	> 0.3	> 0.6	Good
Just-in-time =~				
J1	0.709	> 0.3	> 0.6	Good
J2	0.657	> 0.3	> 0.6	Good
J3	0.802	> 0.3	> 0.6	Good
J4	0.777	> 0.3	> 0.6	Good
J5	0.737	> 0.3	> 0.6	Good
J6	0.649	> 0.3	> 0.6	Good
Culture =~				
C1	0.620	> 0.3	> 0.6	Good
C2	0.629	> 0.3	> 0.6	Good
C3	0.623	> 0.3	> 0.6	Good
C4	0.734	> 0.3	> 0.6	Good
C5	0.767	> 0.3	> 0.6	Good
C6	0.775	> 0.3	> 0.6	Good
C7	0.774	> 0.3	> 0.6	Good
C8	0.755	> 0.3	> 0.6	Good
C9	0.654	> 0.3	> 0.6	Good

The Composite Reliability (CR) was also calculated for each latent variable. CR estimates the level of shared measurement in a set of latent factors, and measures internal consistency among the observed variables and their respective latent factor (Hair, 2006). Table 4-6 shows the summary of the composite reliability of each latent variable in the TPS-TW measurement model compared to the threshold value. All of CR values exceeded the preferable acceptance of 0.7. The results indicate strong internal consistency of the TPS-TW measurement model and provides additional strong evidence of reliability and construct validity.

Table 4-6 Summary of Composite Reliability Values

Construct	**CR Value**	**Acceptable Value**	**Good Value**	**Status**
Standardization	0.864	> 0.6	> 0.7	Good
Built-in Quality	0.894	> 0.6	> 0.7	Good
Just-in-time	0.870	> 0.6	> 0.7	Good
Culture	0.901	> 0.6	> 0.7	Good

The next step in evaluating the convergent validity of the TPS-TW measurement model was testing the Average Variance Extracted (AVE). Table 4-7 summarizes the Average Variance Extracted of each construct. The AVE values all exceeded 0.5 threshold. Based on meeting all of the requirements for the standardized factor loadings, the composite reliability measures, and the AVE, there is strong evidence that the constructs of the TPS-TW model have good convergent validity.

Table 4-7 Summary of Average Variance Extracted

Construct	**AVE Value**	**Acceptable Cut-off**	**Status**
Standardization	0.565	> 0.5	Acceptable
Built-in Quality	0.551	> 0.5	Acceptable
Just-in-time	0.532	> 0.5	Acceptable
Culture	0.517	> 0.5	Acceptable

The other component of the construct validity is the discriminant validity. The Heterotrait-Monotrait Ratio of Correlations (HTMT) between the latent factors as estimates of inter-construct correlations were calculated in R. For the TPS-TW model, all HTMT values between any two latent factors satisfied the requirement that the outcome should not be greater than the 0.9 threshold. Table 4-8 shows the matrix of HTMT. The results suggest each of the survey constructs measures different concepts.

Table 4-8 Matrix of the Heterotrait-Monotrait Ratio of Correlations

	Standardization	Built-in Quality	Just-in-time	Culture
Standardization	1			
Built-in Quality	0.506	1		
Just-in-time	0.264	0.262	1	
Culture	0.256	0.236	0.243	1

The final step in the CFA to establish discriminant validity was to compare the square root of AVE of each construct with the correlation between latent variables. The result shows that the square roots of the AVEs are all greater than the inter-construct correlations which indicates a satisfactory discriminant validity. Table 4-9 summarizes the comparisons between the square root of the AVE and inter-construct correlations for each latent variable. Given the results of tests of HTMT and the square root of AVE vs. correlation, the survey instrument exhibited a satisfactory level of discriminant validity for the TPS-TW measurement model.

Table 4-9 Summary of Average Variance Extracted vs. Inter-Construct Correlation

Construct	AVE	Square Root of AVE	Maximum Inter-Construct Correlation	Is the Square Root of AVE Greater than Correlation?
Standardization	0.565	0.752	0.506	Yes
Built-in Quality	0.551	0.742	0.506	Yes
Just-in-time	0.532	0.729	0.264	Yes
Culture	0.517	0.719	0.256	Yes

Criterion-related validity refers to the extent to which a respondent's answers on a measure are correlated with external criteria of the same performance (Cohen et al., 2002; Drost, 2011). It can be established by assessing concurrent validity when the external criteria exist at the same time as the measure (Drost, 2011). This study obtained the most recent three years of actual performance metrics shown in Appendix-F to compare with results of the survey. The actual performance was ranked by the average of, process downtime %, first-pass-yield %, and on-time delivery % from best to worst and given scores from 6 to 1, respectively. The survey result rankings were ranked by the summation of the percentage of positive attitude (somewhat agree, agree, and strongly agree) from highest to lowest with given scores from 6 to 1 for each construct. The rankings of standardization, built-in quality, and just-in-time were combined with the ranking of culture respectively. The Kendall's Tau was used to measure the similarity between the ranking of actual performance and the ranking of the combined survey results correspondingly. One thousand bootstrap samples were executed to output a 95% Confidence Interval (CI).

For standardization and stability, Plant 4 (truck assembly) was excluded in rankings because it did not exhibit Lean behaviors as it tended to leave quality issues to rework rather than stop the production line and fix it. Since Plant 4 didn't stop the line, it had the best downtime performance but with the worst first-pass-yield and on-time delivery. Kendall's Tau correlation coefficient of 0.671 indicates a strong correlation between the survey results and actual performance. Figure 4-1 illustrates the comparison between the survey results and actual performance for standardization and stability. Plants 1 and 2 perform well (1st, 2nd) here and they also have good combined survey results (2nd, 1st). Plants 6 and 3 have lower performance metrics (4th, 5th) and they also have lower combined survey results (4th, 5th). We could infer that culture may have an important influence on standardization performance. For example, Plant 5 had better standardization agreement than Plant 1 (71.1%:65.8%), while Plant 1 had better culture agreement (59.6%:54%). However, the recorded downtime showed Plant 1 performed better.

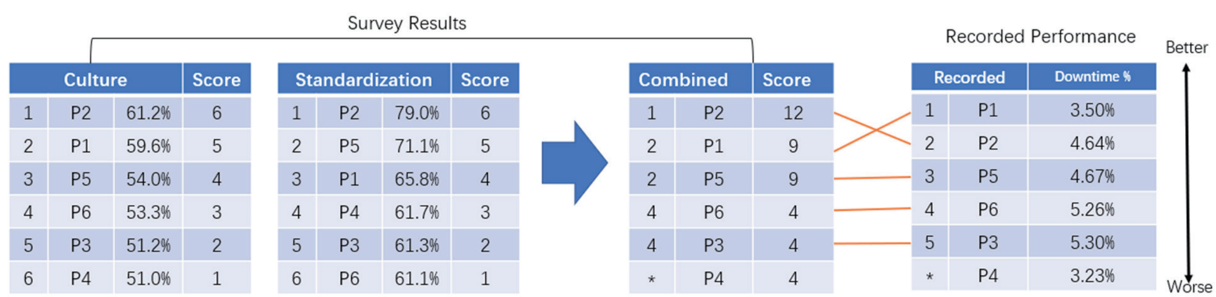

Figure 4-1 Comparison between Survey Results and Actual Metrics for Standardization

For built-in quality, Kendall's Tau correlation coefficient of 0.501 indicates a strong correlation between the survey results and actual performance. Figure 4-2 illustrates the comparison between the survey results and actual performance for the built-in quality. Plants 1 and 2 had the best performances (1st, 2nd) here and they also had the best culture (2nd, 1st) and built-in quality (1st, 2nd) agreements. Plant 4 did not exhibit Lean behaviors when dealing with quality issues in production, as a result their culture agreements and recorded quality performance were lower. The performance ranking is more aligned to the culture ranking rather than built-in quality agreement ranking here. This may imply that culture has significant influence on quality performance.

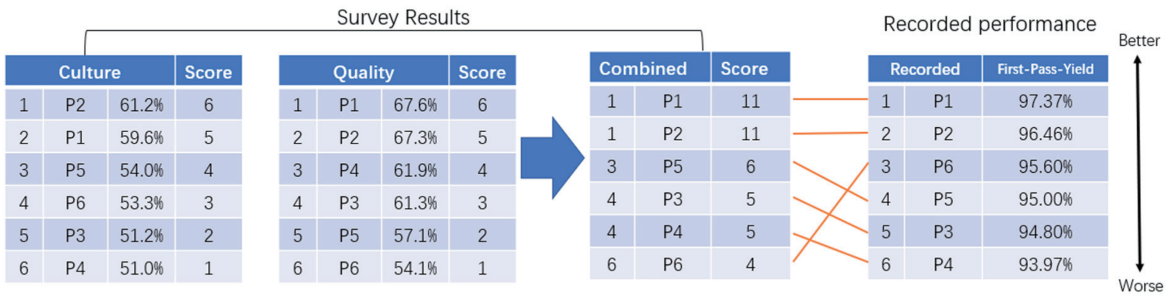

Figure 4-2 Comparison between Survey Results and Actual Metrics for Built-in Quality

For just-in-time, Kendall's Tau correlation coefficient of 0.600 indicates a strong correlation between the survey results and actual performance. Figure 4-3 illustrates the comparison between the survey results and actual performance for just-in-time. Plant 5 (seat manufacturing) maintained a high level of inventory and its daily production schedule was not well-balanced. But it had fewer and simpler production processes than others, and it delivered seats to the subassembly units of the final assembly plants directly. This may explain why Plant 5 had the worst JIT agreement but maintained a relatively good performance in on-time delivery. It appears that Plant 5 relies on extraordinary effort to maintain JIT performance. Plant 4 (truck assembly) tended to leave quality issues to rework rather than stop the line and fix it, hence the workers must spend more time to deal with quality issues in rework process which made Plant 4 have the worst recorded on-time delivery performance.

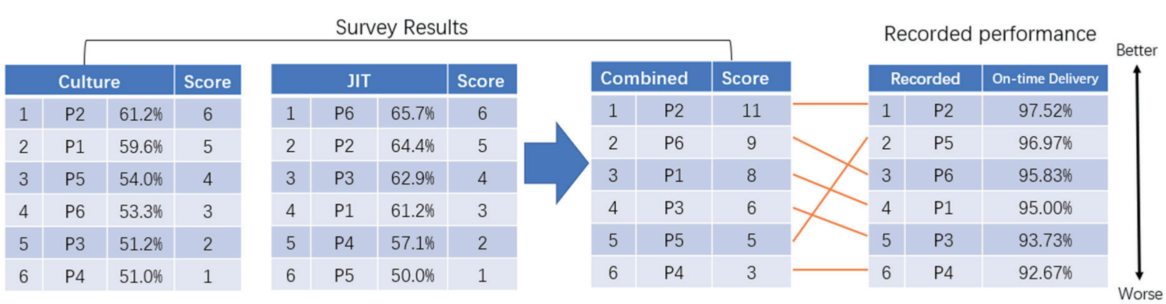

Figure 4-3 Comparison between Survey Results and Actual Metrics for Just-in-time

Last, the overall survey result rankings combining the standardization, built-in quality and just-in-time was compared to the overall recorded performance rankings integrating the process downtime %, first-pass-yield, and on-time delivery. Kendall's Tau value of 0.467 indicates a positive correlation between the overall survey results and the overall actual performance. Figure 4-4 illustrates the comparison between the two overall rankings.

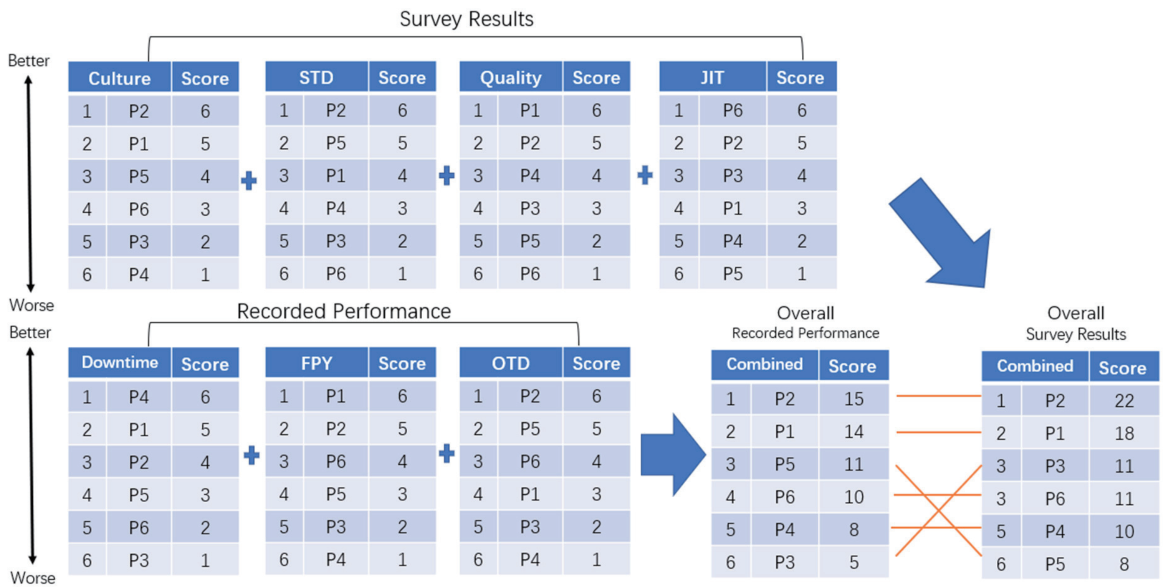

Figure 4-4 Comparison between Overall Survey Results and Actual Metrics

For the output of the Kendall's Tau-b test which is shown in Table 4-10, the estimators of coefficient were large, however, not significant at a 95% CI level. In other words, we cannot reject the null hypothesis that $\tau_b = 0$ which indicates there is no correlation between two ranks. According to Bonett and Wright's (2000) suggestion of required sample size for rank correlation tests, the critical value for Kendall's Tau test largely depends on sample size. In this study, the n = 5 or 6 was too small and led to a large standard error. Even one violation can prevent the 95% CI excluding 0 value. Conducting the same research in more plants (n > 10) is needed for future study to get a solid conclusion of the criterion-related validity. Meanwhile, the recent three years of performance metrics are not enough to rank plants statistically by repeated measures ANOVA. Conducting the research in more than 10 plants and obtaining more than 7 years of actual performance metrics are needed for future study to establish robust criterion-related validity statistically.

Table 4-10 Summary of Kendall’s Tau-b Tests

	Estimate	**Std. Error**	**P-value**	**ci.lower**	**ci.upper**
Standardization	0.671	0.343	0.117	-0.378	1.000
Built-in Quality	0.501	0.411	0.173	-0.636	1.000
Just-in-time	0.600	0.345	0.091	-0.196	1.000
Overall	0.467	0.470	0.188	-1.000	1.000

4.2 Objective 2: Understanding the Effect of the Toyota Way (TW) Culture in a Lean System

The second objective of this study is to investigate the effect of TW culture on Lean deployment and operational performance in the automobile manufacturing sector in China and compare the effect culture has on operational performance between manufacturing companies in the US and China. To achieve this objective, a latent factor “performance,” representing the operational performance of a Lean manufacturing system, was introduced into the structural TPS-TW model with three observed variables “process downtime %,” “first-pass-yield,” and “on-time delivery.” The “culture” latent factor was specified as a mediator variable between “lean” and “performance.” Structural Equation Modeling (SEM) was used to evaluate the relationships and mediating effect among these latent variables of the structural TPS-TW model, described in section 3.4.4 and shown in Figure 3-5.

As in the CFA analysis, the structural TPS-TW model was first examined for model fit. The DWLS parameter estimation method was utilized to approximate the parameters. The Chi-Square per degree of freedom, RMSEA, SRMR, NFI, CFI, TLI, and AGFI, were calculated as fit indices in the R environment using the Lavaan package. Table 4-11 shows the summary of the various fit indices for the TPS-TW structural model compared to their respective acceptable criterion. The result indicates the structural model is considered to have good model fit.

Table 4-11 TPS-TW Structural Model's Fit Indices Compared to Acceptable Criterion

Fit Index	**Value**	**Acceptable Fit**	**Good Fit**	**Status**
Chi-Square	602.79			
Chi-Square/df	1.51	< 3	< 2	Good
RMSEA	0.034	< 0.08	< 0.06	Good
SRMR	0.055	< 0.1	< 0.08	Good
NFI	0.963	> 0.9	> 0.95	Good
CFI	0.987	> 0.9	> 0.95	Good
TLI	0.986	> 0.9	> 0.95	Good
AGFI	0.972	> 0.9	> 0.95	Good

In addition, the standardized factor loadings for each observed variable to its latent variable and each first order latent variable to its respective second order latent variable were examined. For the TPS-TW structural model, all factor loadings exceeded 0.3 and were significant ($p < 0.05$). Table 4-12 shows the summary of the standardized factor loadings compared to the acceptance values. The results indicate that each observed variable or first order latent variable has a strong relationship with its corresponding latent factor or second order latent variable, so the study proceeded to assess the relationships between latent variables.

Table 4-12 Summary of Standardized Factor Loadings for TPS-TW Structural Model

Observed Variable	Std Factor Loading	Acceptable Value	Good Value	Status
Standardization = ~				
S1	0.741	> 0.3	> 0.6	Good
S2	0.802	> 0.3	> 0.6	Good
S3	0.787	> 0.3	> 0.6	Good
S4	0.741	> 0.3	> 0.6	Good
S5	0.642	> 0.3	> 0.6	Good
Built-in Quality =~				
Q1	0.626	> 0.3	> 0.6	Good
Q2	0.737	> 0.3	> 0.6	Good
Q3	0.803	> 0.3	> 0.6	Good
Q4	0.774	> 0.3	> 0.6	Good
Q5	0.798	> 0.3	> 0.6	Good
Q6	0.718	> 0.3	> 0.6	Good
Q7	0.688	> 0.3	> 0.6	Good
Just-in-time =~				
J1	0.707	> 0.3	> 0.6	Good
J2	0.660	> 0.3	> 0.6	Good
J3	0.815	> 0.3	> 0.6	Good
J4	0.773	> 0.3	> 0.6	Good
J5	0.731	> 0.3	> 0.6	Good
J6	0.644	> 0.3	> 0.6	Good
Culture =~				
C1	0.610	> 0.3	> 0.6	Good
C2	0.650	> 0.3	> 0.6	Good
C3	0.639	> 0.3	> 0.6	Good
C4	0.741	> 0.3	> 0.6	Good
C5	0.773	> 0.3	> 0.6	Good
C6	0.769	> 0.3	> 0.6	Good
C7	0.763	> 0.3	> 0.6	Good
C8	0.746	> 0.3	> 0.6	Good
C9	0.642	> 0.3	> 0.6	Good
Performance =~				
P1	0.743	> 0.3	> 0.6	Good
P2	0.731	> 0.3	> 0.6	Good
P3	0.663	> 0.3	> 0.6	Good
Lean =~				
Standardization	0.680	> 0.3	> 0.6	Good
Built-in Quality	0.660	> 0.3	> 0.6	Good
Just-in-time	0.454	> 0.3	> 0.6	Acceptable

To evaluate the relationships among “lean,” “culture” and “performance” and the mediating effect of “culture” in SEM, the standard errors of the parameter estimates were re-estimated using one thousand nonparametric bootstrap samples according to Hayes’s (2009) suggestion. Table 4-13 shows the summary of the regression coefficients, direct, and indirect effects with 95% confidence intervals (CI).

Table 4-13 Summary of Parameter Estimates with 95% CI for TPS-TW Structural Model

	Estimate	**Std.Err**	**z-value**	**P (> |z|)**	**ci.lower**	**ci.upper**
Culture ~						
Lean	0.419	0.096	4.380	0.000	0.259	0.643
Performance ~						
Lean	0.634	0.118	5.386	0.000	0.434	0.889
Culture	0.708	0.091	7.788	0.000	0.548	0.901
Indirect	0.297	0.059	5.031	0.000	0.197	0.431
Direct	0.634	0.118	5.389	0.000	0.434	0.889
Total	0.931	0.143	6.486	0.000	0.696	1.264

The result shows all the coefficients are significant and the 95% bootstrap confidence interval of indirect effect does not include the value of 0, thus the conclusion that the indirect mediating effect exists with 95% confidence can be drawn. Figure 4-5 shows a simplified diagram with the relationships among latent variables indicating direct and indirect effects of “culture” serving as a mediator variable between “lean” and “performance.”

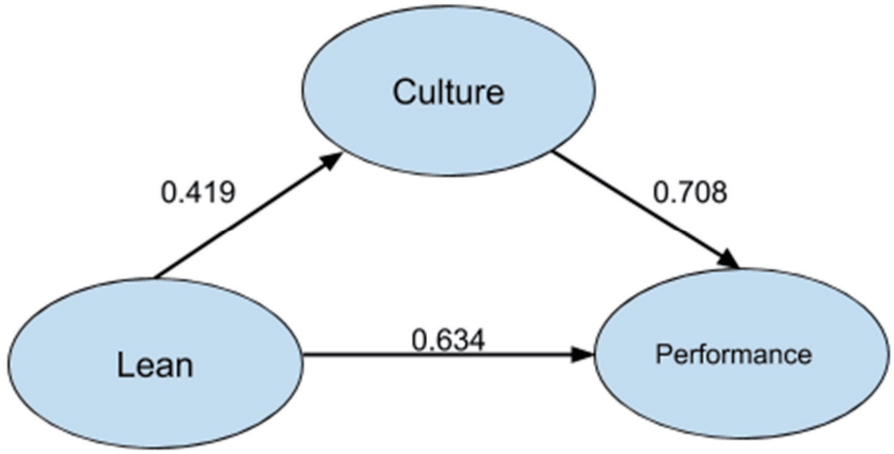

Figure 4-5 Simplified Diagram for Effects Among Latent Variables

The direct effect of “lean” on “performance” is 0.634 while the indirect effect of “lean” on “performance” via the mediator of “culture” is 0.419 * 0.708 = 0.297. The total effect between “lean” and “results” is the sum of the direct and indirect effects, which is 0.634 + 0.297 = 0.931. The proportion of the total effect that is mediated is 0.297 / 0.931 = 31.9%. The results indicate the association between “lean” and “performance” is partially accounted for by the mediator “culture.” In other words, in the Chinese auto manufacturing sector, Lean activities influence the Lean culture, which in turn influences the operational performance, rather than only directly influence the performance. The conclusion is consistent with the results of Loyd’s (2017) study in the US.

A multigroup analysis using global estimation was used to test the influence of country on the relationships among “lean,” “performance” and “culture” in SEM comparing to Loyd’s (2017) data (n = 349). A dichotomous variable “country” (US = 0 and China = 1) was introduced as a group indicator of data. For all the tests in the multigroup analysis phase, the DWLS parameter estimation method was utilized to estimate the parameters by one thousand nonparametric bootstrap samples. The Chi-Square per degree of freedom, RMSEA, SRMR, NFI, CFI, TLI, and

AGFI, were calculated as fit indices in an R environment using the Lavaan package. First, a free structural TPS-TW model in which all parameters were allowed to be different between two groups, was compared to a constrained structural TPS-TW model in which all parameters were fixed across two groups. The result of Chi-Square difference test indicated that the free and constrained models were significantly different ($p < 0.05$). In other words, some paths vary between the two groups of data. The second step was to sequentially relax and constrain paths. A single constraint of the path from "lean" directly to "performance" was introduced by fixing the coefficient between the two groups and re-fitting the model. The single constraint model was compared to the free model by a Chi-Square difference test. The 0.428 P-value indicated that the two models were not significantly different, hence the single constrained model was equivalent to the free model. Third, the previous analysis procedure was repeated with the second path, from "lean" to "culture" fixed. The result of Chi-Square difference test between the free model and the new single constrained model indicated that the two models were significantly different ($p < 0.05$), implying that the path between "lean" to "culture" should not be constrained. Fourth, the same analysis was repeated with the last path, from "culture" to "performance" fixed. The result indicated that the third constrained model was significantly different from the free model fitted previously ($p < 0.05$), implying that the path between "culture" to "performance" should be left to vary between groups. Finally, the first single constrained model, in which "lean" to "performance" was constrained, and "lean" to "culture" and "culture" to "performance" were allowed to vary between groups, was selected as the final model to analyze the influence of country on the relationships among "lean," "performance," and "culture." The above multigroup analysis details in SEM can be found in Appendix-G. Table 4-14 shows the summary of the first single constrained model's various fit indices compared to their respective acceptable criterion. The model showed evidence of good fit.

Table 4-14 Final Model's Fit Indices Compared to Acceptance Criterion

Fit Index	Value	Acceptable Fit	Good Fit	Status
Chi-Square	885.45			
Chi-Square/df	1.108	< 3	< 2	Good
RMSEA	0.017	< 0.08	< 0.06	Good
SRMR	0.052	< 0.1	< 0.08	Good
NFI	0.979	> 0.9	> 0.95	Good
CFI	0.998	> 0.9	> 0.95	Good
TLI	0.998	> 0.9	> 0.95	Good
AGFI	0.997	> 0.9	> 0.95	Good

To assess the influence of "country" in the multigroup analysis, the standard errors of the parameter estimates were re-estimated using one thousand nonparametric bootstrap samples in R. Table 4-15 shows the summary of the regression coefficients and the differences of direct/indirect effects with 95% confidence intervals.

For the final model, all of the regression coefficients were statistically significant ($p < 0.05$). Thus, the mediated models showing effects for US and China were portrayed in Figure 4-6.

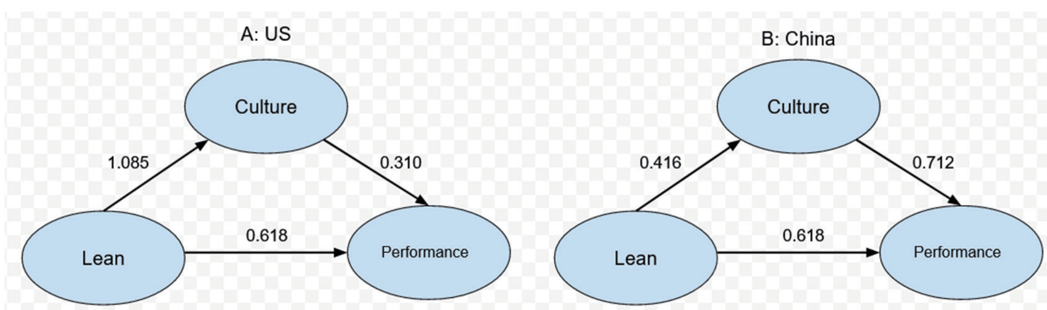

Figure 4-6 Simplified Mediated Models for US and China

Table 4-15 Summary of Parameter Estimates with 95% CI for Final Model

	Estimate	Std.Err	z-value	P (> |z|)	ci.lower	ci.upper
Group US:						
Culture ~						
Lean	1.085	0.097	11.139	0.000	0.920	1.299
Performance ~						
Lean	0.618	0.098	6.289	0.000	0.448	0.843
Culture	0.310	0.098	3.162	0.002	0.106	0.505
Group China:						
Culture ~						
Lean	0.416	0.091	4.560	0.000	0.263	0.615
Performance ~						
Lean	0.618	0.098	6.289	0.000	0.448	0.843
Culture	0.712	0.087	8.204	0.000	0.554	0.906
Lean_Culture.diff	-0.669	0.134	-5.004	0.000	-0.919	-0.415
Culture_Pfm.diff	0.402	0.124	3.240	0.001	0.176	0.659
Indirect.diff	-0.040	0.136	-0.294	0.769	-0.308	0.257

The path coefficients of the direct effects for US and China were fixed to 0.618. It could be concluded that there was no significant difference of the direct effect from “lean” to “performance” for the US and China. For the path from “lean” to “culture,” the effect was stronger for the US than for China (1.085 - 0.416 = 0.669, $p < 0.05$), whereas for the path from “culture” to “performance,” the effect was stronger for China than for the US (0.712 - 0.310 = 0.402, $p < 0.05$). The indirect effect for the US equaled to the product of 1.085 * 0.310 = 0.336. As for China, the indirect effect equaled to the product of 0.416 * 0.712 = 0.296. When the effects from “lean” to "culture" and from "culture" to "performance" multiplied, the two effects offset and did not produce a significant difference in the indirect effect for the US and China (0.336 - 0.296 = 0.040, p = 0.769, 95% CI = [-0.308 to 0.257]). Thus, there was also no significant difference in the total effect which was the sum of the direct and indirect effects for the US and China. It appears that the difference of culture in manufacturing organizations between the US and China does not impact them with achieving Lean performance.

4.3 Objective 3: Comparison of Conceptions on Lean between Frontline and Non-Frontline Employees

For the final research objective, the survey responses to the constructs of standardization and stability, built-in quality, just-in-time, and culture were depicted respectively in the divergent stacked bar charts to compare non-frontline employees consisting of supervisor, management, administration, quality, engineering, and finance functions with frontline workers in the perception of Lean for each of the six plants in the Chinese automobile manufacturing sector. Figure 4-7 through 4-10 illustrate the survey responses of frontline and non-frontline employees in six plants to each survey construct. The survey responses were associated with the average of actual performance metrics in terms of "process downtime %", "first-pass-yield %", and "on-time delivery %" over recent three years in the six plants. Since the three years of performance metrics are not enough to rank plants statistically by repeated measures ANOVA, the findings in this section are only conjectures.

For the standardization and stability construct, the survey responses showed the frontline workers had lower average agreement level of standardization in 6 of 6 plants. In Plant 2, the frontline workers had higher positive attitudes (somewhat agree, agree, and strongly agree) than the non-frontline employees. This may be due to size (51-100) and product as engine parts production tends to have the highest specifications. According to the result of Mann-Whitney U test, which can be found in Table 4-16, the differences were statistically significant in Plants 3, 5, and 6 ($p < 0.05$). And their recorded standardization performances were also lower. This may imply that the larger the difference of perception between frontline and non-frontline employees, the worse the plant performs in standardization.

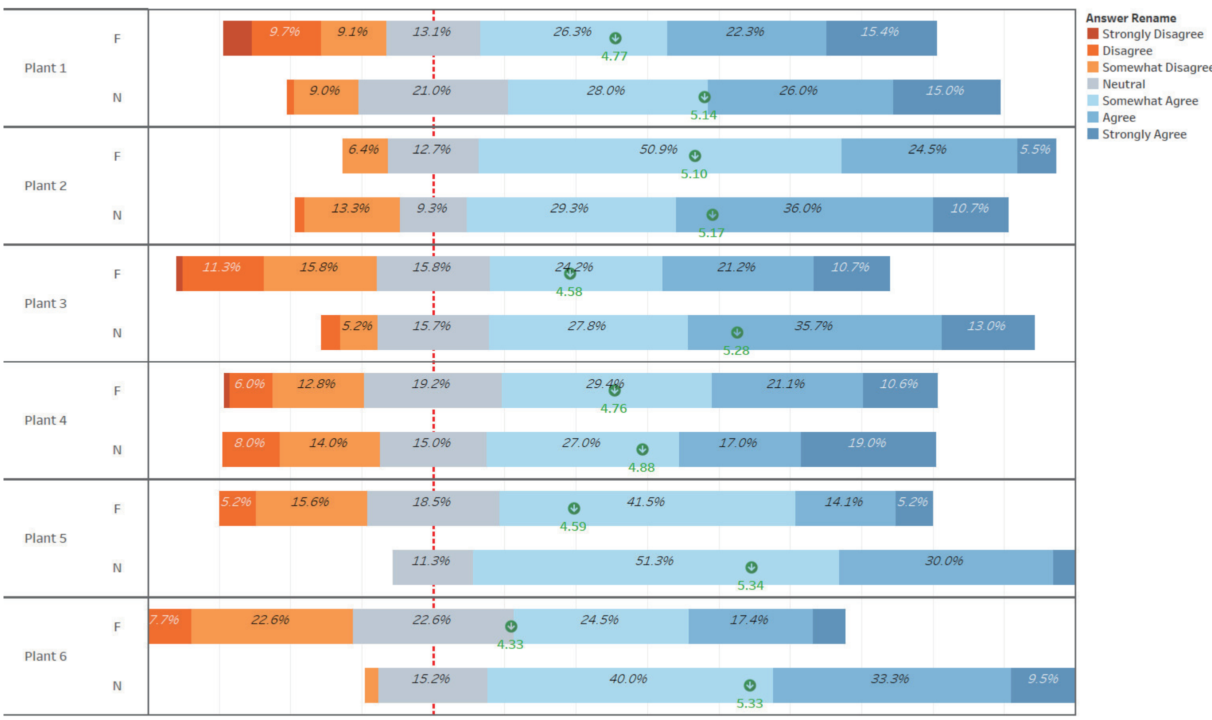

Figure 4-7 Survey Responses of Frontline and Non-Frontline Employees (Standardization)

Table 4-16 Test Statistics of Mann-Whitney U Test for Standardization

	Plant1	Plant2	Plant3	Plant4	Plant5	Plant6
Mann-Whitney U	311.000	141.500	513.500	507.000	105.000	158.500
Wilcoxon W	941.000	394.500	2791.500	1938.000	483.000	654.500
Z	-.684	-.729	-2.388	-.285	-2.801	-3.122
Asymp. Sig. (2-tailed)	.494	.466	.017	.775	.005	.002

For the built-in quality construct, the survey responses showed the frontline workers had lower average agreement level of built-in quality in 5 of 6 plants. In Plant 2, the frontline workers have higher agreement level than the non-frontline employees. This may be due to size (51-100) and product as engine parts production tends to have the highest specifications and quality requirements. According to the result of Mann-Whitney U test, which can be found in Table 4-17, the difference was statistically significant in Plant 3 ($p < 0.05$). Plant 3 (axle) had the biggest differences in both standardization and built-in quality between non-frontline and frontline employees. As the researcher observed, the automation level was lower, and the work duty was heavier in Plant 3. These may cause the frontline operators have the significant lower agreement levels of standardization and quality. We also found that Plant 4 had the second largest difference ($p = 0.141$, not significant when $a = 0.05$ though), and their recorded quality performances were also the worst. This may imply that the larger the difference of perception between frontline and non-frontline employees, the worse the plant performs in built-in quality.

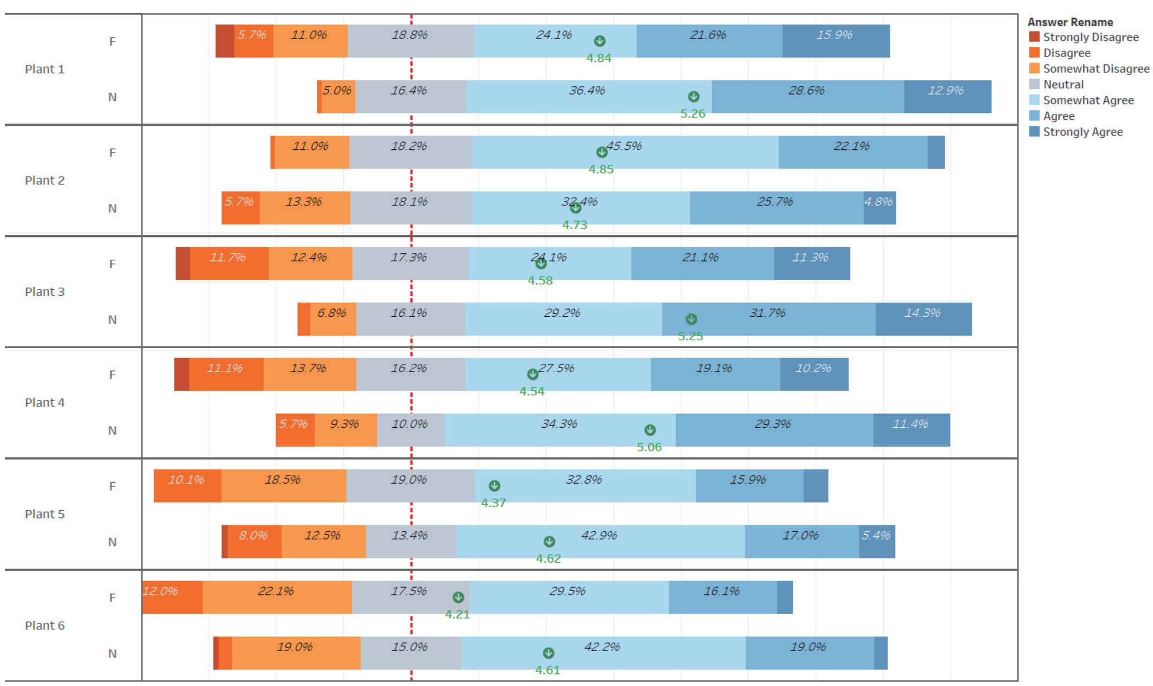

Figure 4-8 Survey Responses of Frontline and Non-Frontline Employees (Built-in Quality)

Table 4-17 Test Statistics of Mann-Whitney U Test for Built-in Quality

	Plant1	Plant2	Plant3	Plant4	Plant5	Plant6
Mann-Whitney U	299.500	161.500	524.500	411.000	182.000	268.500
Wilcoxon W	929.500	281.500	2802.500	1842.000	560.000	764.500
Z	-.885	-.109	-2.278	-1.474	-.856	-1.065
Asymp. Sig. (2-tailed)	.376	.913	.023	.141	.392	.287

For the just-in-time construct, the survey responses showed the frontline workers had lower average agreement level of JIT in 5 of 6 plants. In Plant 2, the frontline workers had higher agreement level than the non-frontline employees. This may be due to size (51-100) and product as engine parts production tends to have the highest specifications and quality. According to the result of Mann-Whitney U test which is shown in Table 4-18, the difference was statistically significant in Plant 6 ($p < 0.05$). Plant 5 had the second largest difference ($p = 0.089$, not significant when a = 0.05 though). But their recorded JIT performances were both higher than average. It seems that the difference of perception on JIT between frontline and non-frontline does not influence on-time delivery. This may be due to that the selected quantifiable metric "on-time delivery" does not reflect the entire JIT performance. Overproduction can result in a good "on-time delivery", however, it is not in accordance with JIT.

Table 4-18 Test Statistics of Mann-Whitney U Test for Just-in-time

	Plant1	Plant2	Plant3	Plant4	Plant5	Plant6
Mann-Whitney U	329.500	146.500	708.500	469.500	148.500	143.000
Wilcoxon W	959.500	266.500	2986.500	1900.500	526.500	639.000
Z	-.359	-.575	-.575	-.749	-1.701	-3.416
Asymp. Sig. (2-tailed)	.719	.566	.566	.454	.089	.001

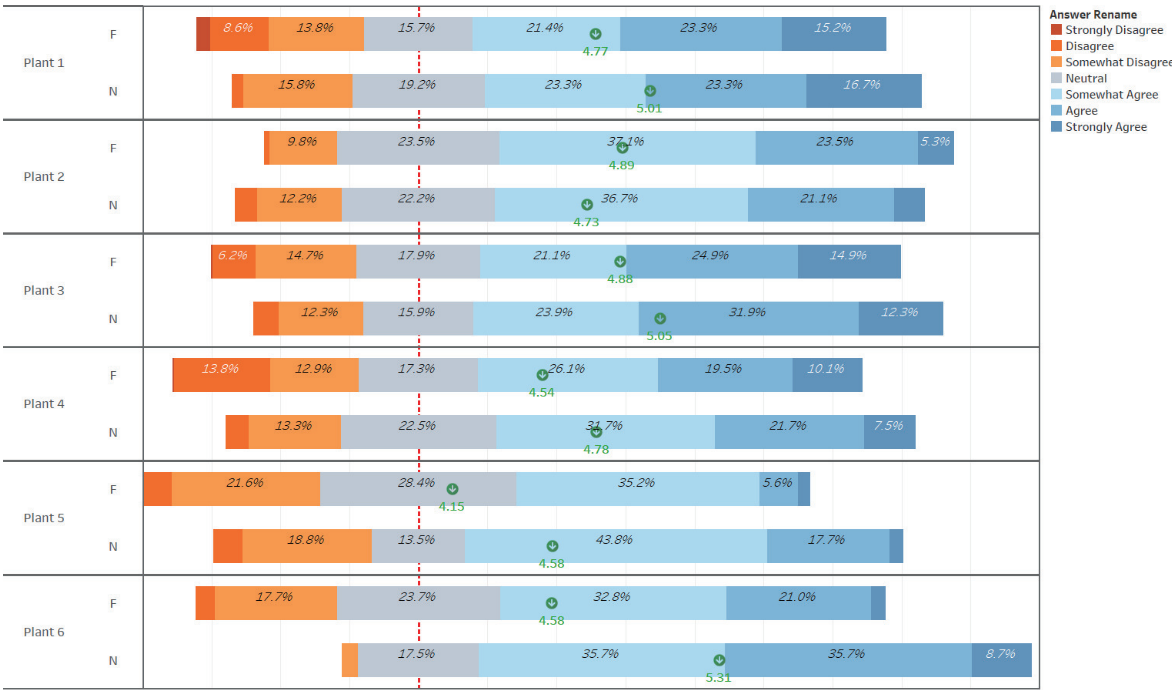

Figure 4-9 Survey Responses of Frontline and Non-Frontline Employees (Just-in-time)

For the last construct, culture, the survey responses showed the frontline workers had lower average agreement level of culture in 6 of 6 plants. In Plant 2, the frontline workers had the closest agreement level between frontline and non-frontline than other plants, this may be due to its smallest size (51-100). According to the result of Mann-Whitney U test shown in Table 4-19, the differences are statistically significant in Plants 3 and 4 ($p < 0.05$). Plants 3 and 4 also had the worst recorded performances in all the aspects (Plant 4 did not exhibit Lean behaviors). This seems to imply that the larger the difference of perception between frontline and non-frontline employees on culture, the worse the plant achieves its Lean objectives.

We found that Plants 1 and 2 did not have statistically significant differences between frontline and non-frontline employees in every aspect. They also had the relatively small company sizes and a long history of Lean adoption. (Plant 1: 101 – 200, 16 years; Plant 2: 51 -100, 13 years).

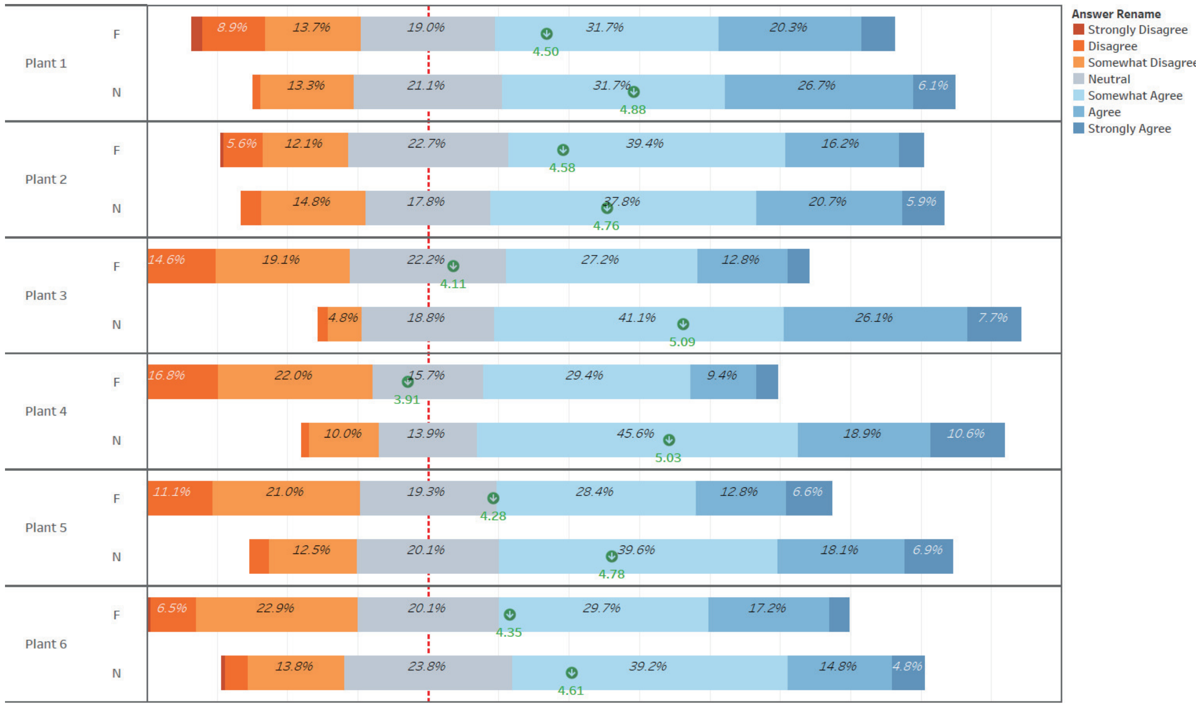

Figure 4-10 Survey Responses of Frontline and Non-Frontline Employees (Culture)

Table 4-19 Test Statistics of Mann-Whitney U Test for Culture

	Plant1	Plant2	Plant3	Plant4	Plant5	Plant6
Mann-Whitney U	287.500	140.000	343.000	255.500	161.500	263.000
Wilcoxon W	917.500	393.000	2621.000	1686.500	539.500	759.000
Z	-1.095	-.776	-3.958	-3.400	-1.371	-1.167
Asymp. Sig. (2-tailed)	.273	.438	.000	.001	.170	.243

Chapter 5 Discussion

5.1 Conclusions

The objectives of this research were to develop and validate a survey instrument using employee perception based on the TPS-TW model, investigate the effect of the TW culture on Lean implementation and operational performance in the Chinese auto manufacturing industry, compare the effects of the supportive culture on Lean implementation in companies in the US and China, and compare between management and frontline employees in the perception of Lean in Chinese automotive plants. The assessment tool based on the TPS-TW model was developed through a pilot study and feedback from a panel of SMEs and translated from English to Simplified Chinese. Three quantifiable metrics, "process downtime %," "first-pass-yield," and "on-time delivery," were added to the survey to represent Lean performance for validation. The panel of SMEs reached a consensus on the finalized questionnaire that provided strong evidence of face validity. The improved assessment instrument passed all statistical requirements for reliability and construct validity in the CFA.

The most recent three years of actual performance metrics were obtained to compare with the results of the survey. The results of Kendall's Tau test indicate positive correlations between the survey results and the actual performance. However, the estimators of Tau coefficient were not significant at a 95% CI level due to the insufficient sample size in this research. Meanwhile, the three years of performance metrics are not enough to rank plants statistically by repeated measures ANOVA. Conducting the same research in more than 10 plants and obtaining more than 7 years of actual performance metrics are needed for future study to establish robust criterion-related validity statistically.

Beyond the validated Lean assessment tool based on employee perception, the effect of a supportive culture on Lean implementation and operational performance was studied. Study of the TPS-TW structural model in SEM provided strong evidence that the Toyota Way culture is related to the Lean production system and has a positive mediating effect on the relationship between Lean implementations and operational performance. Organizations that move towards a supportive Lean culture are positioned to improve performance. This finding for companies in China is consistent with Loyd's research in the US. A multigroup analysis was used to test the influence of country on the relationships among "lean," "performance," and "culture" in SEM compared to Loyd's data which was collected in the American manufacturing companies in 2016. There was no significant difference between the direct effect from "lean" to "performance" for the US and China. For the path from "lean" to "culture," the effect was stronger for the US than for China, whereas for the path from "culture" to "performance," the effect was stronger for China than for the US. When multiplied, the two effects offset and did not produce a significant difference in the indirect effect for the US and China. Thus, there was also no significant difference in the total effect which was the sum of the direct and indirect effects. It appears that the difference of culture in manufacturing organizations in the US and China does not impact them with achieving Lean objectives.

According to the comparison between management and frontline employees in the perception of Lean in six plants from the Chinese auto manufacturing sector, the frontline workers have lower average agreement level in every aspect of the survey. When the differences of perception between frontline and non-frontline employees was related to the actual performance metrics, we found that the larger the difference of perception between frontline and non-frontline employees is on standardization and built-in quality, the worse the plant performs "process downtime %" and "first-pass-yield." The difference of perception on just-in-time between frontline and non-frontline does not influence “on-time delivery.” This may be because the selected quantifiable metric, “on-time delivery,” does not encompass the entirety of JIT performance. Since the three years of performance metrics are not enough to rank plants statistically by repeated measures ANOVA, the findings in this part are only conjectures.

The plants that had significant differences of perception on culture between frontline and non-frontline employees also had the worst recorded Lean performances in all aspects. We may conjecture that the larger the difference of perception between frontline and non-frontline employees on culture, the worse the plant achieves desired performance objectives. Organizations that have less of a difference of perception on Lean implementation between management and frontline workers are positioned to exhibit better performance. This is consistent with Genchi Genbutsu, which is a principle of the Toyota Production System, suggesting managers and engineers should go and see at the actual shop floor to collect facts and data to truly understand and solve a problem.

To sum up, the following findings are revealed from the current research:

- The improved Lean assessment instrument based on the TPS-TW model passed the statistical requirements for reliability and construct validity;
- The Toyota Way culture is strongly related to the Lean production system and has a significant indirect mediating effect on the relationship of Lean implementation and desired operational performance in the Chinese auto manufacturing sector;
- It appears that the direct effect of Lean implementation on operational performance are not significantly different in manufacturing companies in the US and China.
- It appears that the effect of Lean implementation on culture is stronger for the manufacturing companies in the US than in China, whereas the effect of culture on the

desired operational performance is stronger for the companies in China than in the US. The two effects offset and does not produce a significant difference in the indirect effect for the US and China.

- It appears that the larger the difference of perception between management and frontline employees is on standardization and built-in quality, the worse the plant performs "process downtime" and "first-pass-yield."
- It appears that manufacturing organizations that have less of a difference of perception on the TW culture between management and frontline workers are positioned to exhibit better performance.

5.2 Assumptions and Limitations

5.2.1 Assumptions

Several assumptions were made in this research to support and execute various steps of the methodology. These assumptions are:

- The survey respondents answered their job role and quantifiable metrics honestly and accurately.
- The managers in the six plants provided honest and accurate values of the overall operational performance.
- The knowledge of Lean among the panel of SMEs that undertook the content validation phase represents the current state of the Lean concepts and this knowledge was conveyed in an unbiased manner.
- The use of three quantifiable metrics could provide a more robust output to study the effect of the Toyota Way culture in a Lean production system.

5.2.2 Limitations

The limitations to this research are important in understanding the constraints of the findings. These limitations are:

- Participants and plants in this research were self-selecting, since a random selection was viewed not practical.
- The quantifiable metric, "on-time delivery," does not encompass the entirety of JIT performance. Three years of performance metrics are not enough to rank plants statistically. The employee perception rankings were simply based on an unweighted scale. For the reasons above, the criterion-related validity was not fully established by statistical methods.
- Six plants and three years of performance metrics are not sufficient for a robust investigation of how the difference between management and frontline employees on perception of Lean affects operational performance.
- This research used quantifiable metrics to represent operational performance, while Loyd's study used qualitative questions. This may cause bias in the comparison of a country's influence between the US and China.
- This research was tested in relation to the Chinese auto manufacturing industry; the findings do not necessarily apply to other industries or other countries.

5.3 Recommendations for Future Research

Several areas of future related research were identified during the performance of this research or was deemed to be outside the scope of this research. Many opportunities from this research can be undertaken for future research and are listed below.

- Obtaining pre-lean operational performances and comparing to the post-lean performances of the same plants to understand the journey of Lean adoption over time.
- Using a more comprehensive quantifiable metric to replace "on-time delivery" to represent just-in-time performance, using a weighted scale based on Lean implementation and culture to rank employee perception rankings, and conducting the research in more than 10 plants to improve the fidelity of the results and verify the criterion-related validity.
- Obtaining more than 7 years of actual performance from more than 10 plants to understand how the difference of perception on Lean between management and frontline workers affects operational performances.
- Conducting research with same performance metrics in the US and China at the same time or obtaining qualitative data in China while collecting quantitative data to test the hypothesis that the difference of culture between manufacturing organizations in the US and China does not impact them with achieving Lean objectives.
- Using the survey instrument to measure progress in the implementation of Lean in multiple plants in other countries.

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APPENDIX-A

Institutional Review Board Approval Letter

Office of Research Compliance
115 Ramsay Hall, basement
Auburn University, AL 36849

Telephone: 334-844-5966
Fax: 334-844-4391
IRBadmin@auburn.edu
IRBsubmit@auburn.edu

November 13, 2018

MEMORANDUM TO: Mr. Zhengyin Huang
Department of Industrial & Systems Engineering

PROTOCOL TITLE: "Study of The Use of Employee Perception to Assess the Implementation of Lean Based On the Toyota Production System and Toyota Way"

IRB AUTHORIZATION NO: 18-372 EP 1810
APPROVAL DATE: October 22, 2018
EXPIRATION DATE: October 21, 2019

The referenced protocol was approved as "Expedited" by the IRB under Sections 45 CFR 46.110 (6,7) of the Code of Federal Regulations (http://www.hhs.gov/ohrp/humansubjects/guidance/45cfr46.html)

When you accepted this approval, you agreed to the following:

1. **Changes to your protocol** *must* be approved in advance by submitting a modification request to the IRB. The use of any unauthorized procedures may result in penalties.
2. **Unanticipated problems** involving risk to participants *must* be reported *immediately* to the IRB.
3. A **renewal request** *mus*t be submitted three weeks before your protocol expires.
4. A **final report** *must* be submitted when you complete your study, along with copies of any consents used.
5. **Expiration –** If you allow your protocol to expire without contacting the IRB, it will be administratively closed. The project will be suspended. You will then need to submit a new protocol to resume your research.
6. You must **use only the approved, stamped version** of your **information letter.** A copy must be given to participants.

Per memo dated 5/9/2017 from Howard Gobstein, Executive Vice President, Association of Public & Land-Grant Universities, APLU activities will follow the approved AU IRB protocol.

All forms can be found at http://www.auburn.edu/research/vpr/ohs/index.htm. Questions concerning this Board action may be directed to the Office of Research Compliance

If you have any questions concerning this Board action, please contact the Office of Research Compliance.

Sincerely,

Bernie R. Olin, Phar. D.
Chair of Institutional Review Board #2
for the Use of Human Subjects in Research

cc: file

APPENDIX-B

Summary of Wording Adjustments of Survey Items

S1
Before: My company has a system for workplace organization.
After: My company has a well-defined system for workplace organization.

S3
Before: A specific training method is used to introduce, progress and cross-train employees on their jobs.
After: A specific training method is used to introduce, progress and train employees on their jobs.

S4
Before: Normal operating conditions - such as production status, tool and material locations, and equipment status are visually obvious.
After: In my workspace, normal operating conditions - such as production status, tool and material locations, and equipment status are visually obvious.

S5
Before: My company has a system to measure process downtime.
After: My company has a well-defined system to measure process downtime.

Q1
Before: My company has processes and procedures to identify defects as they happen at the process.
After: My company has well-defined processes and procedures to identify defects as they happen at the process.

Q2
Before: Defect rates are measured at my process.
After: Defect rates are accurately measured at my process.

Q4
Before: When mistakes or defects happen, there is a system to provide feedback to the source of the mistake.
After: When mistakes or defects happen, there is a well-defined system to provide feedback to the source of the mistake.

Q5
Before: Employees at my company are trained to use the scientific method to solve problems.
After: Employees at my company are trained to use a well-defined process to solve problems.

Q7
Before: Error-proofing techniques are used at my company.
After: Effective error-proofing techniques are used at my company.

J3
Before: Work in my company is balanced to meet a specific daily goal.
After: Work in my company is well balanced to meet a specific daily goal.

J4
Before: Parts are delivered to the production line in the quantity that is needed, when it is needed.
After: Parts are delivered to the production line in the quantities that are needed, when they are needed.

J5
Before: Work is scheduled visually based on the next process's needs.
After: Work is always scheduled visually based on the next process's needs.

C1
Before: I know the difference between value-added and non-value-added steps of my job.
After: I know which steps in my job are value-added or non-value-added.

C2
Before: Decisions at my company are based on facts and data.
After: Decisions at my company are always based on relevant facts and data.

C3
Before: Management at my company treats me with respect and I feel I can safely express my feelings.
After: Management at my company treats me with respect and I feel I can safely express my opinions.

C4
Before: I am aware of my company's strategic vision and mission.
After: I understand my company's strategic vision and mission.

C5
Before: My company seeks new ideas from all employees.
After: My company values ideas for improvement from all employees.

C6
Before: My company seeks to make the best of all employees' knowledge, skills, and abilities.
After: My company values knowledge, skills, and abilities from all employees.

C7
Before: Teamwork is practiced at my company; everyone is willing and expected to help out and hold each other accountable.
After: Teamwork is practiced at my company; everyone is expected and willing to help out and hold each other accountable.

C8
Before: My manager works with me to improve my process.
After: My manager actively works with me to improve my process.

C9
Before: My company provides opportunities for my growth and development.
After: My company provides good opportunities for my growth and development.

R1
Before: What is the % Process Downtime in your company?
After: What is the % Process Downtime in your workspace?

R2
Before: What is the First Pass Yield (%) in your company?
After: What is the First Pass Yield (%) in your workspace?

R3
Before: What is the On-time Delivery Rate (%) in your company?
After: What is the On-time Delivery Rate (%) in your workspace?

APPENDIX-C

Finalized TPS-TW Model-Based Survey (English Version)

AUBURN UNIVERSITY

SAMUEL GINN COLLEGE OF ENGINEERING
INDUSTRIAL AND SYSTEMS ENGINEERING

(NOTE: DO NOT AGREE TO PARTICIPATE UNLESS AN IRB APPROVAL STAMP WITH CURRENT DATES HAS BEEN APPLIED TO THIS DOCUMENT.)

INFORMATION LETTER
for a Research Study entitled
"Study of The Use of Employee Perception To Assess The Implementation of Lean Based On The Toyota Production System"

You are invited to participate in a research study to evaluate the association between employee perception and the implementation of lean based on the Toyota Production System among manufacturing industry to facilitate an improved assessment tool to empirically measure Lean implementation based on employee perception. The study is being conducted by Zhengyin Huang (doctoral student) under the supervision of Dr.Gregory Harris, Ph.D., P.E. (Associate Professor) in the Auburn University's Department of Industrial and Systems Engineering. You were selected as a possible participant because you were adult over the age of 19, the youngest legal age for human research subjects, who had worked at least 3 months for an organization that had implemented Lean for at least a year.

What will be involved if you participate? Your participation is completely voluntary. If you decide to participate in this research study, you will be asked to complete a short electronic survey. Your total time commitment will be approximately 15-20 minutes.

Are there any risks or discomforts? The risks associated with participating in this study are minimal. No identifiable data will be collected directly or indirectly in this study and all your responses will be kept strictly confidential. You may feel slightly distressed to answering some questions as you think about your working experiences. Your participation in this survey is voluntary. You may refuse to take part in the research or exit the survey at any time without penalty. You are free to decline to answer any question you do not wish to answer for any reason.

Are there any benefits to yourself or others? You will not receive any direct benefit from participating in this study. However, your responses may help us learn more about an assessment tool to empirically measure Lean implementation based on employee perception and to study the effect of culture on the ability of a Lean production system to achieve desired results.

SHELBY CENTER FOR
ENGINEERING TECHNOLOGY
SUITE 3301
AUBURN, AL 36849-5346

TELEPHONE
334-844-4340

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334-844-1381

www.auburn.edu

AUBURN UNIVERSITY

SAMUEL GINN COLLEGE OF ENGINEERING
INDUSTRIAL AND SYSTEMS ENGINEERING

Will you receive compensation for participating? No compensation will be provided for your participation.

Are there any costs? There are no costs (e.g., fees) associated with participation. If you choose not to participate, your decision will not affect your relationship with Auburn University, the Department of Industrial and Systems Engineering or the researcher.

No identifiable data will be collected directly or indirectly in this study and any data obtained in connection with this study will be kept strictly confidential. Information collected through your participation may be used to fulfill an educational requirement, published in a professional journal, or presented at a professional meeting, etc.

If you have questions about this study, please contact Zhengyin Huang at zzh0014@auburn.edu or Dr. Gregory Harris, Ph.D., P.E. at greg.harris@auburn.edu.

If you have questions about your rights as a research participant, you may contact the Auburn University Office of Research Compliance or the Institutional Review Board by phone (334)-844-5966 or e-mail at IRBadmin@auburn.edu or IRBChair@auburn.edu.

HAVING READ THE INFORMATION PROVIDED, YOU MUST DECIDE WHETHER OR NOT YOU WISH TO PARTICIPATE IN THIS RESEARCH STUDY. BY CLICKING NEXT TO CONTINUE TO THE SURVEY, YOU ARE INDICATING YOU HAVE READ THE INFORMATION LETTER AND ARE WILLING TO PARTICIPATE.

The Auburn University Institutional Review Board has approved this document for use from _________ to ________. Protocol #_______.

Shelby Center for Engineering Technology
Suite 3301
Auburn, AL 36849-5346

Telephone
334-844-4340

Fax:
334-844-1381

www.auburn.edu

D1. How many years have your worked for your current company?

D2. What is your age?

[ ]

D3. What is your job responsibility?

- ○ Front line
- ○ Team leader/Supervisor
- ○ Management
- ○ Administration
- ○ Quality
- ○ Engineering
- ○ Finance

D4. Company size (total employees at the site you work at)

0-10	11-50	51-100	101-200	201-300	301-500	Over 500
○	○	○	○	○	○	○

S1. My company has a well-defined system for workplace organization.

○ Strongly disagree ○ Disagree ○ Somewhat disagree ○ Neither agree nor disagree ○ Somewhat agree ○ Agree ○ Strongly agree

○ I don't understand this question

S2.

The best way to do my job is clearly defined and standardized.

○ Strongly disagree ○ Disagree ○ Somewhat disagree ○ Neither agree nor disagree ○ Somewhat agree ○ Agree ○ Strongly agree

○ I don't understand this question

S3.

A specific training method is used to introduce, progress and train employees on their jobs.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't understand this question

S4.
In my workspace, normal operating conditions - such as production status, tool and material locations, and equipment status are visually obvious.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't understand this question

S5.
My company has a well-defined system to measure process downtime.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't know what the process downtime means

Q1. My company has well-defined processes and procedures to identify defects as they happen at the process.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't understand this question

Q2. Defect rates are accurately measured at my process.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor
- Somewhat agree
- Agree
- Strongly agree

disagree

- I don't know what the defect rates means

Q3. My company seeks to fix problems at the root cause level.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't know what the root cause level is

Q4. When mistakes or defects happen, there is a well-defined system to provide feedback to the source of the mistake.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't understand this question

Q5. Employees at my company are trained to use a well-defined process to solve problems.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't understand this question

Q6. My company views problems as opportunities and we stop and learn from them.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't understand

this question

Q7. Effective error-proofing techniques are used at my company.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't know what the error-proofing techniques are

J1. My company seeks to eliminate or reduce batching and work-in-process inventory (WIP)

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't know what the WIP is

J2. Our facility layout allows for work to flow easily from process to process.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't understand this question

J3. Work in my company is well balanced to meet a specific daily goal.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't understand this question

J4. Parts are delivered to the production line in the quantities that are needed, when they are needed.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't understand this question

J5. Work is always scheduled visually based on the next process's needs.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't understand this question

J6. My company aggressively seeks to reduce inventory.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't understand this question

C1. I know which steps in my job are value-added or non-value-added.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't know what the value-added and non-value-added are

C2. Decisions at my company are always based on relevant facts and data.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't understand

this question

C3. Management at my company treats me with respect and I feel I can safely express my opinions.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't understand this question

C4. I understand my company's strategic vision and mission.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't know what the strategic vision and mission are

C5. My company values ideas for improvement from all employees.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't understand this question

C6. My company values knowledge, skills, and abilities from all employees.

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Agree
- Strongly agree
- I don't understand this question

C7. Teamwork is practiced at my company; everyone is expected and willing to help out and hold each other accountable.

- ○ Strongly disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree
- ○ I don't understand this question

C8. My manager actively works with me to improve my process.

- ○ Strongly disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree
- ○ I don't understand this question

C9. My company provides good opportunities for my growth and development.

- ○ Strongly disagree
- ○ Disagree
- ○ Somewhat disagree
- ○ Neither agree nor disagree
- ○ Somewhat agree
- ○ Agree
- ○ Strongly agree
- ○ I don't understand this question

R1. What is the % Process Downtime in your workspace?

- ○ Value: ____________
- ○ I don't know what the indicator means
- ○ I don't know the value of the indicator

R2. What is the First Pass Yield (%) in your workspace?

- ○ Value: ____________
- ○ I don't know what the indicator means
- ○ I don't know the value of the indicator

R3. What is the On-time Delivery Rate (%) in your workspace?

- Value: ______
- I don't know what the indicator means
- I don't know the value of the indicator

APPENDIX-D

Finalized TPS-TW Model-Based Survey (Chinese Version)

背景信息

1. 你是否满 18 岁了？
☐是　　☐否

2. 请问你在现公司工作多少时间了？ ______年______月

3. 你今年多大了？ ______岁

4. 你的工作岗位是什么？
☐生产工人 ☐班长 ☐管理人员 ☐行政 ☐质量保证 ☐生产制造技术 ☐财务

5. 你所在的公司规模有多大？
☐0-10 人 ☐11-50 人 ☐51-100 人 ☐101-200 人 ☐201-300 人 ☐301-500 人 ☐500 人以上

标准化

1. 公司有完善的生产系统来进行生产组织
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

2. 本岗位的最佳作业方法被清楚明确的定义出来形成标准作业
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

3. 我受过专门的培训来帮助我上岗、熟悉并掌握作业内容
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

4. 在我的工作岗位上，日常的运行状况（生产状况、工具及材料位置、设备运转情况等）都可以做到目视化并清楚的展示出来
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

5. 公司有完善的系统来测量停工时间
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不知道什么是停工时间

制造质量

1. 公司有完善的质量控制流程，在质量问题发生时就能及时发现
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

2. 能够在日常准确的监测不良率（Defect Rate）
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不知道什么是不良率

3. 公司努力在根源上解决问题
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

4. 当故障或质量问题发生时，公司能完善的向问题的源头进行反馈
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

5. 公司对员工进行了问题处置的针对性培训，用完善的方法来解决问题
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

6. 公司把解决问题或故障看作是学习和提升管理的机会
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

7. 公司有效的应用了防错技术
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不知道什么是防错技术

准时化生产

1. 公司努力消除或降低批量库存和在制品（Work-In-Process）
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不指导什么是在制品

2. 现场作业布局足够便利，让工序到工序之间的作业流很顺畅
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

3. 生产任务足够均衡来完成每天的产量要求
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

4. 零部件只在被需要的时候，以正确的数量被投送到生产线
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

5. 本工序的任务量总能够基于下道工序的需求并目视化传递给我
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

6. 公司努力减少库存
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

企业文化

1． 我知道自己工作中的哪些步骤属于无附加价值作业，哪些属于有附加价值作业
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不知道什么是附加价值

2． 公司的决策能够基于相关的事实和数据
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

3． 公司的管理能够尊重我，并且我能不用顾虑的表达我自己的意见
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

4． 我充分了解公司的战略愿景和目标
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不知道什么是战略愿景

5． 公司重视所有员工的意见
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

6． 公司重视所有员工的知识、技能和能力
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

7． 公司的团队合作氛围很好，每个员工都期待并愿意帮助别人和承担责任
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

8． 我的领导能够积极的与我一起改善我的工序
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

9． 公司能够提供好的机会来帮助我成长提升
☐非常不同意 ☐不同意 ☐比较不同意 ☐说不准 ☐比较同意 ☐同意 ☐非常同意
☐我不懂题目的意思

精益指标

1. 你所在岗位的停工等待时间比率（% Process Downtime）是多少？
停工等待时间比率：________%
☐我不知道什么是停工等待时间
☐我不知道具体的数值

2. 你所在岗位的一次交检合格率（First Pass Yield）是多少？
一次交检合格率：__________%
☐我不知道什么是一次交检合格率
☐我不知道具体的数值

3. 你所在岗位的准时交付率（On-Time Delivery Rate）是多少？
准时交付率：________%
☐我不知道什么是准时交付率
☐我不知道具体的数值

APPENDIX-E

Institutional Review Board Stamped Request for Modification

AUBURN UNIVERSITY INSTITUTIONAL REVIEW BOARD for RESEARCH INVOLVING HUMAN SUBJECTS

REQUEST for MODIFICATION

For help, contact: **THE OFFICE OF RESEARCH COMPLIANCE (ORC)**, 115 Ramsay Hall, Auburn University
Phone: 334-844-5966 **e-mail:** IRBAdmin@auburn.edu **Web Address:** http://www.auburn.edu/research/vpr/ohs

Revised 2.1.2014 **Submit completed form to IRBsubmit@auburn.edu or 115 Ramsay Hall, Auburn University 36849.**

Form must be populated using Adobe Acrobat / Pro 9 or greater standalone program (do not fill out in browser). Hand written forms will not be accepted.

1. **Protocol Number:** 18-372-EP 1018
2. **Current IRB Approval Dates: From:** 10/22/2018 **To:** 10/21/2019
3. **Project Title:** Study of The Use of Employee Perception To Assess The Implementation of Lean Based On The Toyota Production System and Toyota Way
4. Zhengyin Huang | Graduate | INSY | 334-329-3270 | zzh0014@auburn.edu

Principal Investigator | **Title** | **Department** | **Phone** | **AU E-Mail** (primary)

Zhengyin Huang (Digitally signed by Zhengyin Huang DN: cn=Zhengyin Huang, o=Auburn University, ou=Industrial and Systems Engineering Department, email=zzh0014@auburn.edu, c=US Date: 2018.11.30 14:25:11 -06'00') | 3321 Shelby, Auburn University, AL | huangzhengyin@gmail.com

PI Signature | **Mailing Address** | **Alternate E-Mail**

Gregory A. Harris | Gregory A. Harris, Ph.D., P.E. (Digitally signed by Gregory A. Harris, Ph.D., P.E. Date: 2018.11.30 15:10:32 -06'00') | INSY | 334-844-1407 | greg.harris@auburn.edu

Faculty Advisor | **FA Signature** | **Department** | **Phone** | **AU E-Mail**

Name of Current Department Head: John Evans **AU E-Mail:** evansjl@auburn.edu

5. **Current External Funding Agency and Grant number:** n/a
6. **a. List any contractors, sub-contractors, other entities associated with this project:**

   n/a

   b. List any other IRBs associated with this project: n/a

7. **Nature of change in protocol: (Mark all that apply)**

- ☐ **Change in Key Personnel** (attach CITI forms for new personnel)
- ☐ **Change in Sites** (attach permission forms for new sites)
- ☐ **Change in methods for data storage/protection or location of data/consent documents**
- ☐ **Change in project purpose or questions**
- ☐ **Change in population or recruitment** (attach new or revised recruitment materials as needed)
- ☐ **Change in consent procedures** (attach new or revised consent documents as needed)
- ☐ **Change in data collection methods or procedures** (attach new data collection forms as needed)
- ☑ **Other (explain):** Question and options added, and wording changes in the content of a previously IRB-approved questionnaire

FOR ORC OFFICE USE ONLY

DATE RECEIVED IN ORC:________ by________ MODIFICATION # ________

DATE OF IRB REVIEW:________ by________ PROTOCOL APPROVAL CATEGORY:________

DATE OF IRB APPROVAL:________ by________ MODIFICATION APPROVAL CATEGORY:________

INTERVAL FOR CONTINUING REVIEW:________

COMMENTS:

The Auburn University Institutional Review Board has approved this Document for use from 12/04/2018 to 10/21/2019 Protocol # 18-372 EP 1018

APPENDIX-F

Actual Lean Performance Metrics of the Six Plants (2016-2018)

Plant 1 Product: Sedan Assembly Employees: 101 - 200 Lean Implementation Years: 16		**2016**	**2017**	**2018**	**Average**
	Downtime %	3.70%	3.60%	3.20%	3.50%
	First Pass Yield %	96.80%	97.50%	97.80%	97.37%
	On-time Delivery %	94.50%	95.00%	95.50%	95.00%
Plant 2 Product: Engine Parts Employees: 51-100 Lean Implementation Years: 13					
	Downtime %	4.95%	4.67%	4.30%	4.64%
	First Pass Yield %	96.32%	96.50%	96.65%	96.49%
	On-time Delivery %	96.61%	98.10%	97.85%	97.52%
Plant 3 Product: Axle Employees: 201 - 300 Lean Implementation Years: 9					
	Downtime %	5.80%	5.20%	4.90%	5.30%
	First Pass Yield %	93.80%	95.00%	95.60%	94.80%
	On-time Delivery %	93.20%	93.60%	94.40%	93.73%
Plant 4 Product: Truck Assembly Employees: 201 - 300 Lean Implementation Years: 10					
	Downtime %	3.40%	3.20%	3.10%	3.23%
	First Pass Yield %	92.60%	94.30%	95.00%	93.97%
	On-time Delivery %	91.50%	92.50%	94.00%	92.67%
Plant 5 Product: Seat Employees: 101 - 200 Lean Implementation Years: 7					
	Downtime %	4.80%	4.70%	4.50%	4.67%
	First Pass Yield %	94.50%	95.00%	95.50%	95.00%
	On-time Delivery %	96.80%	97.00%	97.10%	96.97%
Plant 6 Product: Body Employees: 101 - 200 Lean Implementation Years: 10					
	Downtime %	5.67%	5.14%	4.98%	5.26%
	First Pass Yield %	95.40%	95.60%	95.80%	95.60%
	On-time Delivery %	94.80%	96.20%	96.50%	95.83%

APPENDIX-G

Full Multigroup Analysis in Structural Equation Modeling

Full Multigroup Analysis

Zhengyin Huang

September 18, 2019

Generate the free model in which all parameters were allowed to be different between two groups.

```
#combine data from US and CN
test1 <- read_csv("C:/Users/10038/Desktop/testcombined.csv")
```

```
## Parsed with column specification:
## cols(
##   .default = col_double()
## )
```

```
## See spec(...) for full column specifications.
```

```
#set the free model
multigroup.model <- '
standardization =~ S1 + S2 + S3 + S4 + S5
quality =~ Q1 + Q2 + Q3 + Q4 + Q5 + Q6 + Q7
jit =~ J1 + J2 + J3 + J4 + J5 + J6
culture =~ C1 + C2 + C3 + C4 + C5 + C6 + C7 + C8 + C9
performance =~ R1 + R2 + R3
lean =~ standardization + quality + jit
culture ~ lean
performance ~ lean + culture
'

#model fit and parameter estimation
multigroup1 <- sem(multigroup.model, data = test1, estimator = "DWLS", group = "country")
```

```
summary(multigroup1, fit.measures = TRUE, standardized = FALSE, ci = TRUE)
```

```
## lavaan 0.6-3 ended normally after 77 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                        192
##
##   Number of observations per group
##   1                                                442
##   0                                                349
##
##   Estimator                                       DWLS
##   Model Fit Test Statistic                     884.822
##   Degrees of freedom                               798
##   P-value (Chi-square)                           0.017
##
## Chi-square for each group:
##
##   1                                            602.792
```

```
##   0                                           282.030
##
## Model test baseline model:
##
##   Minimum Function Test Statistic           41486.970
##   Degrees of freedom                              870
##   P-value                                       0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                   0.998
##   Tucker-Lewis Index (TLI)                      0.998
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                         0.017
##   90 Percent Confidence Interval          0.008  0.023
##   P-value RMSEA <= 0.05                         1.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                          0.052
##
## Parameter Estimates:
##
##   Information                                Expected
##   Information saturated (h1) model        Unstructured
##   Standard Errors                            Standard
##
##
## Group 1 [1]:
##
## Latent Variables:
##                      Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   standardization =~
##     S1                  1.000                               1.000    1.000
##     S2                  1.247    0.063   19.786    0.000    1.124    1.371
##     S3                  1.243    0.064   19.513    0.000    1.118    1.368
##     S4                  1.142    0.060   19.179    0.000    1.025    1.258
##     S5                  0.844    0.047   17.819    0.000    0.751    0.936
##   quality =~
##     Q1                  1.000                               1.000    1.000
##     Q2                  1.371    0.068   20.209    0.000    1.238    1.504
##     Q3                  1.566    0.076   20.483    0.000    1.416    1.716
##     Q4                  1.591    0.078   20.325    0.000    1.437    1.744
##     Q5                  1.722    0.084   20.528    0.000    1.558    1.887
##     Q6                  1.552    0.078   19.980    0.000    1.400    1.704
##     Q7                  1.450    0.074   19.586    0.000    1.305    1.595
##   jit =~
##     J1                  1.000                               1.000    1.000
##     J2                  0.904    0.051   17.829    0.000    0.805    1.004
##     J3                  1.251    0.066   18.991    0.000    1.122    1.380
##     J4                  1.222    0.065   18.786    0.000    1.095    1.350
##     J5                  1.151    0.062   18.598    0.000    1.030    1.272
```

```
##     J6                 0.905    0.051   17.634    0.000    0.804    1.005
##   culture =~
##     C1                 1.000                               1.000    1.000
##     C2                 1.174    0.056   21.086    0.000    1.065    1.283
##     C3                 1.214    0.058   20.982    0.000    1.101    1.328
##     C4                 1.475    0.066   22.266    0.000    1.345    1.605
##     C5                 1.678    0.074   22.719    0.000    1.533    1.822
##     C6                 1.751    0.077   22.793    0.000    1.600    1.901
##     C7                 1.776    0.078   22.874    0.000    1.624    1.929
##     C8                 1.729    0.077   22.512    0.000    1.578    1.879
##     C9                 1.282    0.061   21.140    0.000    1.163    1.401
##   performance =~
##     R1                 1.000                               1.000    1.000
##     R2                 1.030    0.043   23.748    0.000    0.945    1.115
##     R3                 0.874    0.038   22.760    0.000    0.799    0.950
##   lean =~
##     standardizatin     1.000                               1.000    1.000
##     quality            0.744    0.047   15.986    0.000    0.652    0.835
##     jit                0.673    0.043   15.546    0.000    0.588    0.758
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   culture ~
##     lean              0.419    0.027   15.434    0.000    0.366    0.473
##   performance ~
##     lean              0.634    0.049   12.804    0.000    0.537    0.731
##     culture           0.708    0.044   16.177    0.000    0.622    0.794
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                4.853    0.060   80.888    0.000    4.735    4.971
##    .S2                4.790    0.069   69.204    0.000    4.654    4.925
##    .S3                4.790    0.070   68.189    0.000    4.652    4.927
##    .S4                4.783    0.069   69.793    0.000    4.648    4.917
##    .S5                4.959    0.058   84.878    0.000    4.845    5.074
##    .Q1                5.020    0.055   92.116    0.000    4.914    5.127
##    .Q2                4.636    0.063   73.069    0.000    4.511    4.760
##    .Q3                4.672    0.067   70.187    0.000    4.541    4.802
##    .Q4                4.518    0.070   64.427    0.000    4.381    4.656
##    .Q5                4.541    0.074   61.690    0.000    4.396    4.685
##    .Q6                4.604    0.074   62.434    0.000    4.460    4.749
##    .Q7                4.502    0.072   62.584    0.000    4.361    4.643
##    .J1                4.769    0.064   75.073    0.000    4.645    4.894
##    .J2                4.597    0.062   74.688    0.000    4.477    4.718
##    .J3                4.622    0.069   67.056    0.000    4.487    4.757
##    .J4                4.654    0.071   65.491    0.000    4.515    4.793
##    .J5                4.627    0.071   65.396    0.000    4.488    4.765
##    .J6                4.844    0.063   76.749    0.000    4.720    4.968
##    .C1                4.552    0.052   87.014    0.000    4.450    4.655
##    .C2                4.563    0.058   79.091    0.000    4.450    4.676
##    .C3                4.498    0.061   74.175    0.000    4.379    4.617
##    .C4                4.446    0.064   69.947    0.000    4.321    4.570
##    .C5                4.380    0.069   63.263    0.000    4.244    4.516
##    .C6                4.428    0.073   60.955    0.000    4.285    4.570
```

```
##    .C7              4.586    0.074   61.681    0.000    4.440    4.732
##    .C8              4.480    0.074   60.558    0.000    4.335    4.625
##    .C9              4.290    0.064   67.247    0.000    4.165    4.415
##    .R1              4.428    0.054   81.567    0.000    4.321    4.534
##    .R2              4.414    0.057   77.679    0.000    4.303    4.525
##    .R3              4.600    0.053   86.568    0.000    4.495    4.704
##     standardizatin  0.000                              0.000    0.000
##     quality         0.000                              0.000    0.000
##     jit             0.000                              0.000    0.000
##    .culture         0.000                              0.000    0.000
##    .performance     0.000                              0.000    0.000
##     lean            0.000                              0.000    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                0.716    0.119    6.011    0.000    0.483    0.950
##    .S2                0.756    0.149    5.079    0.000    0.464    1.048
##    .S3                0.829    0.157    5.294    0.000    0.522    1.135
##    .S4                0.935    0.144    6.515    0.000    0.654    1.217
##    .S5                0.886    0.118    7.530    0.000    0.656    1.117
##    .Q1                0.798    0.098    8.169    0.000    0.607    0.990
##    .Q2                0.813    0.114    7.116    0.000    0.589    1.037
##    .Q3                0.697    0.133    5.254    0.000    0.437    0.957
##    .Q4                0.872    0.142    6.143    0.000    0.594    1.150
##    .Q5                0.869    0.153    5.663    0.000    0.568    1.170
##    .Q6                1.165    0.150    7.787    0.000    0.871    1.458
##    .Q7                1.205    0.147    8.209    0.000    0.918    1.493
##    .J1                0.892    0.126    7.065    0.000    0.644    1.139
##    .J2                0.945    0.110    8.555    0.000    0.729    1.162
##    .J3                0.704    0.147    4.789    0.000    0.416    0.992
##    .J4                0.900    0.143    6.296    0.000    0.620    1.180
##    .J5                1.030    0.136    7.556    0.000    0.763    1.298
##    .J6                1.030    0.122    8.458    0.000    0.792    1.269
##    .C1                0.759    0.079    9.626    0.000    0.604    0.914
##    .C2                0.850    0.098    8.718    0.000    0.659    1.041
##    .C3                0.961    0.102    9.385    0.000    0.760    1.162
##    .C4                0.806    0.122    6.627    0.000    0.567    1.044
##    .C5                0.851    0.134    6.371    0.000    0.589    1.113
##    .C6                0.951    0.144    6.613    0.000    0.669    1.233
##    .C7                1.022    0.148    6.901    0.000    0.731    1.312
##    .C8                1.072    0.140    7.640    0.000    0.797    1.348
##    .C9                1.058    0.113    9.326    0.000    0.836    1.280
##    .R1                0.584    0.103    5.688    0.000    0.383    0.785
##    .R2                0.665    0.113    5.861    0.000    0.443    0.887
##    .R3                0.698    0.095    7.336    0.000    0.512    0.885
##     standardizatin    0.470    0.046   10.274    0.000    0.380    0.559
##     quality           0.290    0.026   11.222    0.000    0.240    0.341
##     jit               0.708    0.056   12.588    0.000    0.598    0.818
##    .culture           0.379    0.026   14.455    0.000    0.328    0.430
##    .performance       0.178    0.050    3.578    0.000    0.080    0.275
##     lean              0.405    0.034   11.984    0.000    0.339    0.471
##
##
## Group 2 [0]:
```

```
##
## Latent Variables:
##                      Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   standardization =~
##     S1                  1.000                               1.000    1.000
##     S2                  1.131    0.041   27.520    0.000    1.051    1.212
##     S3                  1.183    0.043   27.779    0.000    1.099    1.266
##     S4                  1.156    0.042   27.742    0.000    1.075    1.238
##     S5                  1.077    0.042   25.413    0.000    0.994    1.160
##   quality =~
##     Q1                  1.000                               1.000    1.000
##     Q2                  1.088    0.042   25.776    0.000    1.005    1.171
##     Q3                  1.120    0.042   26.895    0.000    1.038    1.201
##     Q4                  1.099    0.041   26.985    0.000    1.020    1.179
##     Q5                  1.210    0.045   26.725    0.000    1.121    1.298
##     Q6                  1.317    0.048   27.689    0.000    1.224    1.411
##     Q7                  1.144    0.042   26.919    0.000    1.060    1.227
##   jit =~
##     J1                  1.000                               1.000    1.000
##     J2                  0.949    0.032   29.269    0.000    0.885    1.012
##     J3                  1.054    0.035   30.162    0.000    0.986    1.123
##     J4                  0.987    0.033   29.696    0.000    0.921    1.052
##     J5                  1.140    0.036   31.323    0.000    1.068    1.211
##     J6                  0.943    0.033   28.744    0.000    0.879    1.008
##   culture =~
##     C1                  1.000                               1.000    1.000
##     C2                  0.975    0.032   30.164    0.000    0.912    1.038
##     C3                  0.820    0.031   26.052    0.000    0.758    0.882
##     C4                  0.755    0.028   26.850    0.000    0.700    0.810
##     C5                  0.991    0.033   29.665    0.000    0.925    1.056
##     C6                  1.053    0.035   30.492    0.000    0.985    1.120
##     C7                  1.005    0.034   29.861    0.000    0.939    1.070
##     C8                  0.878    0.032   27.352    0.000    0.815    0.941
##     C9                  0.806    0.030   26.654    0.000    0.746    0.865
##   performance =~
##     R1                  1.000                               1.000    1.000
##     R2                  0.801    0.034   23.579    0.000    0.735    0.868
##     R3                  0.558    0.025   22.037    0.000    0.508    0.608
##   lean =~
##     standardizatin      1.000                               1.000    1.000
##     quality             1.062    0.044   24.155    0.000    0.976    1.148
##     jit                 1.164    0.044   26.376    0.000    1.077    1.250
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   culture ~
##     lean              1.080    0.042   25.813    0.000    0.998    1.162
##   performance ~
##     lean              0.536    0.111    4.821    0.000    0.318    0.754
##     culture           0.372    0.090    4.133    0.000    0.195    0.548
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                5.533    0.078   70.568    0.000    5.379    5.687
```

```
##    .S2               4.862    0.089   54.548    0.000    4.688    5.037
##    .S3               4.736    0.093   50.954    0.000    4.554    4.919
##    .S4               5.095    0.087   58.869    0.000    4.925    5.264
##    .S5               5.126    0.099   51.612    0.000    4.931    5.321
##    .Q1               5.387    0.091   59.117    0.000    5.208    5.565
##    .Q2               5.201    0.090   57.613    0.000    5.024    5.377
##    .Q3               5.347    0.082   64.960    0.000    5.185    5.508
##    .Q4               5.149    0.086   59.949    0.000    4.981    5.317
##    .Q5               4.771    0.095   50.055    0.000    4.584    4.958
##    .Q6               4.903    0.093   52.668    0.000    4.720    5.085
##    .Q7               4.722    0.088   53.626    0.000    4.549    4.895
##    .J1               4.851    0.093   52.274    0.000    4.669    5.033
##    .J2               4.788    0.090   53.194    0.000    4.612    4.964
##    .J3               4.708    0.094   50.020    0.000    4.523    4.892
##    .J4               4.556    0.093   48.817    0.000    4.373    4.739
##    .J5               4.470    0.101   44.336    0.000    4.272    4.668
##    .J6               4.716    0.099   47.517    0.000    4.522    4.911
##    .C1               4.974    0.088   56.830    0.000    4.803    5.146
##    .C2               5.057    0.082   61.452    0.000    4.896    5.219
##    .C3               5.453    0.091   59.731    0.000    5.274    5.632
##    .C4               5.794    0.076   76.374    0.000    5.645    5.942
##    .C5               5.275    0.085   61.855    0.000    5.108    5.442
##    .C6               5.023    0.086   58.430    0.000    4.854    5.191
##    .C7               5.049    0.085   59.115    0.000    4.881    5.216
##    .C8               5.178    0.093   55.775    0.000    4.996    5.360
##    .C9               5.327    0.086   61.931    0.000    5.158    5.495
##    .R1               5.278    0.086   61.253    0.000    5.109    5.447
##    .R2               6.057    0.068   89.152    0.000    5.924    6.190
##    .R3               6.255    0.055  113.916    0.000    6.147    6.363
##     standardizatin   0.000                               0.000    0.000
##     quality          0.000                               0.000    0.000
##     jit              0.000                               0.000    0.000
##    .culture          0.000                               0.000    0.000
##    .performance      0.000                               0.000    0.000
##     lean             0.000                               0.000    0.000
##
## Variances:
##                   Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1               1.013    0.221    4.578    0.000    0.579    1.446
##    .S2               1.324    0.197    6.708    0.000    0.937    1.710
##    .S3               1.431    0.197    7.251    0.000    1.044    1.818
##    .S4               1.099    0.209    5.267    0.000    0.690    1.508
##    .S5               2.129    0.246    8.667    0.000    1.648    2.611
##    .Q1               1.692    0.248    6.820    0.000    1.205    2.178
##    .Q2               1.416    0.237    5.983    0.000    0.952    1.879
##    .Q3               0.852    0.202    4.209    0.000    0.455    1.248
##    .Q4               1.116    0.209    5.351    0.000    0.707    1.525
##    .Q5               1.405    0.228    6.160    0.000    0.958    1.852
##    .Q6               0.930    0.229    4.061    0.000    0.481    1.378
##    .Q7               1.128    0.203    5.557    0.000    0.730    1.526
##    .J1               1.106    0.219    5.049    0.000    0.677    1.536
##    .J2               1.119    0.216    5.186    0.000    0.696    1.542
##    .J3               0.981    0.226    4.346    0.000    0.539    1.424
##    .J4               1.192    0.208    5.734    0.000    0.784    1.599
```

```
##    .J5                 1.082    0.222    4.878    0.000    0.647    1.516
##    .J6                 1.748    0.212    8.229    0.000    1.332    2.164
##    .C1                 0.929    0.210    4.418    0.000    0.517    1.341
##    .C2                 0.705    0.196    3.596    0.000    0.321    1.090
##    .C3                 1.735    0.252    6.895    0.000    1.242    2.228
##    .C4                 1.014    0.205    4.957    0.000    0.613    1.416
##    .C5                 0.825    0.219    3.758    0.000    0.395    1.255
##    .C6                 0.646    0.214    3.017    0.003    0.226    1.065
##    .C7                 0.785    0.210    3.739    0.000    0.373    1.196
##    .C8                 1.662    0.236    7.051    0.000    1.200    2.123
##    .C9                 1.449    0.224    6.463    0.000    1.010    1.889
##    .R1                 1.056    0.250    4.215    0.000    0.565    1.546
##    .R2                 0.625    0.224    2.792    0.005    0.186    1.065
##    .R3                 0.574    0.162    3.536    0.000    0.256    0.892
##     standardizatin     0.100    0.052    1.933    0.053   -0.001    0.201
##     quality            0.042    0.041    1.010    0.312   -0.039    0.123
##     jit                0.500    0.063    7.984    0.000    0.377    0.622
##    .culture            0.541    0.051   10.687    0.000    0.442    0.640
##    .performance        0.554    0.149    3.710    0.000    0.261    0.846
##     lean               1.034    0.058   17.835    0.000    0.920    1.147
```

```
#goodness-of-fit test
fitMeasures(multigroup1,c("chisq","df", "rmsea", "srmr", "nfi", "cfi", "tli", "agfi"))
```

```
##   chisq      df   rmsea    srmr     nfi     cfi     tli    agfi
## 884.822 798.000   0.017   0.052   0.979   0.998   0.998   0.997
```

Generate a full constrained model in which all parameters were fixed across two groups. Then compared the full constrained model to the free model.

```
#set all path coefficients fixed between groups
multigroup1.constrained <- sem(multigroup.model, data = test1, estimator = "DWLS",
group = "country", gr
```

```
##     The variance-covariance matrix of the estimated parameters (vcov)
##     does not appear to be positive definite! The smallest eigenvalue
##     (= 1.683666e-17) is close to zero. This may be a symptom that the
##     model is not identified.
```

```
#model fit and parameter estimation
summary(multigroup1.constrained, fit.measures = TRUE, standardized = FALSE, ci = TRUE)
```

```
## lavaan 0.6-3 ended normally after 146 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                        198
##   Number of equality constraints                    33
##
##   Number of observations per group
##   1                                                442
##   0                                                349
##
##   Estimator                                       DWLS
##   Model Fit Test Statistic                    1441.864
```

```
##   Degrees of freedom                               825
##   P-value (Chi-square)                           0.000
##
## Chi-square for each group:
##
##   1                                            879.036
##   0                                            562.828
##
## Model test baseline model:
##
##   Minimum Function Test Statistic            41486.970
##   Degrees of freedom                               870
##   P-value                                        0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.985
##   Tucker-Lewis Index (TLI)                       0.984
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.044
##   90 Percent Confidence Interval          0.040  0.047
##   P-value RMSEA <= 0.05                          0.998
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.065
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model        Unstructured
##   Standard Errors                             Standard
##
##
## Group 1 [1]:
##
## Latent Variables:
##                      Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   standardization =~
##     S1                  1.000                               1.000    1.000
##     S2                  1.437    0.069   20.806    0.000    1.301    1.572
##     S3                  1.444    0.070   20.519    0.000    1.306    1.582
##     S4                  1.323    0.066   20.134    0.000    1.194    1.452
##     S5                  0.976    0.053   18.544    0.000    0.873    1.079
##   quality =~
##     Q1                  1.000                               1.000    1.000
##     Q2                  1.369    0.069   19.962    0.000    1.235    1.504
##     Q3                  1.571    0.077   20.271    0.000    1.419    1.722
##     Q4                  1.604    0.080   20.133    0.000    1.448    1.760
##     Q5                  1.746    0.086   20.352    0.000    1.578    1.914
##     Q6                  1.569    0.079   19.799    0.000    1.413    1.724
##     Q7                  1.473    0.076   19.438    0.000    1.324    1.621
```

```
##   jit =~
##     J1                1.000                               1.000    1.000
##     J2                0.906    0.051   17.910    0.000    0.807    1.005
##     J3                1.252    0.066   19.067    0.000    1.123    1.381
##     J4                1.219    0.065   18.849    0.000    1.092    1.346
##     J5                1.150    0.062   18.662    0.000    1.029    1.270
##     J6                0.904    0.051   17.702    0.000    0.804    1.005
##   culture =~
##     C1                1.000                               1.000    1.000
##     C2                0.938    0.039   24.317    0.000    0.863    1.014
##     C3                0.963    0.040   24.037    0.000    0.885    1.042
##     C4                1.176    0.045   26.066    0.000    1.087    1.264
##     C5                1.334    0.050   26.825    0.000    1.236    1.431
##     C6                1.385    0.052   26.869    0.000    1.284    1.486
##     C7                1.412    0.052   26.933    0.000    1.309    1.515
##     C8                1.371    0.052   26.401    0.000    1.269    1.473
##     C9                1.013    0.042   24.181    0.000    0.931    1.095
##   performance =~
##     R1                1.000                               1.000    1.000
##     R2                1.263    0.053   23.897    0.000    1.160    1.367
##     R3                1.082    0.047   22.975    0.000    0.989    1.174
##   lean =~
##     standardizatin    1.000                               1.000    1.000
##     quality           0.886    0.051   17.416    0.000    0.787    0.986
##     jit               0.846    0.049   17.142    0.000    0.749    0.942
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   culture ~
##     lean    (.34.)    0.787    0.027   29.298    0.000    0.734    0.840
##   performance ~
##     lean    (.35.)    0.476    0.036   13.360    0.000    0.406    0.546
##     culture (.36.)    0.510    0.031   16.405    0.000    0.449    0.571
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1      (.73.)    5.013    0.051   98.786    0.000    4.913    5.112
##    .S2      (.74.)    4.719    0.058   81.615    0.000    4.605    4.832
##    .S3      (.75.)    4.671    0.059   78.965    0.000    4.555    4.787
##    .S4      (.76.)    4.800    0.057   83.851    0.000    4.688    4.912
##    .S5      (.77.)    4.938    0.052   95.267    0.000    4.837    5.040
##    .Q1      (.78.)    5.017    0.048  104.814    0.000    4.923    5.111
##    .Q2      (.79.)    4.685    0.054   87.213    0.000    4.580    4.791
##    .Q3      (.80.)    4.770    0.054   87.570    0.000    4.663    4.876
##    .Q4      (.81.)    4.603    0.057   80.929    0.000    4.491    4.714
##    .Q5      (.82.)    4.456    0.061   73.362    0.000    4.337    4.575
##    .Q6      (.83.)    4.527    0.061   74.323    0.000    4.408    4.647
##    .Q7      (.84.)    4.417    0.058   75.684    0.000    4.303    4.532
##    .J1      (.85.)    4.795    0.055   87.977    0.000    4.688    4.902
##    .J2      (.86.)    4.657    0.053   88.305    0.000    4.554    4.761
##    .J3      (.87.)    4.651    0.058   79.902    0.000    4.537    4.765
##    .J4      (.88.)    4.617    0.059   78.231    0.000    4.502    4.733
##    .J5      (.89.)    4.574    0.061   75.580    0.000    4.456    4.693
##    .J6      (.90.)    4.807    0.055   87.788    0.000    4.699    4.914
```

```
##    .C1      (.91.)    4.486    0.046   97.755    0.000    4.396    4.575
##    .C2      (.92.)    4.461    0.049   90.672    0.000    4.365    4.558
##    .C3      (.93.)    4.575    0.052   88.223    0.000    4.474    4.677
##    .C4      (.94.)    4.729    0.051   92.953    0.000    4.630    4.829
##    .C5      (.95.)    4.404    0.056   77.985    0.000    4.293    4.514
##    .C6      (.96.)    4.312    0.059   73.590    0.000    4.197    4.427
##    .C7      (.97.)    4.427    0.059   74.882    0.000    4.311    4.543
##    .C8      (.98.)    4.464    0.060   74.529    0.000    4.346    4.581
##    .C9      (.99.)    4.412    0.053   83.359    0.000    4.309    4.516
##    .R1      (.100)    4.177    0.050   83.210    0.000    4.078    4.275
##    .R2      (.101)    4.505    0.050   89.831    0.000    4.407    4.604
##    .R3      (.102)    4.883    0.045  109.666    0.000    4.796    4.971
##     stndrdz           0.000                               0.000    0.000
##     quality           0.000                               0.000    0.000
##     jit               0.000                               0.000    0.000
##    .culture           0.000                               0.000    0.000
##    .prfrmnc           0.000                               0.000    0.000
##     lean              0.000                               0.000    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                0.903    0.112    8.093    0.000    0.684    1.121
##    .S2                0.696    0.152    4.588    0.000    0.399    0.994
##    .S3                0.746    0.160    4.660    0.000    0.432    1.060
##    .S4                0.871    0.146    5.953    0.000    0.584    1.158
##    .S5                0.853    0.119    7.169    0.000    0.620    1.086
##    .Q1                0.806    0.098    8.248    0.000    0.614    0.997
##    .Q2                0.828    0.114    7.259    0.000    0.605    1.052
##    .Q3                0.708    0.133    5.338    0.000    0.448    0.968
##    .Q4                0.870    0.142    6.115    0.000    0.591    1.149
##    .Q5                0.849    0.154    5.507    0.000    0.547    1.152
##    .Q6                1.156    0.150    7.708    0.000    0.862    1.450
##    .Q7                1.188    0.147    8.058    0.000    0.899    1.477
##    .J1                0.891    0.126    7.066    0.000    0.644    1.138
##    .J2                0.942    0.110    8.532    0.000    0.726    1.159
##    .J3                0.701    0.147    4.769    0.000    0.413    0.989
##    .J4                0.906    0.143    6.353    0.000    0.626    1.185
##    .J5                1.033    0.136    7.583    0.000    0.766    1.299
##    .J6                1.030    0.122    8.464    0.000    0.792    1.269
##    .C1                0.528    0.080    6.576    0.000    0.371    0.686
##    .C2                0.871    0.097    8.991    0.000    0.681    1.061
##    .C3                0.993    0.102    9.779    0.000    0.794    1.192
##    .C4                0.844    0.121    7.002    0.000    0.608    1.080
##    .C5                0.907    0.132    6.868    0.000    0.648    1.166
##    .C6                1.025    0.142    7.217    0.000    0.746    1.303
##    .C7                1.085    0.146    7.411    0.000    0.798    1.372
##    .C8                1.138    0.139    8.214    0.000    0.867    1.410
##    .C9                1.099    0.112    9.770    0.000    0.879    1.319
##    .R1                0.754    0.096    7.815    0.000    0.565    0.943
##    .R2                0.553    0.118    4.684    0.000    0.321    0.784
##    .R3                0.606    0.099    6.154    0.000    0.413    0.799
##     standardizatin    0.421    0.039   10.762    0.000    0.344    0.498
##     quality           0.297    0.026   11.323    0.000    0.246    0.349
##     jit               0.701    0.056   12.592    0.000    0.592    0.811
```

```
##    .culture           0.516    0.030   17.364    0.000    0.457    0.574
##    .performance       0.209    0.038    5.503    0.000    0.134    0.283
##     lean              0.267    0.017   15.750    0.000    0.234    0.300
##
##
## Group 2 [0]:
##
## Latent Variables:
##                      Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   standardization =~
##     S1                  1.000                               1.000    1.000
##     S2                  1.058    0.036   29.543    0.000    0.988    1.128
##     S3                  1.103    0.037   29.848    0.000    1.030    1.175
##     S4                  1.084    0.036   29.851    0.000    1.013    1.155
##     S5                  1.007    0.037   26.971    0.000    0.934    1.080
##   quality =~
##     Q1                  1.000                               1.000    1.000
##     Q2                  1.093    0.042   25.917    0.000    1.010    1.175
##     Q3                  1.125    0.042   27.029    0.000    1.044    1.207
##     Q4                  1.104    0.041   27.105    0.000    1.024    1.184
##     Q5                  1.204    0.045   26.761    0.000    1.116    1.292
##     Q6                  1.311    0.047   27.736    0.000    1.218    1.404
##     Q7                  1.138    0.042   26.969    0.000    1.056    1.221
##   jit =~
##     J1                  1.000                               1.000    1.000
##     J2                  0.951    0.033   29.211    0.000    0.887    1.014
##     J3                  1.055    0.035   30.089    0.000    0.986    1.124
##     J4                  0.988    0.033   29.624    0.000    0.923    1.053
##     J5                  1.141    0.037   31.245    0.000    1.069    1.212
##     J6                  0.945    0.033   28.676    0.000    0.880    1.009
##   culture =~
##     C1                  1.000                               1.000    1.000
##     C2                  1.190    0.040   29.383    0.000    1.111    1.269
##     C3                  1.039    0.040   26.059    0.000    0.961    1.118
##     C4                  0.978    0.036   27.091    0.000    0.907    1.049
##     C5                  1.238    0.042   29.183    0.000    1.155    1.321
##     C6                  1.294    0.044   29.734    0.000    1.208    1.379
##     C7                  1.231    0.042   29.120    0.000    1.148    1.314
##     C8                  1.094    0.041   27.005    0.000    1.015    1.174
##     C9                  1.024    0.038   26.634    0.000    0.948    1.099
##   performance =~
##     R1                  1.000                               1.000    1.000
##     R2                  0.820    0.029   28.075    0.000    0.763    0.877
##     R3                  0.616    0.023   27.060    0.000    0.572    0.661
##   lean =~
##     standardizatin      1.000                               1.000    1.000
##     quality             0.991    0.039   25.671    0.000    0.916    1.067
##     jit                 1.082    0.038   28.318    0.000    1.007    1.157
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   culture ~
##     lean    (.34.)    0.787    0.027   29.298    0.000    0.734    0.840
##   performance ~
```

```
##     lean    (.35.)    0.476    0.036   13.360    0.000    0.406    0.546
##     culture (.36.)    0.510    0.031   16.405    0.000    0.449    0.571
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1      (.73.)    5.013    0.051   98.786    0.000    4.913    5.112
##    .S2      (.74.)    4.719    0.058   81.615    0.000    4.605    4.832
##    .S3      (.75.)    4.671    0.059   78.965    0.000    4.555    4.787
##    .S4      (.76.)    4.800    0.057   83.851    0.000    4.688    4.912
##    .S5      (.77.)    4.938    0.052   95.267    0.000    4.837    5.040
##    .Q1      (.78.)    5.017    0.048  104.814    0.000    4.923    5.111
##    .Q2      (.79.)    4.685    0.054   87.213    0.000    4.580    4.791
##    .Q3      (.80.)    4.770    0.054   87.570    0.000    4.663    4.876
##    .Q4      (.81.)    4.603    0.057   80.929    0.000    4.491    4.714
##    .Q5      (.82.)    4.456    0.061   73.362    0.000    4.337    4.575
##    .Q6      (.83.)    4.527    0.061   74.323    0.000    4.408    4.647
##    .Q7      (.84.)    4.417    0.058   75.684    0.000    4.303    4.532
##    .J1      (.85.)    4.795    0.055   87.977    0.000    4.688    4.902
##    .J2      (.86.)    4.657    0.053   88.305    0.000    4.554    4.761
##    .J3      (.87.)    4.651    0.058   79.902    0.000    4.537    4.765
##    .J4      (.88.)    4.617    0.059   78.231    0.000    4.502    4.733
##    .J5      (.89.)    4.574    0.061   75.580    0.000    4.456    4.693
##    .J6      (.90.)    4.807    0.055   87.788    0.000    4.699    4.914
##    .C1      (.91.)    4.486    0.046   97.755    0.000    4.396    4.575
##    .C2      (.92.)    4.461    0.049   90.672    0.000    4.365    4.558
##    .C3      (.93.)    4.575    0.052   88.223    0.000    4.474    4.677
##    .C4      (.94.)    4.729    0.051   92.953    0.000    4.630    4.829
##    .C5      (.95.)    4.404    0.056   77.985    0.000    4.293    4.514
##    .C6      (.96.)    4.312    0.059   73.590    0.000    4.197    4.427
##    .C7      (.97.)    4.427    0.059   74.882    0.000    4.311    4.543
##    .C8      (.98.)    4.464    0.060   74.529    0.000    4.346    4.581
##    .C9      (.99.)    4.412    0.053   83.359    0.000    4.309    4.516
##    .R1      (.100)    4.177    0.050   83.210    0.000    4.078    4.275
##    .R2      (.101)    4.505    0.050   89.831    0.000    4.407    4.604
##    .R3      (.102)    4.883    0.045  109.666    0.000    4.796    4.971
##     stndrdz          -0.096    0.041   -2.358    0.018   -0.175   -0.016
##     quality           0.040    0.034    1.178    0.239   -0.027    0.107
##     jit              -0.369    0.040   -9.291    0.000   -0.447   -0.291
##    .culture           0.405    0.034   12.040    0.000    0.339    0.471
##    .prfrmnc           1.226    0.069   17.655    0.000    1.090    1.363
##     lean              0.343    0.019   18.418    0.000    0.306    0.379
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                0.882    0.222    3.975    0.000    0.447    1.318
##    .S2                1.359    0.196    6.921    0.000    0.974    1.744
##    .S3                1.480    0.196    7.546    0.000    1.096    1.865
##    .S4                1.129    0.208    5.433    0.000    0.722    1.537
##    .S5                2.162    0.245    8.826    0.000    1.682    2.642
##    .Q1                1.690    0.248    6.817    0.000    1.204    2.176
##    .Q2                1.402    0.237    5.924    0.000    0.938    1.866
##    .Q3                0.835    0.203    4.121    0.000    0.438    1.232
##    .Q4                1.103    0.209    5.286    0.000    0.694    1.512
##    .Q5                1.420    0.228    6.231    0.000    0.973    1.866
```

```
##    .Q6                  0.948    0.229    4.148    0.000    0.500    1.396
##    .Q7                  1.141    0.203    5.628    0.000    0.744    1.538
##    .J1                  1.111    0.219    5.068    0.000    0.681    1.540
##    .J2                  1.115    0.216    5.167    0.000    0.692    1.538
##    .J3                  0.982    0.226    4.348    0.000    0.539    1.424
##    .J4                  1.190    0.208    5.723    0.000    0.782    1.597
##    .J5                  1.082    0.222    4.879    0.000    0.648    1.517
##    .J6                  1.747    0.213    8.223    0.000    1.331    2.164
##    .C1                  1.500    0.202    7.437    0.000    1.105    1.895
##    .C2                  0.701    0.196    3.579    0.000    0.317    1.086
##    .C3                  1.640    0.252    6.496    0.000    1.145    2.135
##    .C4                  0.885    0.206    4.299    0.000    0.482    1.288
##    .C5                  0.739    0.220    3.354    0.001    0.307    1.171
##    .C6                  0.614    0.214    2.868    0.004    0.195    1.034
##    .C7                  0.767    0.210    3.651    0.000    0.355    1.178
##    .C8                  1.602    0.236    6.780    0.000    1.139    2.065
##    .C9                  1.352    0.225    6.005    0.000    0.911    1.793
##    .R1                  1.161    0.241    4.813    0.000    0.688    1.634
##    .R2                  0.649    0.221    2.934    0.003    0.216    1.083
##    .R3                  0.509    0.164    3.110    0.002    0.188    0.830
##     standardizatin      0.066    0.058    1.150    0.250   -0.047    0.179
##     quality             0.032    0.041    0.763    0.445   -0.050    0.113
##     jit                 0.495    0.062    7.918    0.000    0.372    0.617
##    .culture             0.433    0.036   12.034    0.000    0.362    0.503
##    .performance         0.397    0.138    2.883    0.004    0.127    0.667
##     lean                1.197    0.058   20.623    0.000    1.084    1.311
```

```
#goodness-of-fit test
fitMeasures(multigroup1.constrained,c("chisq","rmsea","srmr","nfi","cfi","tli","agfi"))
```

```
##    chisq       df    rmsea     srmr      nfi      cfi      tli     agfi
## 1441.864  825.000    0.044    0.065    0.965    0.985    0.984    0.995
```

```
#Chi-square difference test between free model and full constrained model
anova(multigroup1,multigroup1.constrained)
```

```
## Chi Square Difference Test
##
##                          Df AIC BIC   Chisq Chisq diff Df diff Pr(>Chisq)
## multigroup1             798           884.82
## multigroup1.constrained 825          1441.86     557.04      27  < 2.2e-16
##
## multigroup1
## multigroup1.constrained ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The free model and the full constrained model are significantly different. Some paths vary between the two groups of data. The next step was to sequentially relax and constrain paths. A single constraint of the path from "lean" directly to "performance" was introduced by fixing the coefficient between the two groups and re-fitting the model.

```
#set the path "lean -> performance" fixed
multigroup.model2 <- '
standardization =~ S1 + S2 + S3 + S4 + S5
quality =~ Q1 + Q2 + Q3 + Q4 + Q5 + Q6 + Q7
jit =~ J1 + J2 + J3 + J4 + J5 + J6
```

```
culture =~ C1 + C2 + C3 + C4 + C5 + C6 + C7 + C8 + C9
performance =~ R1 + R2 + R3
lean =~ standardization + quality + jit
culture ~ lean
performance ~ c("c1","c1")*lean + culture
'

#model fit and parameter estimation
multigroup2 <- sem(multigroup.model2, data = test1, estimator = "DWLS", group = "country")
```

```
summary(multigroup2, fit.measures = TRUE, standardized = FALSE, ci = TRUE)
```

```
## lavaan 0.6-3 ended normally after 80 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                        192
##   Number of equality constraints                     1
##
##   Number of observations per group
##   1                                                442
##   0                                                349
##
##   Estimator                                       DWLS
##   Model Fit Test Statistic                     885.450
##   Degrees of freedom                               799
##   P-value (Chi-square)                           0.018
##
## Chi-square for each group:
##
##   1                                            602.893
##   0                                            282.558
##
## Model test baseline model:
##
##   Minimum Function Test Statistic            41486.970
##   Degrees of freedom                               870
##   P-value                                        0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.998
##   Tucker-Lewis Index (TLI)                       0.998
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.017
##   90 Percent Confidence Interval          0.008  0.023
##   P-value RMSEA <= 0.05                          1.000
##
## Standardized Root Mean Square Residual:
##
```

```
##   SRMR                                           0.052
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model        Unstructured
##   Standard Errors                             Standard
##
##
## Group 1 [1]:
##
## Latent Variables:
##                      Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   standardization =~
##     S1                  1.000                               1.000    1.000
##     S2                  1.241    0.062   20.024    0.000    1.119    1.362
##     S3                  1.236    0.063   19.736    0.000    1.114    1.359
##     S4                  1.135    0.059   19.394    0.000    1.021    1.250
##     S5                  0.839    0.047   17.987    0.000    0.747    0.930
##   quality =~
##     Q1                  1.000                               1.000    1.000
##     Q2                  1.371    0.068   20.212    0.000    1.238    1.503
##     Q3                  1.566    0.076   20.486    0.000    1.416    1.715
##     Q4                  1.590    0.078   20.327    0.000    1.437    1.744
##     Q5                  1.722    0.084   20.531    0.000    1.557    1.886
##     Q6                  1.552    0.078   19.982    0.000    1.400    1.704
##     Q7                  1.450    0.074   19.587    0.000    1.305    1.595
##   jit =~
##     J1                  1.000                               1.000    1.000
##     J2                  0.904    0.051   17.828    0.000    0.805    1.004
##     J3                  1.251    0.066   18.989    0.000    1.122    1.380
##     J4                  1.222    0.065   18.785    0.000    1.094    1.349
##     J5                  1.151    0.062   18.597    0.000    1.030    1.272
##     J6                  0.905    0.051   17.633    0.000    0.804    1.005
##   culture =~
##     C1                  1.000                               1.000    1.000
##     C2                  1.174    0.056   21.088    0.000    1.065    1.283
##     C3                  1.214    0.058   20.984    0.000    1.101    1.328
##     C4                  1.475    0.066   22.268    0.000    1.345    1.605
##     C5                  1.678    0.074   22.720    0.000    1.533    1.822
##     C6                  1.751    0.077   22.794    0.000    1.600    1.901
##     C7                  1.776    0.078   22.874    0.000    1.624    1.929
##     C8                  1.728    0.077   22.513    0.000    1.578    1.879
##     C9                  1.282    0.061   21.140    0.000    1.163    1.401
##   performance =~
##     R1                  1.000                               1.000    1.000
##     R2                  1.033    0.043   23.840    0.000    0.948    1.118
##     R3                  0.877    0.038   22.840    0.000    0.802    0.953
##   lean =~
##     standardizatin      1.000                               1.000    1.000
##     quality             0.738    0.046   16.179    0.000    0.649    0.828
##     jit                 0.668    0.042   15.746    0.000    0.585    0.751
##
## Regressions:
```

```
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   culture ~
##     lean              0.416    0.027   15.652    0.000    0.364    0.468
##   performance ~
##     lean      (c1)    0.618    0.045   13.865    0.000    0.530    0.705
##     culture           0.712    0.044   16.351    0.000    0.627    0.798
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                4.853    0.060   80.888    0.000    4.735    4.971
##    .S2                4.790    0.069   69.204    0.000    4.654    4.925
##    .S3                4.790    0.070   68.189    0.000    4.652    4.927
##    .S4                4.783    0.069   69.793    0.000    4.648    4.917
##    .S5                4.959    0.058   84.878    0.000    4.845    5.074
##    .Q1                5.020    0.055   92.116    0.000    4.914    5.127
##    .Q2                4.636    0.063   73.069    0.000    4.511    4.760
##    .Q3                4.672    0.067   70.187    0.000    4.541    4.802
##    .Q4                4.518    0.070   64.427    0.000    4.381    4.656
##    .Q5                4.541    0.074   61.690    0.000    4.396    4.685
##    .Q6                4.604    0.074   62.434    0.000    4.460    4.749
##    .Q7                4.502    0.072   62.584    0.000    4.361    4.643
##    .J1                4.769    0.064   75.073    0.000    4.645    4.894
##    .J2                4.597    0.062   74.688    0.000    4.477    4.718
##    .J3                4.622    0.069   67.056    0.000    4.487    4.757
##    .J4                4.654    0.071   65.491    0.000    4.515    4.793
##    .J5                4.627    0.071   65.396    0.000    4.488    4.765
##    .J6                4.844    0.063   76.749    0.000    4.720    4.968
##    .C1                4.552    0.052   87.014    0.000    4.450    4.655
##    .C2                4.563    0.058   79.091    0.000    4.450    4.676
##    .C3                4.498    0.061   74.175    0.000    4.379    4.617
##    .C4                4.446    0.064   69.947    0.000    4.321    4.570
##    .C5                4.380    0.069   63.263    0.000    4.244    4.516
##    .C6                4.428    0.073   60.955    0.000    4.285    4.570
##    .C7                4.586    0.074   61.681    0.000    4.440    4.732
##    .C8                4.480    0.074   60.558    0.000    4.335    4.625
##    .C9                4.290    0.064   67.247    0.000    4.165    4.415
##    .R1                4.428    0.054   81.567    0.000    4.321    4.534
##    .R2                4.414    0.057   77.679    0.000    4.303    4.525
##    .R3                4.600    0.053   86.568    0.000    4.495    4.704
##     standardizatin    0.000                               0.000    0.000
##     quality           0.000                               0.000    0.000
##     jit               0.000                               0.000    0.000
##    .culture           0.000                               0.000    0.000
##    .performance       0.000                               0.000    0.000
##     lean              0.000                               0.000    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                0.708    0.119    5.957    0.000    0.475    0.941
##    .S2                0.759    0.149    5.102    0.000    0.467    1.050
##    .S3                0.832    0.156    5.319    0.000    0.525    1.138
##    .S4                0.938    0.143    6.542    0.000    0.657    1.219
##    .S5                0.888    0.118    7.549    0.000    0.658    1.119
##    .Q1                0.798    0.098    8.167    0.000    0.607    0.990
```

```
##    .Q2                0.812    0.114    7.113    0.000    0.589    1.036
##    .Q3                0.697    0.133    5.256    0.000    0.437    0.957
##    .Q4                0.872    0.142    6.143    0.000    0.594    1.150
##    .Q5                0.869    0.153    5.666    0.000    0.569    1.170
##    .Q6                1.165    0.150    7.788    0.000    0.871    1.458
##    .Q7                1.205    0.147    8.209    0.000    0.918    1.493
##    .J1                0.892    0.126    7.063    0.000    0.644    1.139
##    .J2                0.945    0.110    8.554    0.000    0.728    1.162
##    .J3                0.704    0.147    4.792    0.000    0.416    0.992
##    .J4                0.900    0.143    6.296    0.000    0.620    1.180
##    .J5                1.030    0.136    7.553    0.000    0.763    1.297
##    .J6                1.030    0.122    8.459    0.000    0.792    1.269
##    .C1                0.759    0.079    9.630    0.000    0.605    0.914
##    .C2                0.850    0.098    8.720    0.000    0.659    1.042
##    .C3                0.961    0.102    9.389    0.000    0.760    1.162
##    .C4                0.806    0.122    6.632    0.000    0.568    1.044
##    .C5                0.852    0.134    6.376    0.000    0.590    1.113
##    .C6                0.952    0.144    6.621    0.000    0.670    1.234
##    .C7                1.023    0.148    6.909    0.000    0.733    1.313
##    .C8                1.073    0.140    7.648    0.000    0.798    1.348
##    .C9                1.059    0.113    9.332    0.000    0.836    1.281
##    .R1                0.587    0.102    5.727    0.000    0.386    0.787
##    .R2                0.663    0.113    5.843    0.000    0.441    0.885
##    .R3                0.697    0.095    7.317    0.000    0.510    0.883
##     standardizatin    0.471    0.046   10.256    0.000    0.381    0.561
##     quality           0.290    0.026   11.216    0.000    0.239    0.341
##     jit               0.708    0.056   12.589    0.000    0.598    0.819
##    .culture           0.379    0.026   14.457    0.000    0.328    0.430
##    .performance       0.179    0.049    3.632    0.000    0.083    0.276
##     lean              0.411    0.033   12.382    0.000    0.346    0.477
##
##
## Group 2 [0]:
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   standardization =~
##     S1                1.000                               1.000    1.000
##     S2                1.135    0.041   27.616    0.000    1.054    1.215
##     S3                1.186    0.043   27.871    0.000    1.102    1.269
##     S4                1.160    0.042   27.844    0.000    1.078    1.241
##     S5                1.080    0.042   25.478    0.000    0.997    1.163
##   quality =~
##     Q1                1.000                               1.000    1.000
##     Q2                1.088    0.042   25.777    0.000    1.005    1.171
##     Q3                1.120    0.042   26.897    0.000    1.038    1.201
##     Q4                1.099    0.041   26.986    0.000    1.020    1.179
##     Q5                1.210    0.045   26.727    0.000    1.121    1.298
##     Q6                1.318    0.048   27.691    0.000    1.224    1.411
##     Q7                1.143    0.042   26.919    0.000    1.060    1.227
##   jit =~
##     J1                1.000                               1.000    1.000
##     J2                0.949    0.032   29.269    0.000    0.885    1.012
##     J3                1.054    0.035   30.160    0.000    0.986    1.123
```

```
##     J4                 0.987    0.033   29.696    0.000    0.922    1.052
##     J5                 1.140    0.036   31.322    0.000    1.068    1.211
##     J6                 0.944    0.033   28.745    0.000    0.879    1.008
##   culture =~
##     C1                 1.000                               1.000    1.000
##     C2                 0.975    0.032   30.156    0.000    0.912    1.038
##     C3                 0.821    0.031   26.049    0.000    0.759    0.882
##     C4                 0.755    0.028   26.844    0.000    0.700    0.810
##     C5                 0.991    0.033   29.658    0.000    0.926    1.057
##     C6                 1.053    0.035   30.487    0.000    0.985    1.121
##     C7                 1.005    0.034   29.853    0.000    0.939    1.071
##     C8                 0.879    0.032   27.349    0.000    0.816    0.942
##     C9                 0.806    0.030   26.651    0.000    0.747    0.865
##   performance =~
##     R1                 1.000                               1.000    1.000
##     R2                 0.797    0.034   23.764    0.000    0.731    0.863
##     R3                 0.555    0.025   22.199    0.000    0.506    0.604
##   lean =~
##     standardizatin     1.000                               1.000    1.000
##     quality            1.065    0.044   24.223    0.000    0.979    1.151
##     jit                1.167    0.044   26.464    0.000    1.081    1.254
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   culture ~
##     lean              1.085    0.042   26.080    0.000    1.003    1.166
##   performance ~
##     lean      (c1)    0.618    0.045   13.865    0.000    0.530    0.705
##     culture           0.310    0.044    7.095    0.000    0.224    0.396
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                5.533    0.078   70.568    0.000    5.379    5.687
##    .S2                4.862    0.089   54.548    0.000    4.688    5.037
##    .S3                4.736    0.093   50.954    0.000    4.554    4.919
##    .S4                5.095    0.087   58.869    0.000    4.925    5.264
##    .S5                5.126    0.099   51.612    0.000    4.931    5.321
##    .Q1                5.387    0.091   59.117    0.000    5.208    5.565
##    .Q2                5.201    0.090   57.613    0.000    5.024    5.377
##    .Q3                5.347    0.082   64.960    0.000    5.185    5.508
##    .Q4                5.149    0.086   59.949    0.000    4.981    5.317
##    .Q5                4.771    0.095   50.055    0.000    4.584    4.958
##    .Q6                4.903    0.093   52.668    0.000    4.720    5.085
##    .Q7                4.722    0.088   53.626    0.000    4.549    4.895
##    .J1                4.851    0.093   52.274    0.000    4.669    5.033
##    .J2                4.788    0.090   53.194    0.000    4.612    4.964
##    .J3                4.708    0.094   50.020    0.000    4.523    4.892
##    .J4                4.556    0.093   48.817    0.000    4.373    4.739
##    .J5                4.470    0.101   44.336    0.000    4.272    4.668
##    .J6                4.716    0.099   47.517    0.000    4.522    4.911
##    .C1                4.974    0.088   56.830    0.000    4.803    5.146
##    .C2                5.057    0.082   61.452    0.000    4.896    5.219
##    .C3                5.453    0.091   59.731    0.000    5.274    5.632
##    .C4                5.794    0.076   76.374    0.000    5.645    5.942
```

```
##    .C5               5.275    0.085   61.855    0.000    5.108    5.442
##    .C6               5.023    0.086   58.430    0.000    4.854    5.191
##    .C7               5.049    0.085   59.115    0.000    4.881    5.216
##    .C8               5.178    0.093   55.775    0.000    4.996    5.360
##    .C9               5.327    0.086   61.931    0.000    5.158    5.495
##    .R1               5.278    0.086   61.253    0.000    5.109    5.447
##    .R2               6.057    0.068   89.152    0.000    5.924    6.190
##    .R3               6.255    0.055  113.916    0.000    6.147    6.363
##     standardizatin   0.000                               0.000    0.000
##     quality          0.000                               0.000    0.000
##     jit              0.000                               0.000    0.000
##    .culture          0.000                               0.000    0.000
##    .performance      0.000                               0.000    0.000
##     lean             0.000                               0.000    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                1.018    0.221    4.605    0.000    0.585    1.451
##    .S2                1.322    0.197    6.699    0.000    0.935    1.709
##    .S3                1.430    0.197    7.242    0.000    1.043    1.817
##    .S4                1.097    0.209    5.259    0.000    0.688    1.506
##    .S5                2.128    0.246    8.662    0.000    1.647    2.610
##    .Q1                1.692    0.248    6.820    0.000    1.205    2.178
##    .Q2                1.416    0.237    5.984    0.000    0.952    1.879
##    .Q3                0.852    0.202    4.208    0.000    0.455    1.248
##    .Q4                1.116    0.209    5.350    0.000    0.707    1.525
##    .Q5                1.405    0.228    6.159    0.000    0.958    1.852
##    .Q6                0.929    0.229    4.060    0.000    0.481    1.378
##    .Q7                1.128    0.203    5.559    0.000    0.731    1.526
##    .J1                1.107    0.219    5.051    0.000    0.677    1.536
##    .J2                1.119    0.216    5.185    0.000    0.696    1.541
##    .J3                0.981    0.226    4.346    0.000    0.539    1.424
##    .J4                1.191    0.208    5.733    0.000    0.784    1.599
##    .J5                1.082    0.222    4.878    0.000    0.647    1.516
##    .J6                1.748    0.212    8.228    0.000    1.332    2.164
##    .C1                0.925    0.210    4.401    0.000    0.513    1.337
##    .C2                0.702    0.196    3.577    0.000    0.317    1.086
##    .C3                1.732    0.252    6.881    0.000    1.238    2.225
##    .C4                1.012    0.205    4.946    0.000    0.611    1.414
##    .C5                0.820    0.219    3.737    0.000    0.390    1.250
##    .C6                0.640    0.214    2.990    0.003    0.220    1.059
##    .C7                0.780    0.210    3.718    0.000    0.369    1.192
##    .C8                1.657    0.236    7.033    0.000    1.196    2.119
##    .C9                1.446    0.224    6.446    0.000    1.006    1.885
##    .R1                1.046    0.251    4.172    0.000    0.555    1.538
##    .R2                0.630    0.224    2.815    0.005    0.191    1.069
##    .R3                0.576    0.162    3.551    0.000    0.258    0.894
##     standardizatin    0.102    0.051    1.993    0.046    0.002    0.203
##     quality           0.043    0.041    1.050    0.294   -0.037    0.124
##     jit               0.502    0.063    8.025    0.000    0.379    0.624
##    .culture           0.543    0.051   10.716    0.000    0.443    0.642
##    .performance       0.559    0.150    3.736    0.000    0.266    0.853
##     lean              1.026    0.057   18.037    0.000    0.915    1.137
```

```r
#goodness-of-fit test
fitMeasures(multigroup2,c("chisq","df", "rmsea", "srmr", "nfi", "cfi", "tli", "agfi"))
```

```
##   chisq      df   rmsea    srmr     nfi     cfi     tli    agfi
## 885.450 799.000   0.017   0.052   0.979   0.998   0.998   0.997
```

```r
#Chi-square difference test between the free model and the single constrained model
anova(multigroup1,multigroup2)
```

```
## Chi Square Difference Test
##
##              Df AIC BIC  Chisq Chisq diff Df diff Pr(>Chisq)
## multigroup1 798         884.82
## multigroup2 799         885.45    0.62837       1      0.428
```

The 0.428 P-value implied the two models were not significantly different, hence the single constrained model was equivalent to the free model.

```r
#set the path "culture -> performance" fixed
multigroup.model3 <- '
standardization =~ S1 + S2 + S3 + S4 + S5
quality =~ Q1 + Q2 + Q3 + Q4 + Q5 + Q6 + Q7
jit =~ J1 + J2 + J3 + J4 + J5 + J6
culture =~ C1 + C2 + C3 + C4 + C5 + C6 + C7 + C8 + C9
performance =~ R1 + R2 + R3
lean =~ standardization + quality + jit
culture ~ lean
performance ~ lean + c("b1","b1")*culture
'

#model fit and parameter estimation
multigroup3 <- sem(multigroup.model3, data = test1, estimator = "DWLS", group = "country")
```

```r
summary(multigroup3, fit.measures = TRUE, standardized = FALSE, ci = TRUE)
```

```
## lavaan 0.6-3 ended normally after 78 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                        192
##   Number of equality constraints                     1
##
##   Number of observations per group
##   1                                                442
##   0                                                349
##
##   Estimator                                       DWLS
##   Model Fit Test Statistic                     895.063
##   Degrees of freedom                               799
##   P-value (Chi-square)                           0.010
##
## Chi-square for each group:
##
##   1                                            604.154
```

```
##   0                                          290.909
##
## Model test baseline model:
##
##   Minimum Function Test Statistic          41486.970
##   Degrees of freedom                             870
##   P-value                                      0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                  0.998
##   Tucker-Lewis Index (TLI)                     0.997
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                        0.017
##   90 Percent Confidence Interval        0.009  0.023
##   P-value RMSEA <= 0.05                        1.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                         0.052
##
## Parameter Estimates:
##
##   Information                               Expected
##   Information saturated (h1) model      Unstructured
##   Standard Errors                           Standard
##
##
## Group 1 [1]:
##
## Latent Variables:
##                      Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   standardization =~
##     S1                  1.000                               1.000    1.000
##     S2                  1.248    0.063   19.776    0.000    1.124    1.371
##     S3                  1.243    0.064   19.503    0.000    1.118    1.368
##     S4                  1.142    0.060   19.168    0.000    1.025    1.259
##     S5                  0.844    0.047   17.810    0.000    0.751    0.936
##   quality =~
##     Q1                  1.000                               1.000    1.000
##     Q2                  1.371    0.068   20.200    0.000    1.238    1.503
##     Q3                  1.567    0.077   20.477    0.000    1.417    1.717
##     Q4                  1.591    0.078   20.320    0.000    1.438    1.745
##     Q5                  1.723    0.084   20.524    0.000    1.559    1.888
##     Q6                  1.553    0.078   19.976    0.000    1.401    1.705
##     Q7                  1.451    0.074   19.583    0.000    1.306    1.597
##   jit =~
##     J1                  1.000                               1.000    1.000
##     J2                  0.904    0.051   17.837    0.000    0.805    1.004
##     J3                  1.252    0.066   19.001    0.000    1.123    1.381
##     J4                  1.222    0.065   18.794    0.000    1.095    1.349
##     J5                  1.151    0.062   18.605    0.000    1.030    1.272
```

```
##     J6                 0.905    0.051   17.642    0.000    0.804    1.006
##   culture =~
##     C1                 1.000                               1.000    1.000
##     C2                 1.149    0.053   21.495    0.000    1.044    1.254
##     C3                 1.188    0.056   21.372    0.000    1.079    1.297
##     C4                 1.444    0.064   22.728    0.000    1.319    1.569
##     C5                 1.642    0.071   23.221    0.000    1.503    1.780
##     C6                 1.714    0.074   23.294    0.000    1.570    1.858
##     C7                 1.740    0.074   23.381    0.000    1.594    1.886
##     C8                 1.693    0.074   22.996    0.000    1.549    1.837
##     C9                 1.256    0.058   21.543    0.000    1.141    1.370
##   performance =~
##     R1                 1.000                               1.000    1.000
##     R2                 1.047    0.044   23.738    0.000    0.960    1.133
##     R3                 0.888    0.039   22.745    0.000    0.811    0.964
##   lean =~
##     standardizatin     1.000                               1.000    1.000
##     quality            0.743    0.046   16.004    0.000    0.652    0.835
##     jit                0.676    0.043   15.557    0.000    0.591    0.762
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   culture ~
##     lean              0.433    0.028   15.662    0.000    0.378    0.487
##   performance ~
##     lean              0.652    0.050   13.056    0.000    0.554    0.750
##     culture   (b1)    0.658    0.039   16.986    0.000    0.582    0.734
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                4.853    0.060   80.888    0.000    4.735    4.971
##    .S2                4.790    0.069   69.204    0.000    4.654    4.925
##    .S3                4.790    0.070   68.189    0.000    4.652    4.927
##    .S4                4.783    0.069   69.793    0.000    4.648    4.917
##    .S5                4.959    0.058   84.878    0.000    4.845    5.074
##    .Q1                5.020    0.055   92.116    0.000    4.914    5.127
##    .Q2                4.636    0.063   73.069    0.000    4.511    4.760
##    .Q3                4.672    0.067   70.187    0.000    4.541    4.802
##    .Q4                4.518    0.070   64.427    0.000    4.381    4.656
##    .Q5                4.541    0.074   61.690    0.000    4.396    4.685
##    .Q6                4.604    0.074   62.434    0.000    4.460    4.749
##    .Q7                4.502    0.072   62.584    0.000    4.361    4.643
##    .J1                4.769    0.064   75.073    0.000    4.645    4.894
##    .J2                4.597    0.062   74.688    0.000    4.477    4.718
##    .J3                4.622    0.069   67.056    0.000    4.487    4.757
##    .J4                4.654    0.071   65.491    0.000    4.515    4.793
##    .J5                4.627    0.071   65.396    0.000    4.488    4.765
##    .J6                4.844    0.063   76.749    0.000    4.720    4.968
##    .C1                4.552    0.052   87.014    0.000    4.450    4.655
##    .C2                4.563    0.058   79.091    0.000    4.450    4.676
##    .C3                4.498    0.061   74.175    0.000    4.379    4.617
##    .C4                4.446    0.064   69.947    0.000    4.321    4.570
##    .C5                4.380    0.069   63.263    0.000    4.244    4.516
##    .C6                4.428    0.073   60.955    0.000    4.285    4.570
```

```
##    .C7               4.586    0.074   61.681    0.000    4.440    4.732
##    .C8               4.480    0.074   60.558    0.000    4.335    4.625
##    .C9               4.290    0.064   67.247    0.000    4.165    4.415
##    .R1               4.428    0.054   81.567    0.000    4.321    4.534
##    .R2               4.414    0.057   77.679    0.000    4.303    4.525
##    .R3               4.600    0.053   86.568    0.000    4.495    4.704
##     standardizatin   0.000                               0.000    0.000
##     quality          0.000                               0.000    0.000
##     jit              0.000                               0.000    0.000
##    .culture          0.000                               0.000    0.000
##    .performance      0.000                               0.000    0.000
##     lean             0.000                               0.000    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1               0.716    0.119    6.011    0.000    0.483    0.950
##    .S2               0.756    0.149    5.077    0.000    0.464    1.048
##    .S3               0.829    0.157    5.294    0.000    0.522    1.135
##    .S4               0.935    0.144    6.514    0.000    0.654    1.217
##    .S5               0.886    0.118    7.530    0.000    0.656    1.117
##    .Q1               0.799    0.098    8.174    0.000    0.607    0.990
##    .Q2               0.814    0.114    7.125    0.000    0.590    1.037
##    .Q3               0.697    0.133    5.252    0.000    0.437    0.957
##    .Q4               0.872    0.142    6.143    0.000    0.594    1.150
##    .Q5               0.868    0.153    5.656    0.000    0.567    1.169
##    .Q6               1.164    0.150    7.784    0.000    0.871    1.457
##    .Q7               1.205    0.147    8.205    0.000    0.917    1.493
##    .J1               0.892    0.126    7.067    0.000    0.645    1.139
##    .J2               0.945    0.110    8.554    0.000    0.728    1.161
##    .J3               0.703    0.147    4.783    0.000    0.415    0.991
##    .J4               0.900    0.143    6.302    0.000    0.620    1.180
##    .J5               1.031    0.136    7.563    0.000    0.764    1.298
##    .J6               1.030    0.122    8.457    0.000    0.791    1.269
##    .C1               0.739    0.079    9.363    0.000    0.584    0.893
##    .C2               0.850    0.098    8.714    0.000    0.659    1.041
##    .C3               0.960    0.102    9.377    0.000    0.759    1.161
##    .C4               0.804    0.122    6.609    0.000    0.565    1.042
##    .C5               0.850    0.134    6.362    0.000    0.588    1.112
##    .C6               0.949    0.144    6.594    0.000    0.667    1.231
##    .C7               1.018    0.148    6.873    0.000    0.728    1.308
##    .C8               1.069    0.140    7.615    0.000    0.794    1.345
##    .C9               1.056    0.113    9.307    0.000    0.834    1.279
##    .R1               0.597    0.102    5.853    0.000    0.397    0.798
##    .R2               0.655    0.114    5.756    0.000    0.432    0.878
##    .R3               0.692    0.095    7.256    0.000    0.505    0.879
##     standardizatin   0.473    0.046   10.324    0.000    0.383    0.562
##     quality          0.292    0.026   11.258    0.000    0.241    0.342
##     jit              0.708    0.056   12.592    0.000    0.598    0.818
##    .culture          0.395    0.026   14.984    0.000    0.344    0.447
##    .performance      0.181    0.049    3.715    0.000    0.085    0.276
##     lean             0.402    0.034   11.984    0.000    0.336    0.467
##
##
## Group 2 [0]:
```

```
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   standardization =~
##     S1                1.000                               1.000    1.000
##     S2                1.132    0.041   27.521    0.000    1.051    1.212
##     S3                1.183    0.043   27.782    0.000    1.100    1.267
##     S4                1.157    0.042   27.743    0.000    1.075    1.238
##     S5                1.078    0.042   25.415    0.000    0.995    1.161
##   quality =~
##     Q1                1.000                               1.000    1.000
##     Q2                1.088    0.042   25.769    0.000    1.005    1.171
##     Q3                1.120    0.042   26.889    0.000    1.038    1.201
##     Q4                1.099    0.041   26.980    0.000    1.020    1.179
##     Q5                1.210    0.045   26.720    0.000    1.121    1.298
##     Q6                1.318    0.048   27.684    0.000    1.225    1.411
##     Q7                1.144    0.043   26.915    0.000    1.061    1.227
##   jit =~
##     J1                1.000                               1.000    1.000
##     J2                0.948    0.032   29.267    0.000    0.885    1.012
##     J3                1.054    0.035   30.164    0.000    0.986    1.123
##     J4                0.986    0.033   29.696    0.000    0.921    1.051
##     J5                1.139    0.036   31.324    0.000    1.068    1.211
##     J6                0.943    0.033   28.741    0.000    0.879    1.007
##   culture =~
##     C1                1.000                               1.000    1.000
##     C2                0.984    0.033   30.215    0.000    0.920    1.048
##     C3                0.825    0.032   26.052    0.000    0.763    0.888
##     C4                0.761    0.028   26.888    0.000    0.706    0.817
##     C5                0.998    0.034   29.686    0.000    0.932    1.064
##     C6                1.060    0.035   30.502    0.000    0.992    1.128
##     C7                1.013    0.034   29.889    0.000    0.946    1.079
##     C8                0.884    0.032   27.364    0.000    0.821    0.948
##     C9                0.810    0.030   26.644    0.000    0.751    0.870
##   performance =~
##     R1                1.000                               1.000    1.000
##     R2                0.795    0.033   23.806    0.000    0.730    0.861
##     R3                0.554    0.025   22.204    0.000    0.505    0.603
##   lean =~
##     standardizatin    1.000                               1.000    1.000
##     quality           1.062    0.044   24.149    0.000    0.976    1.148
##     jit               1.165    0.044   26.373    0.000    1.078    1.252
##
## Regressions:
##                  Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   culture ~
##     lean            1.075    0.042   25.787    0.000    0.993    1.157
##   performance ~
##     lean            0.204    0.056    3.661    0.000    0.095    0.313
##     culture   (b1)  0.658    0.039   16.986    0.000    0.582    0.734
##
## Intercepts:
##                  Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1              5.533    0.078   70.568    0.000    5.379    5.687
```

```
##    .S2               4.862    0.089   54.548    0.000    4.688    5.037
##    .S3               4.736    0.093   50.954    0.000    4.554    4.919
##    .S4               5.095    0.087   58.869    0.000    4.925    5.264
##    .S5               5.126    0.099   51.612    0.000    4.931    5.321
##    .Q1               5.387    0.091   59.117    0.000    5.208    5.565
##    .Q2               5.201    0.090   57.613    0.000    5.024    5.377
##    .Q3               5.347    0.082   64.960    0.000    5.185    5.508
##    .Q4               5.149    0.086   59.949    0.000    4.981    5.317
##    .Q5               4.771    0.095   50.055    0.000    4.584    4.958
##    .Q6               4.903    0.093   52.668    0.000    4.720    5.085
##    .Q7               4.722    0.088   53.626    0.000    4.549    4.895
##    .J1               4.851    0.093   52.274    0.000    4.669    5.033
##    .J2               4.788    0.090   53.194    0.000    4.612    4.964
##    .J3               4.708    0.094   50.020    0.000    4.523    4.892
##    .J4               4.556    0.093   48.817    0.000    4.373    4.739
##    .J5               4.470    0.101   44.336    0.000    4.272    4.668
##    .J6               4.716    0.099   47.517    0.000    4.522    4.911
##    .C1               4.974    0.088   56.830    0.000    4.803    5.146
##    .C2               5.057    0.082   61.452    0.000    4.896    5.219
##    .C3               5.453    0.091   59.731    0.000    5.274    5.632
##    .C4               5.794    0.076   76.374    0.000    5.645    5.942
##    .C5               5.275    0.085   61.855    0.000    5.108    5.442
##    .C6               5.023    0.086   58.430    0.000    4.854    5.191
##    .C7               5.049    0.085   59.115    0.000    4.881    5.216
##    .C8               5.178    0.093   55.775    0.000    4.996    5.360
##    .C9               5.327    0.086   61.931    0.000    5.158    5.495
##    .R1               5.278    0.086   61.253    0.000    5.109    5.447
##    .R2               6.057    0.068   89.152    0.000    5.924    6.190
##    .R3               6.255    0.055  113.916    0.000    6.147    6.363
##     standardizatin   0.000                               0.000    0.000
##     quality          0.000                               0.000    0.000
##     jit              0.000                               0.000    0.000
##    .culture          0.000                               0.000    0.000
##    .performance      0.000                               0.000    0.000
##     lean             0.000                               0.000    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1               1.014    0.221    4.582    0.000    0.580    1.447
##    .S2               1.324    0.197    6.710    0.000    0.937    1.710
##    .S3               1.430    0.197    7.245    0.000    1.043    1.817
##    .S4               1.100    0.209    5.271    0.000    0.691    1.508
##    .S5               2.128    0.246    8.663    0.000    1.647    2.610
##    .Q1               1.692    0.248    6.821    0.000    1.206    2.178
##    .Q2               1.416    0.237    5.986    0.000    0.952    1.880
##    .Q3               0.852    0.202    4.211    0.000    0.456    1.249
##    .Q4               1.117    0.209    5.353    0.000    0.708    1.525
##    .Q5               1.405    0.228    6.160    0.000    0.958    1.852
##    .Q6               0.929    0.229    4.057    0.000    0.480    1.377
##    .Q7               1.127    0.203    5.552    0.000    0.729    1.525
##    .J1               1.106    0.219    5.045    0.000    0.676    1.535
##    .J2               1.119    0.216    5.189    0.000    0.697    1.542
##    .J3               0.980    0.226    4.343    0.000    0.538    1.423
##    .J4               1.192    0.208    5.735    0.000    0.784    1.599
```

```
##     .J5                 1.081    0.222    4.875    0.000    0.646    1.516
##     .J6                 1.749    0.212    8.234    0.000    1.333    2.165
##     .C1                 0.992    0.208    4.767    0.000    0.584    1.400
##     .C2                 0.736    0.195    3.769    0.000    0.353    1.119
##     .C3                 1.763    0.251    7.022    0.000    1.271    2.255
##     .C4                 1.034    0.204    5.061    0.000    0.634    1.434
##     .C5                 0.863    0.219    3.949    0.000    0.435    1.291
##     .C6                 0.690    0.213    3.243    0.001    0.273    1.108
##     .C7                 0.821    0.209    3.931    0.000    0.412    1.231
##     .C8                 1.693    0.235    7.205    0.000    1.232    2.154
##     .C9                 1.478    0.224    6.609    0.000    1.040    1.917
##     .R1                 1.043    0.251    4.154    0.000    0.551    1.535
##     .R2                 0.632    0.224    2.823    0.005    0.193    1.070
##     .R3                 0.577    0.162    3.557    0.000    0.259    0.895
##      standardizatin     0.098    0.052    1.895    0.058   -0.003    0.199
##      quality            0.040    0.041    0.966    0.334   -0.041    0.121
##      jit                0.497    0.063    7.934    0.000    0.374    0.619
##     .culture            0.486    0.046   10.588    0.000    0.396    0.576
##     .performance        0.479    0.151    3.178    0.001    0.184    0.775
##      lean               1.035    0.058   17.834    0.000    0.921    1.148
```

```
#goodness-of-fit test
fitMeasures(multigroup3,c("chisq","df", "rmsea", "srmr", "nfi", "cfi", "tli", "agfi"))
```

```
##   chisq      df   rmsea    srmr     nfi     cfi     tli    agfi 
## 895.063 799.000   0.017   0.052   0.978   0.998   0.997   0.997
```

```
#Chi-square difference test between the free model and the single constrained model
anova(multigroup1,multigroup3)
```

```
## Chi Square Difference Test
## 
##              Df AIC BIC  Chisq Chisq diff Df diff Pr(>Chisq)   
## multigroup1 798         884.82                                 
## multigroup3 799         895.06     10.241       1   0.001374 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The result of Chi-Square difference test between the free model and the single constrained model indicated that the two models were significantly different ($p < 0.05$), implying that the path between “culture” to “performance” should not be constrained.

```
#set the path "lean-> culture" fixed
multigroup.model4 <- '
standardization =~ S1 + S2 + S3 + S4 + S5
quality =~ Q1 + Q2 + Q3 + Q4 + Q5 + Q6 + Q7
jit =~ J1 + J2 + J3 + J4 + J5 + J6
culture =~ C1 + C2 + C3 + C4 + C5 + C6 + C7 + C8 + C9
performance =~ R1 + R2 + R3
lean =~ standardization + quality + jit
culture ~ c("a1","a1")*lean
performance ~ lean + culture
'

#model fit and parameter estimation
multigroup4 <- sem(multigroup.model4, data = test1, estimator = "DWLS", group = "country")
```

```r
summary(multigroup4, fit.measures = TRUE, standardized = FALSE, ci = TRUE)
```

```
## lavaan 0.6-3 ended normally after 79 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                        192
##   Number of equality constraints                     1
##
##   Number of observations per group
##   1                                                442
##   0                                                349
##
##   Estimator                                       DWLS
##   Model Fit Test Statistic                    1029.871
##   Degrees of freedom                               799
##   P-value (Chi-square)                           0.000
##
## Chi-square for each group:
##
##   1                                            714.997
##   0                                            314.874
##
## Model test baseline model:
##
##   Minimum Function Test Statistic            41486.970
##   Degrees of freedom                               870
##   P-value                                        0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                    0.994
##   Tucker-Lewis Index (TLI)                       0.994
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                          0.027
##   90 Percent Confidence Interval          0.022  0.032
##   P-value RMSEA <= 0.05                          1.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                           0.056
##
## Parameter Estimates:
##
##   Information                                 Expected
##   Information saturated (h1) model        Unstructured
##   Standard Errors                             Standard
##
##
## Group 1 [1]:
```

```
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   standardization =~
##     S1                1.000                               1.000    1.000
##     S2                1.677    0.087   19.261    0.000    1.507    1.848
##     S3                1.692    0.089   19.069    0.000    1.518    1.866
##     S4                1.557    0.083   18.772    0.000    1.394    1.720
##     S5                1.151    0.066   17.498    0.000    1.022    1.280
##   quality =~
##     Q1                1.000                               1.000    1.000
##     Q2                1.370    0.069   19.923    0.000    1.235    1.504
##     Q3                1.578    0.078   20.245    0.000    1.425    1.730
##     Q4                1.607    0.080   20.111    0.000    1.450    1.763
##     Q5                1.749    0.086   20.324    0.000    1.580    1.918
##     Q6                1.571    0.079   19.780    0.000    1.415    1.726
##     Q7                1.474    0.076   19.423    0.000    1.325    1.623
##   jit =~
##     J1                1.000                               1.000    1.000
##     J2                0.906    0.051   17.894    0.000    0.807    1.006
##     J3                1.259    0.066   19.073    0.000    1.130    1.389
##     J4                1.223    0.065   18.841    0.000    1.096    1.350
##     J5                1.151    0.062   18.657    0.000    1.030    1.271
##     J6                0.909    0.051   17.707    0.000    0.808    1.010
##   culture =~
##     C1                1.000                               1.000    1.000
##     C2                1.018    0.044   23.203    0.000    0.932    1.104
##     C3                1.048    0.046   23.009    0.000    0.959    1.137
##     C4                1.277    0.052   24.768    0.000    1.176    1.378
##     C5                1.452    0.057   25.412    0.000    1.340    1.563
##     C6                1.509    0.059   25.476    0.000    1.393    1.625
##     C7                1.537    0.060   25.536    0.000    1.419    1.655
##     C8                1.494    0.060   25.079    0.000    1.377    1.610
##     C9                1.105    0.048   23.168    0.000    1.011    1.198
##   performance =~
##     R1                1.000                               1.000    1.000
##     R2                1.040    0.044   23.701    0.000    0.954    1.126
##     R3                0.887    0.039   22.758    0.000    0.811    0.964
##   lean =~
##     standardizatin    1.000                               1.000    1.000
##     quality           1.063    0.065   16.430    0.000    0.936    1.190
##     jit               1.029    0.064   16.175    0.000    0.904    1.154
##
## Regressions:
##                  Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   culture ~
##     lean      (a1)    0.864    0.029   29.558    0.000    0.806    0.921
##   performance ~
##     lean              1.006    0.081   12.452    0.000    0.848    1.164
##     culture           0.559    0.038   14.785    0.000    0.485    0.633
##
## Intercepts:
##                  Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                4.853    0.060   80.888    0.000    4.735    4.971
```

```
##    .S2                4.790    0.069   69.204    0.000    4.654    4.925
##    .S3                4.790    0.070   68.189    0.000    4.652    4.927
##    .S4                4.783    0.069   69.793    0.000    4.648    4.917
##    .S5                4.959    0.058   84.878    0.000    4.845    5.074
##    .Q1                5.020    0.055   92.116    0.000    4.914    5.127
##    .Q2                4.636    0.063   73.069    0.000    4.511    4.760
##    .Q3                4.672    0.067   70.187    0.000    4.541    4.802
##    .Q4                4.518    0.070   64.427    0.000    4.381    4.656
##    .Q5                4.541    0.074   61.690    0.000    4.396    4.685
##    .Q6                4.604    0.074   62.434    0.000    4.460    4.749
##    .Q7                4.502    0.072   62.584    0.000    4.361    4.643
##    .J1                4.769    0.064   75.073    0.000    4.645    4.894
##    .J2                4.597    0.062   74.688    0.000    4.477    4.718
##    .J3                4.622    0.069   67.056    0.000    4.487    4.757
##    .J4                4.654    0.071   65.491    0.000    4.515    4.793
##    .J5                4.627    0.071   65.396    0.000    4.488    4.765
##    .J6                4.844    0.063   76.749    0.000    4.720    4.968
##    .C1                4.552    0.052   87.014    0.000    4.450    4.655
##    .C2                4.563    0.058   79.091    0.000    4.450    4.676
##    .C3                4.498    0.061   74.175    0.000    4.379    4.617
##    .C4                4.446    0.064   69.947    0.000    4.321    4.570
##    .C5                4.380    0.069   63.263    0.000    4.244    4.516
##    .C6                4.428    0.073   60.955    0.000    4.285    4.570
##    .C7                4.586    0.074   61.681    0.000    4.440    4.732
##    .C8                4.480    0.074   60.558    0.000    4.335    4.625
##    .C9                4.290    0.064   67.247    0.000    4.165    4.415
##    .R1                4.428    0.054   81.567    0.000    4.321    4.534
##    .R2                4.414    0.057   77.679    0.000    4.303    4.525
##    .R3                4.600    0.053   86.568    0.000    4.495    4.704
##     standardizatin    0.000                               0.000    0.000
##     quality           0.000                               0.000    0.000
##     jit               0.000                               0.000    0.000
##    .culture           0.000                               0.000    0.000
##    .performance       0.000                               0.000    0.000
##     lean              0.000                               0.000    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                1.070    0.109    9.834    0.000    0.857    1.283
##    .S2                0.651    0.154    4.221    0.000    0.349    0.953
##    .S3                0.688    0.163    4.226    0.000    0.369    1.008
##    .S4                0.812    0.149    5.453    0.000    0.520    1.104
##    .S5                0.818    0.120    6.802    0.000    0.582    1.054
##    .Q1                0.807    0.098    8.267    0.000    0.616    0.999
##    .Q2                0.831    0.114    7.283    0.000    0.607    1.054
##    .Q3                0.701    0.133    5.273    0.000    0.440    0.961
##    .Q4                0.869    0.142    6.111    0.000    0.591    1.148
##    .Q5                0.849    0.154    5.502    0.000    0.546    1.151
##    .Q6                1.157    0.150    7.716    0.000    0.863    1.451
##    .Q7                1.190    0.147    8.073    0.000    0.901    1.478
##    .J1                0.896    0.126    7.113    0.000    0.649    1.143
##    .J2                0.945    0.110    8.563    0.000    0.729    1.161
##    .J3                0.692    0.147    4.703    0.000    0.404    0.980
##    .J4                0.905    0.143    6.344    0.000    0.625    1.184
```

```
##    .J5                1.037    0.136    7.627    0.000    0.771    1.304
##    .J6                1.027    0.122    8.430    0.000    0.788    1.265
##    .C1                0.624    0.080    7.825    0.000    0.468    0.780
##    .C2                0.864    0.097    8.897    0.000    0.674    1.054
##    .C3                0.982    0.102    9.647    0.000    0.783    1.182
##    .C4                0.830    0.121    6.866    0.000    0.593    1.067
##    .C5                0.885    0.133    6.677    0.000    0.625    1.145
##    .C6                0.998    0.143    7.002    0.000    0.719    1.278
##    .C7                1.060    0.147    7.214    0.000    0.772    1.349
##    .C8                1.112    0.139    7.989    0.000    0.839    1.385
##    .C9                1.084    0.113    9.605    0.000    0.863    1.305
##    .R1                0.595    0.102    5.817    0.000    0.394    0.795
##    .R2                0.661    0.114    5.821    0.000    0.438    0.884
##    .R3                0.690    0.095    7.233    0.000    0.503    0.877
##     standardizatin    0.342    0.033   10.348    0.000    0.277    0.407
##     quality           0.303    0.027   11.436    0.000    0.251    0.355
##     jit               0.698    0.056   12.580    0.000    0.590    0.807
##    .culture           0.452    0.028   16.069    0.000    0.397    0.507
##    .performance       0.170    0.049    3.471    0.001    0.074    0.267
##     lean              0.179    0.013   13.303    0.000    0.152    0.205
##
##
## Group 2 [0]:
##
## Latent Variables:
##                      Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   standardization =~
##     S1                  1.000                               1.000    1.000
##     S2                  1.030    0.035   29.607    0.000    0.962    1.098
##     S3                  1.076    0.036   29.942    0.000    1.005    1.146
##     S4                  1.053    0.035   29.883    0.000    0.984    1.122
##     S5                  0.981    0.036   27.017    0.000    0.910    1.052
##   quality =~
##     Q1                  1.000                               1.000    1.000
##     Q2                  1.088    0.042   25.766    0.000    1.005    1.171
##     Q3                  1.118    0.042   26.869    0.000    1.037    1.200
##     Q4                  1.099    0.041   26.966    0.000    1.019    1.179
##     Q5                  1.208    0.045   26.699    0.000    1.120    1.297
##     Q6                  1.315    0.048   27.658    0.000    1.222    1.408
##     Q7                  1.143    0.042   26.905    0.000    1.060    1.226
##   jit =~
##     J1                  1.000                               1.000    1.000
##     J2                  0.950    0.032   29.250    0.000    0.886    1.013
##     J3                  1.055    0.035   30.138    0.000    0.986    1.123
##     J4                  0.987    0.033   29.671    0.000    0.922    1.052
##     J5                  1.140    0.036   31.294    0.000    1.069    1.211
##     J6                  0.944    0.033   28.720    0.000    0.880    1.009
##   culture =~
##     C1                  1.000                               1.000    1.000
##     C2                  1.074    0.036   29.616    0.000    1.003    1.145
##     C3                  0.909    0.035   25.758    0.000    0.840    0.978
##     C4                  0.836    0.032   26.525    0.000    0.775    0.898
##     C5                  1.097    0.038   29.195    0.000    1.023    1.170
##     C6                  1.162    0.039   29.950    0.000    1.086    1.238
```

```
##     C7                 1.109    0.038   29.352    0.000    1.035    1.183
##     C8                 0.973    0.036   26.997    0.000    0.902    1.043
##     C9                 0.893    0.034   26.336    0.000    0.827    0.960
##   performance =~
##     R1                 1.000                               1.000    1.000
##     R2                 0.802    0.034   23.564    0.000    0.736    0.869
##     R3                 0.559    0.025   22.031    0.000    0.509    0.609
##   lean =~
##     standardizatin     1.000                               1.000    1.000
##     quality            0.959    0.037   25.614    0.000    0.885    1.032
##     jit                1.050    0.037   28.324    0.000    0.977    1.122
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   culture ~
##     lean      (a1)    0.864    0.029   29.558    0.000    0.806    0.921
##   performance ~
##     lean              0.472    0.086    5.491    0.000    0.303    0.640
##     culture           0.421    0.085    4.943    0.000    0.254    0.589
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                5.533    0.078   70.568    0.000    5.379    5.687
##    .S2                4.862    0.089   54.548    0.000    4.688    5.037
##    .S3                4.736    0.093   50.954    0.000    4.554    4.919
##    .S4                5.095    0.087   58.869    0.000    4.925    5.264
##    .S5                5.126    0.099   51.612    0.000    4.931    5.321
##    .Q1                5.387    0.091   59.117    0.000    5.208    5.565
##    .Q2                5.201    0.090   57.613    0.000    5.024    5.377
##    .Q3                5.347    0.082   64.960    0.000    5.185    5.508
##    .Q4                5.149    0.086   59.949    0.000    4.981    5.317
##    .Q5                4.771    0.095   50.055    0.000    4.584    4.958
##    .Q6                4.903    0.093   52.668    0.000    4.720    5.085
##    .Q7                4.722    0.088   53.626    0.000    4.549    4.895
##    .J1                4.851    0.093   52.274    0.000    4.669    5.033
##    .J2                4.788    0.090   53.194    0.000    4.612    4.964
##    .J3                4.708    0.094   50.020    0.000    4.523    4.892
##    .J4                4.556    0.093   48.817    0.000    4.373    4.739
##    .J5                4.470    0.101   44.336    0.000    4.272    4.668
##    .J6                4.716    0.099   47.517    0.000    4.522    4.911
##    .C1                4.974    0.088   56.830    0.000    4.803    5.146
##    .C2                5.057    0.082   61.452    0.000    4.896    5.219
##    .C3                5.453    0.091   59.731    0.000    5.274    5.632
##    .C4                5.794    0.076   76.374    0.000    5.645    5.942
##    .C5                5.275    0.085   61.855    0.000    5.108    5.442
##    .C6                5.023    0.086   58.430    0.000    4.854    5.191
##    .C7                5.049    0.085   59.115    0.000    4.881    5.216
##    .C8                5.178    0.093   55.775    0.000    4.996    5.360
##    .C9                5.327    0.086   61.931    0.000    5.158    5.495
##    .R1                5.278    0.086   61.253    0.000    5.109    5.447
##    .R2                6.057    0.068   89.152    0.000    5.924    6.190
##    .R3                6.255    0.055  113.916    0.000    6.147    6.363
##     standardizatin    0.000                               0.000    0.000
##     quality           0.000                               0.000    0.000
```

```
##     jit                0.000                               0.000    0.000
##    .culture            0.000                               0.000    0.000
##    .performance        0.000                               0.000    0.000
##     lean               0.000                               0.000    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                0.828    0.223    3.712    0.000    0.391    1.265
##    .S2                1.376    0.196    7.021    0.000    0.992    1.760
##    .S3                1.491    0.196    7.609    0.000    1.107    1.875
##    .S4                1.153    0.207    5.563    0.000    0.747    1.560
##    .S5                2.175    0.245    8.888    0.000    1.695    2.654
##    .Q1                1.690    0.248    6.811    0.000    1.203    2.176
##    .Q2                1.413    0.237    5.971    0.000    0.949    1.877
##    .Q3                0.852    0.202    4.211    0.000    0.456    1.249
##    .Q4                1.115    0.209    5.347    0.000    0.707    1.524
##    .Q5                1.406    0.228    6.163    0.000    0.959    1.853
##    .Q6                0.935    0.229    4.084    0.000    0.486    1.383
##    .Q7                1.127    0.203    5.550    0.000    0.729    1.525
##    .J1                1.108    0.219    5.058    0.000    0.679    1.538
##    .J2                1.117    0.216    5.178    0.000    0.694    1.540
##    .J3                0.981    0.226    4.346    0.000    0.539    1.424
##    .J4                1.191    0.208    5.733    0.000    0.784    1.599
##    .J5                1.082    0.222    4.881    0.000    0.648    1.517
##    .J6                1.747    0.212    8.221    0.000    1.330    2.163
##    .C1                1.205    0.206    5.840    0.000    0.800    1.609
##    .C2                0.669    0.197    3.398    0.001    0.283    1.054
##    .C3                1.696    0.252    6.722    0.000    1.201    2.190
##    .C4                0.981    0.205    4.781    0.000    0.579    1.383
##    .C5                0.772    0.220    3.501    0.000    0.340    1.204
##    .C6                0.595    0.215    2.767    0.006    0.173    1.016
##    .C7                0.738    0.211    3.503    0.000    0.325    1.151
##    .C8                1.618    0.236    6.844    0.000    1.154    2.081
##    .C9                1.410    0.225    6.272    0.000    0.970    1.851
##    .R1                1.058    0.250    4.230    0.000    0.568    1.549
##    .R2                0.625    0.224    2.788    0.005    0.185    1.064
##    .R3                0.573    0.162    3.529    0.000    0.255    0.891
##     standardizatin    0.044    0.060    0.722    0.470   -0.075    0.162
##     quality           0.038    0.041    0.908    0.364   -0.044    0.119
##     jit               0.494    0.063    7.895    0.000    0.371    0.616
##    .culture           0.519    0.044   11.714    0.000    0.432    0.606
##    .performance       0.551    0.149    3.694    0.000    0.258    0.843
##     lean              1.275    0.062   20.609    0.000    1.154    1.396
```

```
#goodness-of-fit test
fitMeasures(multigroup4,c("chisq","df", "rmsea", "srmr", "nfi", "cfi", "tli", "agfi"))
```

```
##    chisq       df    rmsea     srmr      nfi      cfi      tli     agfi
## 1029.871  799.000    0.027    0.056    0.975    0.994    0.994    0.996
```

```
#Chi-square difference test between the free model and the single constrained model
anova(multigroup1,multigroup4)
```

```
## Chi Square Difference Test
##
##              Df AIC BIC   Chisq Chisq diff Df diff Pr(>Chisq)
```

```
## multigroup1 798          884.82
## multigroup4 799         1029.87     145.05       1  < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The result of Chi-Square difference test between the free model and the single constrained model indicated that the two models were significantly different ($p < 0.05$), implying that the path between "lean" to "culture" should not be constrained. Thus, the final model should be the first constrained model having "lean -> performance" fixed and other two paths free to vary. The final model was used to draw the conclusion.

```
#choose the model with "lean -> performance" fixed as the final model
multigroup.model.final <- '
standardization =~ S1 + S2 + S3 + S4 + S5
quality =~ Q1 + Q2 + Q3 + Q4 + Q5 + Q6 + Q7
jit =~ J1 + J2 + J3 + J4 + J5 + J6
culture =~ C1 + C2 + C3 + C4 + C5 + C6 + C7 + C8 + C9
performance =~ R1 + R2 + R3
lean =~ standardization + quality + jit
culture ~ c("a1","a2")*lean
performance ~ c("c1","c1")*lean + c("b1","b2")*culture

#set parameters representing indirect effects
indirect.cn := a1*b1
indirect.us := a2*b2
x_m.diff := a1 - a2
m_y.diff := b1 - b2
indirect.diff := indirect.cn - indirect.us
total.cn := indirect.cn + c1
total.us := indirect.us + c1
total.diff := total.cn - total.us
'
#model fit and parameter estimation
multigroup.final <- sem(multigroup.model.final, data = test1, se = "bootstrap", estimator
= "DWLS", grou
## Warning in lav_options_set(opt): lavaan WARNING: information will be set to
## "expected" for estimator = "DWLS"
```

```
summary(multigroup.final, fit.measures = TRUE, standardized = FALSE, ci = TRUE)
```

```
## lavaan 0.6-3 ended normally after 80 iterations
##
##   Optimization method                           NLMINB
##   Number of free parameters                        192
##   Number of equality constraints                     1
##
##   Number of observations per group
##   1                                                442
##   0                                                349
##
##   Estimator                                       DWLS
##   Model Fit Test Statistic                     885.450
##   Degrees of freedom                               799
##   P-value (Chi-square)                           0.018
```

```
##
## Chi-square for each group:
##
##   1                                          602.893
##   0                                          282.558
##
## Model test baseline model:
##
##   Minimum Function Test Statistic          41486.970
##   Degrees of freedom                             870
##   P-value                                      0.000
##
## User model versus baseline model:
##
##   Comparative Fit Index (CFI)                  0.998
##   Tucker-Lewis Index (TLI)                     0.998
##
## Root Mean Square Error of Approximation:
##
##   RMSEA                                        0.017
##   90 Percent Confidence Interval          0.008  0.023
##   P-value RMSEA <= 0.05                        1.000
##
## Standardized Root Mean Square Residual:
##
##   SRMR                                         0.052
##
## Parameter Estimates:
##
##   Standard Errors                          Bootstrap
##   Number of requested bootstrap draws           1000
##   Number of successful bootstrap draws          1000
##
##
## Group 1 [1]:
##
## Latent Variables:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   standardization =~
##     S1                1.000                               1.000    1.000
##     S2                1.241    0.089   14.012    0.000    1.079    1.425
##     S3                1.236    0.102   12.088    0.000    1.054    1.461
##     S4                1.135    0.098   11.589    0.000    0.965    1.351
##     S5                0.839    0.082   10.271    0.000    0.692    1.012
##   quality =~
##     Q1                1.000                               1.000    1.000
##     Q2                1.371    0.101   13.575    0.000    1.191    1.590
##     Q3                1.566    0.132   11.877    0.000    1.340    1.857
##     Q4                1.590    0.144   11.036    0.000    1.342    1.914
##     Q5                1.722    0.155   11.099    0.000    1.457    2.034
##     Q6                1.552    0.151   10.281    0.000    1.269    1.867
##     Q7                1.450    0.150    9.658    0.000    1.188    1.784
##   jit =~
##     J1                1.000                               1.000    1.000
```

```
##     J2                  0.904    0.080   11.367    0.000    0.760    1.071
##     J3                  1.251    0.103   12.186    0.000    1.078    1.471
##     J4                  1.222    0.108   11.314    0.000    1.033    1.466
##     J5                  1.151    0.095   12.059    0.000    0.978    1.354
##     J6                  0.905    0.084   10.821    0.000    0.761    1.078
##   culture =~
##     C1                  1.000                               1.000    1.000
##     C2                  1.174    0.108   10.848    0.000    0.979    1.406
##     C3                  1.214    0.113   10.789    0.000    1.008    1.459
##     C4                  1.475    0.124   11.856    0.000    1.253    1.738
##     C5                  1.678    0.158   10.606    0.000    1.387    2.012
##     C6                  1.751    0.164   10.679    0.000    1.450    2.109
##     C7                  1.776    0.150   11.821    0.000    1.509    2.103
##     C8                  1.728    0.160   10.800    0.000    1.445    2.086
##     C9                  1.282    0.131    9.791    0.000    1.052    1.560
##   performance =~
##     R1                  1.000                               1.000    1.000
##     R2                  1.033    0.088   11.781    0.000    0.880    1.215
##     R3                  0.877    0.078   11.286    0.000    0.724    1.035
##   lean =~
##     standardizatin      1.000                               1.000    1.000
##     quality             0.738    0.113    6.507    0.000    0.547    0.973
##     jit                 0.668    0.138    4.849    0.000    0.427    0.977
##
## Regressions:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   culture ~
##     lean      (a1)    0.416    0.093    4.494    0.000    0.267    0.621
##   performance ~
##     lean      (c1)    0.618    0.094    6.565    0.000    0.450    0.822
##     culture   (b1)    0.712    0.091    7.863    0.000    0.544    0.911
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                4.853    0.061   79.138    0.000    4.731    4.973
##    .S2                4.790    0.069   69.850    0.000    4.658    4.925
##    .S3                4.790    0.070   68.424    0.000    4.654    4.925
##    .S4                4.783    0.068   70.176    0.000    4.652    4.919
##    .S5                4.959    0.059   84.736    0.000    4.848    5.079
##    .Q1                5.020    0.055   92.041    0.000    4.912    5.124
##    .Q2                4.636    0.064   72.944    0.000    4.514    4.767
##    .Q3                4.672    0.067   69.932    0.000    4.545    4.803
##    .Q4                4.518    0.070   64.238    0.000    4.378    4.656
##    .Q5                4.541    0.075   60.493    0.000    4.396    4.690
##    .Q6                4.604    0.074   62.275    0.000    4.459    4.744
##    .Q7                4.502    0.074   60.585    0.000    4.351    4.656
##    .J1                4.769    0.065   73.930    0.000    4.643    4.898
##    .J2                4.597    0.062   74.586    0.000    4.480    4.731
##    .J3                4.622    0.070   65.738    0.000    4.482    4.753
##    .J4                4.654    0.071   65.446    0.000    4.523    4.799
##    .J5                4.627    0.073   63.608    0.000    4.489    4.783
##    .J6                4.844    0.063   76.435    0.000    4.717    4.968
##    .C1                4.552    0.051   89.768    0.000    4.452    4.649
##    .C2                4.563    0.058   78.818    0.000    4.446    4.674
```

```
##    .C3               4.498    0.062   72.742    0.000    4.369    4.620
##    .C4               4.446    0.064   69.825    0.000    4.308    4.566
##    .C5               4.380    0.070   62.915    0.000    4.240    4.511
##    .C6               4.428    0.074   59.843    0.000    4.278    4.570
##    .C7               4.586    0.074   61.730    0.000    4.441    4.729
##    .C8               4.480    0.077   58.323    0.000    4.328    4.638
##    .C9               4.290    0.066   65.294    0.000    4.152    4.412
##    .R1               4.428    0.054   82.002    0.000    4.321    4.532
##    .R2               4.414    0.058   75.633    0.000    4.296    4.534
##    .R3               4.600    0.054   85.272    0.000    4.495    4.701
##     standardizatin   0.000                               0.000    0.000
##     quality          0.000                               0.000    0.000
##     jit              0.000                               0.000    0.000
##    .culture          0.000                               0.000    0.000
##    .performance      0.000                               0.000    0.000
##     lean             0.000                               0.000    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1               0.708    0.083    8.565    0.000    0.547    0.864
##    .S2               0.759    0.114    6.673    0.000    0.539    0.968
##    .S3               0.832    0.106    7.872    0.000    0.624    1.040
##    .S4               0.938    0.094    9.995    0.000    0.751    1.121
##    .S5               0.888    0.079   11.182    0.000    0.731    1.040
##    .Q1               0.798    0.065   12.235    0.000    0.661    0.918
##    .Q2               0.812    0.079   10.310    0.000    0.655    0.959
##    .Q3               0.697    0.076    9.176    0.000    0.546    0.832
##    .Q4               0.872    0.087   10.059    0.000    0.708    1.044
##    .Q5               0.869    0.088    9.872    0.000    0.704    1.040
##    .Q6               1.165    0.101   11.576    0.000    0.982    1.377
##    .Q7               1.205    0.108   11.162    0.000    0.990    1.411
##    .J1               0.892    0.090    9.910    0.000    0.710    1.063
##    .J2               0.945    0.104    9.121    0.000    0.744    1.145
##    .J3               0.704    0.107    6.582    0.000    0.503    0.909
##    .J4               0.900    0.108    8.314    0.000    0.687    1.121
##    .J5               1.030    0.104    9.881    0.000    0.832    1.246
##    .J6               1.030    0.099   10.455    0.000    0.821    1.211
##    .C1               0.759    0.055   13.726    0.000    0.647    0.860
##    .C2               0.850    0.064   13.251    0.000    0.724    0.979
##    .C3               0.961    0.071   13.582    0.000    0.820    1.100
##    .C4               0.806    0.077   10.417    0.000    0.651    0.953
##    .C5               0.852    0.083   10.222    0.000    0.691    1.015
##    .C6               0.952    0.085   11.173    0.000    0.794    1.124
##    .C7               1.023    0.085   12.083    0.000    0.860    1.202
##    .C8               1.073    0.099   10.854    0.000    0.876    1.263
##    .C9               1.059    0.088   12.011    0.000    0.887    1.238
##    .R1               0.587    0.058   10.133    0.000    0.472    0.705
##    .R2               0.663    0.063   10.476    0.000    0.542    0.787
##    .R3               0.697    0.062   11.192    0.000    0.575    0.822
##     standardizatin   0.471    0.098    4.806    0.000    0.278    0.664
##     quality          0.290    0.063    4.600    0.000    0.171    0.415
##     jit              0.708    0.100    7.101    0.000    0.509    0.903
##    .culture          0.379    0.055    6.911    0.000    0.277    0.489
##    .performance      0.179    0.047    3.826    0.000    0.088    0.272
```

```
##     lean              0.411    0.087    4.738    0.000    0.257    0.598
##
##
## Group 2 [0]:
##
## Latent Variables:
##                     Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   standardization =~
##     S1                 1.000                               1.000    1.000
##     S2                 1.135    0.105   10.804    0.000    0.941    1.367
##     S3                 1.186    0.108   10.977    0.000    1.001    1.425
##     S4                 1.160    0.086   13.456    0.000    1.014    1.342
##     S5                 1.080    0.100   10.799    0.000    0.893    1.280
##   quality =~
##     Q1                 1.000                               1.000    1.000
##     Q2                 1.088    0.086   12.650    0.000    0.940    1.271
##     Q3                 1.120    0.098   11.476    0.000    0.964    1.344
##     Q4                 1.099    0.097   11.361    0.000    0.942    1.328
##     Q5                 1.210    0.109   11.054    0.000    1.033    1.451
##     Q6                 1.318    0.124   10.657    0.000    1.117    1.608
##     Q7                 1.143    0.099   11.528    0.000    0.980    1.361
##   jit =~
##     J1                 1.000                               1.000    1.000
##     J2                 0.949    0.067   14.057    0.000    0.825    1.092
##     J3                 1.054    0.070   15.018    0.000    0.930    1.201
##     J4                 0.987    0.077   12.824    0.000    0.843    1.149
##     J5                 1.140    0.071   16.079    0.000    1.013    1.287
##     J6                 0.944    0.077   12.273    0.000    0.806    1.108
##   culture =~
##     C1                 1.000                               1.000    1.000
##     C2                 0.975    0.060   16.138    0.000    0.857    1.101
##     C3                 0.821    0.087    9.381    0.000    0.657    0.997
##     C4                 0.755    0.077    9.746    0.000    0.607    0.917
##     C5                 0.991    0.078   12.663    0.000    0.849    1.146
##     C6                 1.053    0.072   14.656    0.000    0.920    1.200
##     C7                 1.005    0.066   15.111    0.000    0.879    1.139
##     C8                 0.879    0.097    9.032    0.000    0.695    1.069
##     C9                 0.806    0.083    9.674    0.000    0.648    0.978
##   performance =~
##     R1                 1.000                               1.000    1.000
##     R2                 0.797    0.082    9.683    0.000    0.636    0.963
##     R3                 0.555    0.076    7.302    0.000    0.411    0.712
##   lean =~
##     standardizatin     1.000                               1.000    1.000
##     quality            1.065    0.103   10.369    0.000    0.886    1.290
##     jit                1.167    0.123    9.474    0.000    0.958    1.449
##
## Regressions:
##                   Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##   culture ~
##     lean      (a2)    1.085    0.101   10.774    0.000    0.909    1.325
##   performance ~
##     lean      (c1)    0.618    0.094    6.565    0.000    0.450    0.822
##     culture   (b2)    0.310    0.094    3.302    0.001    0.142    0.497
```

```
##
## Intercepts:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                5.533    0.078   71.220    0.000    5.373    5.688
##    .S2                4.862    0.088   55.067    0.000    4.676    5.037
##    .S3                4.736    0.093   50.795    0.000    4.559    4.931
##    .S4                5.095    0.086   59.297    0.000    4.931    5.264
##    .S5                5.126    0.098   52.426    0.000    4.934    5.332
##    .Q1                5.387    0.093   57.995    0.000    5.201    5.559
##    .Q2                5.201    0.088   59.129    0.000    5.020    5.378
##    .Q3                5.347    0.081   65.810    0.000    5.183    5.504
##    .Q4                5.149    0.081   63.283    0.000    4.989    5.309
##    .Q5                4.771    0.096   49.460    0.000    4.582    4.963
##    .Q6                4.903    0.090   54.454    0.000    4.728    5.074
##    .Q7                4.722    0.089   52.816    0.000    4.544    4.903
##    .J1                4.851    0.093   51.980    0.000    4.673    5.037
##    .J2                4.788    0.088   54.484    0.000    4.605    4.951
##    .J3                4.708    0.094   49.911    0.000    4.530    4.897
##    .J4                4.556    0.090   50.832    0.000    4.370    4.725
##    .J5                4.470    0.098   45.501    0.000    4.272    4.665
##    .J6                4.716    0.096   49.173    0.000    4.530    4.897
##    .C1                4.974    0.084   59.004    0.000    4.805    5.140
##    .C2                5.057    0.083   61.092    0.000    4.900    5.221
##    .C3                5.453    0.090   60.299    0.000    5.281    5.636
##    .C4                5.794    0.077   75.529    0.000    5.650    5.957
##    .C5                5.275    0.085   62.169    0.000    5.103    5.444
##    .C6                5.023    0.086   58.565    0.000    4.851    5.198
##    .C7                5.049    0.085   59.500    0.000    4.883    5.218
##    .C8                5.178    0.094   55.309    0.000    4.986    5.370
##    .C9                5.327    0.088   60.847    0.000    5.149    5.507
##    .R1                5.278    0.083   63.686    0.000    5.118    5.444
##    .R2                6.057    0.067   90.985    0.000    5.928    6.183
##    .R3                6.255    0.056  112.688    0.000    6.146    6.367
##     standardizatin    0.000                               0.000    0.000
##     quality           0.000                               0.000    0.000
##     jit               0.000                               0.000    0.000
##    .culture           0.000                               0.000    0.000
##    .performance       0.000                               0.000    0.000
##     lean              0.000                               0.000    0.000
##
## Variances:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##    .S1                1.018    0.132    7.737    0.000    0.775    1.289
##    .S2                1.322    0.162    8.170    0.000    1.025    1.662
##    .S3                1.430    0.149    9.609    0.000    1.143    1.733
##    .S4                1.097    0.115    9.513    0.000    0.871    1.325
##    .S5                2.128    0.183   11.629    0.000    1.779    2.498
##    .Q1                1.692    0.174    9.697    0.000    1.356    2.045
##    .Q2                1.416    0.164    8.657    0.000    1.113    1.735
##    .Q3                0.852    0.101    8.393    0.000    0.646    1.045
##    .Q4                1.116    0.134    8.319    0.000    0.846    1.378
##    .Q5                1.405    0.135   10.441    0.000    1.135    1.670
##    .Q6                0.929    0.113    8.209    0.000    0.698    1.150
##    .Q7                1.128    0.124    9.089    0.000    0.899    1.369
```

```
##    .J1                 1.107    0.171    6.488    0.000    0.793    1.439
##    .J2                 1.119    0.137    8.154    0.000    0.859    1.395
##    .J3                 0.981    0.124    7.904    0.000    0.748    1.239
##    .J4                 1.191    0.161    7.408    0.000    0.884    1.524
##    .J5                 1.082    0.145    7.458    0.000    0.806    1.379
##    .J6                 1.748    0.194    9.020    0.000    1.382    2.122
##    .C1                 0.925    0.146    6.353    0.000    0.645    1.205
##    .C2                 0.702    0.111    6.309    0.000    0.492    0.914
##    .C3                 1.732    0.165   10.476    0.000    1.407    2.072
##    .C4                 1.012    0.105    9.634    0.000    0.802    1.222
##    .C5                 0.820    0.099    8.250    0.000    0.630    1.027
##    .C6                 0.640    0.095    6.760    0.000    0.455    0.828
##    .C7                 0.780    0.095    8.233    0.000    0.599    0.972
##    .C8                 1.657    0.185    8.973    0.000    1.288    2.019
##    .C9                 1.446    0.147    9.816    0.000    1.170    1.733
##    .R1                 1.046    0.174    6.015    0.000    0.696    1.373
##    .R2                 0.630    0.084    7.477    0.000    0.466    0.798
##    .R3                 0.576    0.078    7.430    0.000    0.429    0.728
##     standardizatin     0.102    0.050    2.060    0.039    0.014    0.212
##     quality            0.043    0.034    1.262    0.207   -0.021    0.115
##     jit                0.502    0.081    6.190    0.000    0.350    0.672
##    .culture            0.543    0.098    5.543    0.000    0.353    0.739
##    .performance        0.559    0.104    5.383    0.000    0.375    0.772
##     lean               1.026    0.173    5.930    0.000    0.693    1.373
##
## Defined Parameters:
##                    Estimate  Std.Err  z-value  P(>|z|) ci.lower ci.upper
##     indirect.cn       0.296    0.056    5.265    0.000    0.201    0.423
##     indirect.us       0.336    0.110    3.053    0.002    0.152    0.586
##     x_m.diff         -0.669    0.136   -4.925    0.000   -0.937   -0.400
##     m_y.diff          0.402    0.123    3.271    0.001    0.170    0.644
##     indirect.diff    -0.040    0.130   -0.309    0.757   -0.291    0.203
##     total.cn          0.914    0.118    7.754    0.000    0.706    1.173
##     total.us          0.954    0.094   10.152    0.000    0.790    1.158
##     total.diff       -0.040    0.130   -0.309    0.757   -0.291    0.203
```

```
#goodness-of-fit test
fitMeasures(multigroup.final,c("chisq","df","rmsea","srmr","nfi","cfi","tli","agfi"))
```

```
##   chisq      df   rmsea    srmr     nfi     cfi     tli    agfi
## 885.450 799.000   0.017   0.052   0.979   0.998   0.998   0.997
```