Volume: 8, Issue: 1
Page: 58-67
2022

International Journal of Science and Business

Journal homepage: ijsab.com/ijsb

Empirical Study of the Optimization of the Lean Production System in China

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Abstract

Lean design can bring more significant benefits. Especially under the background of weak management foundation and weakening labour cost in China's manufacturing industry, lean design is an effective way to significantly reduce cost, simplify management, improve quality and efficiency. However, the industry has not paid attention to and effectively solved the problem of lean design. The purpose of this Paper is to redesign the lean production system of enterprises, explore the redesign theory of lean production system and the evaluation method of lean enterprise rate, and try to make lean production more widely used in enterprises. The main contents of this study include: putting forward the redesign theory of the lean production system. This study systematically analyzes the connotation and structure of enterprise lean production systems and puts forward the redesign theory of lean production systems. This study discusses lean balance, lean improvement and overall lean from the three dimensions of point, line and surface. Considering the influence of environmental dynamics, this study puts forward improvement suggestions on the lean production level of enterprises from the two aspects of market dynamics and technology dynamics and completes the redesign of the lean production system. The research results further enrich the lean related theory and connotation and provide some reference for introducing and promoting lean in enterprises.

IJSB
Accepted 17 January 2022
Published 24 January 2022
DOI: 10.5281/zenodo.5895906

Keywords: *Lean redesign, Overall lean, Lean rate, Environmental dynamics, Knowledge management.*

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INTRODUCTION

According to the investigation and prediction of a new product development research group in the United States, by about 1986, 40% of an enterprise's profits will come from its new products. After more than 30 years of development, the market has changed more rapidly and diverse, and its data does not stay at 40%. The increase of new products will naturally bring changes to the production process, thus affecting the results of the layout of production facilities. When the product variety and batch change greatly, without a good internal layout and spatial topology of the manufacturing system, it is easy to lead to confusion and low efficiency in the production site and improve the operation cost of the enterprise. According to the survey data of Gupta (1990), 1 / 3 of American enterprises rearrange their production workshops every other year. With the continuous prevalence of consumers' personalized needs, small batch, multiple varieties and multiple changes have become the biggest demand characteristics of the new market. Therefore, the product production process of manufacturing enterprises that meet the market demand is more complex and changeable. The traditional production operation and management concept that can meet the needs of few varieties and large batch can no longer be based. At this time, if there is no scientific lean design, it will bring miscellaneous and chaotic spatial organization relations in the manufacturing system and increase the production cost (Wagner et al.2017). The new market environment brings new design and management challenges. In recent years, scholars at home and abroad continue to put forward new management concepts and models such as agile manufacturing, flexible manufacturing, lean manufacturing and cell manufacturing, but these new concepts are still rarely successfully applied in domestic manufacturing industry. There is still a big gap between the product quality of China's manufacturing industry and developed countries such as the United States, Japan and Germany, which is not only related to China's technical level, but also directly related to the low management level of Chinese manufacturing enterprises. However, the improvement of management level is a gradual process, which needs to be accumulated slowly. This requires an article on the preliminary planning and design of the manufacturing system, and the introduction of lean design concept from the source to eliminate waste and facilitate continuous improvement, and simplify the management complexity in the follow-up operation. From the above analysis, it can be seen that no matter from the perspective of market demand, manufacturing industry environment or the development of manufacturing enterprises, lean ideas need to be introduced in the preliminary planning and design stage of manufacturing system to carry out scientific and reasonable planning and design, simplify management, reduce costs and improve efficiency. So as to enhance the competitiveness of domestic manufacturing industry and lay the foundation for the transformation of China's manufacturing industry to intelligent manufacturing.

Problem Statement

Lean production is a production mode formed on the basis of Toyota's combination of Japanese local ideas of "zero inventory" and "just in time production". Japanese enterprises call it "Toyota production mode". The MIT team summarizes this production mode and calls it precision production. More and more domestic and foreign enterprises introduce lean production and establish their own lean production system. Through lean production, many enterprises have achieved good economic benefits by using tools such as value flow diagram, 5S, visual management, rapid type change, one-piece flow and so on. A large number of statistical data show that the lean production level of most enterprises is still not high, the promotion of lean production mode is insufficient, and the effect is difficult to sustain. Even enterprises with better lean implementation will encounter the bottleneck of transformation or development. In essence, these problems are that enterprises do not know enough about their own lean production level and do not know how to carry out the lean improvement. At

present, the development status of enterprise lean production system can be divided into the following three aspects (Wagner et al.2017; Jiang 2017). For enterprises with a high degree of lean in Europe, the United States, Japan and other countries, up to 10 - 15 lean tools are widely used. The lean degree of these enterprises seems to be enough to meet the requirements of enterprises, and the excessive pursuit of lean is not in line with the original intention of enterprise development. However, in the face of globalization, market changes and other external environments, the rapid adaptability of the whole lean production system is not flexible enough, and the existing lean level has no advantages in peer enterprises. In China, state-owned enterprises, foreign enterprises and other enterprises with lean awareness have initially introduced lean production. Although the enterprise lean awareness germinated late, after decades of development, the application of lean tools in enterprises has reached 5-10. However, there is still much room for improvement in lean improvement.

Research Question

Taking the enterprise lean production system as the research object, the lean production system evaluation model is established to evaluate the lean level of the enterprise. At the same time, it analyzes the impact of enterprise scale on enterprise lean production level, and considers the redesign and optimization of enterprise lean production system in dynamic environment. Finally, the lean redesign knowledge management system is established, and the effectiveness of the system is verified by evaluating the lean rate of enterprises. Based on the connotation and framework system of lean production system, this paper systematically puts forward the redesign theory of lean production system, including lean balance theory, lean improvement theory and overall lean theory, and considers the impact of enterprise scale on lean production level as a supplement to the redesign theory of lean production system.

Research Objective

Based on the traditional lean production theory, this paper establishes the theoretical framework of enterprise lean production system and puts forward the concept and connotation of lean production system redesign. Combining lean balance theory, lean improvement theory and overall lean theory, and taking the dynamic changes of the external environment of the enterprise as a supplement, this paper constructs the lean production system redesign theory.

Significance of Research

Lean production system redesign is to use theories and tools to evaluate the lean production level of enterprises in the process of introducing lean or implementing lean continuous improvement, and fully consider the dynamic changes of external market and technology, so as to improve and continuously improve the lean production system of enterprises. The significance of this paper lies in: It is conducive to promote enterprises, especially manufacturing enterprises, to improve their management mechanism and realize information-based and knowledge-based management. The redesign of lean production system can improve the lean production system and promote the improvement of lean production level. Enterprises can use information technology to realize information and knowledge management in combination with their own actual situation.

LITERATURE REVIEW

Empirical Leanness Indicator

The research of lean production began in the automobile manufacturing industry. At present, the most widely used and in-depth research is still in the manufacturing industry. Aiming at the main body of this study, this paper focuses on the summary of lean production theory, the application status and problems of lean production mode, and the proposal of lean design idea

at home and abroad. Lean production theory is different from many theories. It is a summary process based on experience. In 1988, naiichi Ono, former vice president of Toyota, published the most classic work Toyota production mode, which systematically introduced the seven wastes in Toyota production system, as well as a set of management innovation methods for discovering problems and continuous improvement of Toyota. Later, Krafcik of the United States applied the term lean production for the first time in his master's thesis in 1988. In 1990, Womack and others officially named it lean production in the five-year research achievement of Toyota's production mode "machines that change the world". After that, it attracted extensive attention and research from scholars at home and abroad. Womack and others published lean thinking again, which further summarized the core idea of Toyota's lean production mode, put forward five principles of Lean: value, value stream, flow, pull and perfection, and emphasized the importance of value stream analysis. The application research of lean production mode can be divided into two aspects: the application research of lean production mode and method and the summary research of lean production mode application experience. Firstly, in terms of the application of lean production methods and methods, since the concept of lean production was put forward, it has been widely used in manufacturing enterprises with few varieties and mass production due to its market environment. In recent years, many experts and scholars have begun to study its application in the manufacturing system of multi variety and small batch production according to order or design according to order. However, in the research literature after the 21st century, a large number of lean theories such as JIT and eliminating waste are widely used in most industries such as hospitals, service industries, information technology, office management, construction industry and non-profit organizations outside the manufacturing industry.

Market Dynamics

Lean design refers to the process of using lean technology and means to design products, processes or factories. The first step for lean enterprises to implement lean production must start with lean design. In the research of lean design, Zhou j et al. (2018) combined with value stream mapping and simulation, introduced an independent component, proposed the design framework of lean system, and constructed a lean system for engineering manufacturing. In order to improve the production management level of prefabricated parts and reduce the production cost, Li (2019) developed a lean prefabricated parts production system by using the usual manufacturing method, which effectively controlled the queue length and saved the labor cost. Yamazaki y (2015) proposed a new design method of lean automation integrated equipment material handling system to solve the problem of high labor cost in traditional flexible manufacturing system. E seralathan et al. (2016) proposed an integrated structured product development method based on lean design, which helps to identify and eliminate waste. Pezzotta g et al. (2017) put forward the lean design method of product service system and developed the product service system in the whole life cycle under the background of traditional industries moving towards service. Jia et al. (2015) analyzed the mathematical model of production line layout optimization design, and developed a prototype system of production line lean facility layout by using some methods of lean design. As for the research on redesign, Meng et al. (2018) studied the impact of the combination of lean production and modular production on production organization, proposed the modular level evaluation method of production system, and improved the lean system. Das K (2013) integrated the application of lean system in supply chain design and planning model, and applied the results to the design of sustainable supply chain from the perspective of established sustainability indicators. Houshmand m et al. (2019) proposed axiomatic modeling design using process variables and constructed a hierarchical model based on the design process of lean production system, which can be applied to different redesign occasions. Based on environmental

innovation, s Aguado (2018) transformed traditional production system into lean production system through environmental innovation, which improved the income, social responsibility and sustainability of enterprises. Hvam Lars (2018) proposed a visual modeling method integrating product characteristic model and business process model on the basis of considering product characteristics, and redesigned the business process.

METHODOLOGY

Research Design

This study takes the enterprise lean production system as the research object, establishes the lean production system evaluation model to evaluate the lean level of the enterprise. At the same time, the influence of enterprise size on enterprise lean production level is analyzed, and the redesign optimization of enterprise lean production system in dynamic environment is considered. Finally, the lean redesign knowledge management system is established, and the effectiveness of the system is verified by evaluating the lean rate of enterprises. Based on the connotation and framework system of lean production system, this study systematically puts forward the redesign theory of lean production system, including lean balance theory, lean improvement theory and overall lean theory, and considers the impact of enterprise size on lean production level as a supplement to the redesign theory of lean production system. This study proposes lean redesign optimization under enterprise size. This paper analyzes the index selection and measurement methods of enterprise size, takes market dynamics and technical dynamics as the two measurement dimensions of enterprise size, studies the relationship between enterprise lean production level and enterprise size, and puts forward the optimization technology of fine redesign considering enterprise size.

Table 3-1 Measurement description of variables

Variables	Measured variables	Remarks
DV	Inventory Turnover Rate(ITA)	Operating income / inventory
IV	Market dynamics(MD)	MD = log10 (variation coefficient of operating revenue + variation coefficient of operating profit)
	Technical dynamics(TD)	Td = (R & D investment x 100% / operating revenue)
Mediator	Enterprise size(SIZE)	SIZE=Ln (total assets)
	Business growth ability(BAS)	Revenue growth rate = (Operating revenue of the current year-Operating revenue of the previous year) X 100%/previous year's operating income
	Original profitability (OPAI)	Operating profit x 100%/operating income
	Earnings quality(EQa)	EQa=Net cash flow x 100%/operating income

Reliability and Validity Test

The validity refers to the degree of psychological or behavioral traits that can be measured by the set measurement tools. Generally speaking, validity can be divided into three categories: content validity, criterion validity and construction validity. Content validity refers to measuring the applicability and consistency of content. Testing content validity is to test whether the empirical deduction from concept to index is logical and effective. The measurement of this study is based on the relevant literature, and quotes the measurement

items used by scholars. At the same time, before the formal distribution of the questionnaire, the questionnaire has been revised, so that the content of the questionnaire can fully cover the content to be measured. Criterion validity refers to the correlation between test scores and external indicators of the traits to be measured. Each measurement model shall be verified before structural model analysis. The analysis of structural validity is mainly based on factor analysis. In factor analysis, SPSS provides several test methods to determine whether they are suitable for factor analysis, including Bartlett test of sphericity, anti image correlation matrix and kmo (Kaiser Meyer Olkin) test. In this paper, SPSS software is used to test the validity of the questionnaire. When kmo exceeds 0.7, the structural validity is better. The structural validity results of the questionnaire are shown in Table 3-3.

Table 3-2 KMO and Bartlett sphericity test results

Measurement Index	KMO	Bartlett's Test of Sphericity		
		Approx. Chi-Square	df	Sig.
Results	0.864	5982.421	431	0.000

Data Collection Process

This paper uses the data of the Chinese mainland enterprises in the sixth round of the International Manufac-turing Strategy Survey (hereinafter referred to as IMSS) to conduct an empirical analysis in combination with the data obtained by the research team. IMSS project is an academic investigation activity on global manufacturing strategy, practice and development law initiated by London Business School and kamos University in Sweden in 1992. The sixth round of IMSS project involves 26 universities and research institutions around the world. After the first five surveys and the continuous revision and supplement of scholars, the survey content of IMSS project has become more and more reliable, and many papers have been published in internationally renowned journals. IMSS project mainly adopts the questionnaire form of Likert five point scale. 1 indicates the lightest degree and 5 indicates the heaviest degree; The survey was made in the international standard industrial classification C25 to C30 category manufacturing enterprises, mainly involving 7 industries, including machinery, power, electronics, computers, optics, metal products and transport equipment manufacturing. The project obtained 931 manufacturing enterprises samples, of which 128 were Chinese mainland samples. Due to the insufficient sample size of Chinese manufacturing enterprises, the research group translated the IMSS questionnaire and again distributed the questionnaire to Chinese manufacturing enterprises in C25 ~ C30 categories; The members of the research group mainly distributed 300 questionnaires and recovered 263 questionnaires by means of on-site filling and e-mail. Excluding 12 samples with serious data loss, 251 valid questionnaires were obtained, and the effective recovery rate was 83.67%; In addition to the original data in the IMSS project, the research group obtained a total of 251 data samples of China's manufacturing industry. Taking the enterprise lean production system as the research object, the lean production system evaluation model is established to evaluate the lean level of the enterprise. At the same time, the influence of enterprise size on enterprise lean production level is analyzed, and the redesign optimization of enterprise lean production system in dynamic environment is considered. Finally, the lean redesign knowledge management system is established, and the effectiveness of the system is verified by evaluating the lean rate of enterprises.

FINDINGS AND DISCUSSION

Profile of Respondents

This study selects the data of 251 enterprises in three industries from 2014 to 2017, including 108 intelligent machine enterprises, 95 automobile industries and 48 iron and steel industries.

This study compares the maximum, minimum, mean and standard deviation of inventory turnover rate, market dynamics and technical dynamics in these different industries. The analysis results are shown in tables 4-1, 4-2 and 4-3.

Statistical analysis of inventory turnover rate in different industries

Variable	Sample size	Minimum	Maximum	Mean	Mid-value	SD
Intelligent machine	108	0.4822	48.2385	5.6154	3.7907	7.1912
Automobile	95	1.3033	53.3277	8.0363	6.2301	6.7832
Steel	48	1.2369	62.9291	8.2696	6.3866	10.4480

It can be seen from the mean in table 4-1 that the inventory turnover rate of manufacturing enterprises such as automobile and steel industry is high, and their mean is close. The inventory turnover rate of intelligent machine, an enterprise with high added value, is lower than that of the other two industries. According to SD analysis, the inventory turnover ratesd of the iron and steel industry is the highest, indicating that the industry fluctuates greatly.

Table 4-3 Statistical analysis of market dynamics in different industries

Variable	Sample size	Minimum	Maximum	Mean	Mid-value	SD
Intelligent machine	108	-0.8808	1.0455	-0.0420	-0.0608	0.4110
Automobile	95	-0.8880	1.3145	-0.1332	-0.2637	0.4514
Steel	48	-0.7346	3.3737	0.3699	0.2573	0.8372

As can be seen from the mean in table 4-2, the market dynamics of the iron and steel industry is the highest, with a value of 0.3699, indicating that its market fluctuation is large. The market dynamics of intelligent machine industry is the lowest, with a value of -0.0420, indicating that its market fluctuation is small, which is basically consistent with the situation in table 4-3.

Table 4-4 Statistical analysis of technical dynamics in different industries

Variable	Sample size	Minimum	Maximum	Mean	Mid-value	SD
Intelligent machine	108	0.2005	43.0805	6.1641	4.9061	5.6315
Automobile	95	0.0541	60.7721	4.1571	3.5897	6.0724
Steel	48	0.1282	27.7128	3.2825	2.8769	4.1257

It can be seen from the mean in table 4-3 that the technical dynamics of intelligent machine industry and automobile industry are higher than that of steel industry. The high value of technical dynamics shows that as an emerging technology industry, the overall R & D investment of the industry is high, which is basically consistent with the reality.

Impact of Market Dynamics on Enterprise Lean Production Level

Analysis

In order to demonstrate the rationality of the selected variable, it is necessary to test the correlation of the variable. See table 4-4 for the results. It can be found that the enterprise's inventory turnover rate is highly correlated with market dynamics and technical dynamics, and the correlation coefficients are -0.070 and -0.269 respectively. Among them, technical dynamics and market dynamics are negatively correlated with the enterprise's inventory turnover rate. At the same time, the correlation coefficient between BRS and IRT is the lowest, which is 0.059, which is positive correlation, but its correlation is weak. The correlation between other variables is significant, so it is necessary to further test the multicollinearity of variables. See table 4-5 for the results.

Table 4-5 Overall correlation analysis

	ITR	MD	TD	SIZE	BRS	OPRI	EQa
ITR	1.000	-0.040	0.105*	0.006	0.024	0.101*	0.082*
MD	-0.070	1.000	0.047	0.108*	0.154**	-0.254**	-0.077*
TD	-0.269**	0.041*	1.000	-0.222**	0.052	-0.016	-0.171**
SIZE	0.302**	0.046	-0.251**	1.000	0.012	-0.017	0.002
BRS	0.001	0.200**	0.242**	-0.162**	1.000	-0.030	-0.006
OPRI	0.049	-0.518**	0.214**	-0.219**	0.283**	1.000	0.074*
EQa	0.197**	-0.242**	-0.062	0.006	-0.027*	0.434**	1.000

Note: The lower left corner is Spearman correlation, ** indicates that the correlation is significant when the confidence (double test) is 0.01; * indicates that the correlation is significant when the confidence (double test) is 0.05. The upper right corner is the Pearson correlation.

Through the regression of the model, the influence of market dynamics, technical dynamics and their interaction items on enterprise lean production level is verified, and the lean redesign optimization methods under different dynamic environments are proposed. The measurement methods of lean production level of enterprises include lean maturity, lean evaluation and improvement, system evaluation and system dynamics. The above studies mostly evaluate from the aspects of theoretical improvement or system, and do not analyze and sort the factors affecting the lean level of enterprises as a whole, which will lead to the incomplete evaluation of the lean production level. Eroglu believes that the relationship between lean production and enterprise performance varies according to different industries. In inventory management, they add the consideration of enterprise economic scale, and use the empirical leakage indicator (ELI) to measure the enterprise lean production level. However, according to the actual production, the inventory turnover rate of enterprises in the same industry can represent the lean production level of enterprises to a certain extent. Therefore, unlike Eroglu describing the lean production level of enterprises with Eli, this paper uses the inventory turnover rate of enterprises to represent the lean production level of enterprises. Where, inventory turnover rate = enterprise operating revenue / inventory. Among them, inventory includes raw material inventory, WIP on production site and finished product inventory. Sometimes the products in transit to customers are also the inventory of the enterprise.

CONCLUSION

Through the literature review of the empirical research on lean production and enterprise performance, it can be seen that the domestic empirical research on the relationship between lean production and enterprise performance mostly describes the relationship between them from a linear perspective, and pays little attention to the impact of enterprise size on the relationship. Moreover, more research focuses on the data obtained by questionnaire survey, and lacks the empirical analysis of second-hand data (Jiang 2017). Therefore, this paper mainly takes the unbalanced panel data of Chinese manufacturing listed companies from 2015 to 2019 as a sample to empirically test the relationship between enterprise size regulating lean production and enterprise performance. The main research conclusions are as follows: First, build an alternative variable Eli (empirical leakage indicator) to better describe the lean production degree of the enterprise. Compared with the traditional indicators for measuring enterprise lean inventory, such as inventory turnover rate (ITO), Eli is more suitable for the comparison of lean inventory in different industries, and solves the potential observation

deviation, so as to better reflect the change degree of inventory. Secondly, the study found that there is not only a significant inverted U-shaped relationship between lean production and enterprise profitability, but also a significant inverted U-shaped relationship between lean production and enterprise development ability, that is, enterprise profitability and development ability first rise and then decline with the increase of lean production degree. Before the emergence of the pole, the enterprise performance will increase with the increase of the degree of lean production. After the emergence of the pole, the enterprise performance will show a downward trend with the increase of the degree of lean production. Therefore, enterprises need to make a reasonable choice between the saving of inventory cost caused by lean production and the increase of out of stock cost according to the actual situation of enterprises, so as to optimize the level of lean inventory (Wagner et al. 2017). Finally, this paper explores the relationship between the three dimensions of enterprise size regulating lean production and enterprise performance. It is found that industry innovation intensity has a significant positive mediating role not only for lean production and enterprise profitability, but also for lean production and enterprise development ability. Industry growth has a significant negative mediating role for lean production and enterprise profitability, and also has a significant negative mediating role for lean production and enterprise development ability. However, the mediating role of industry competition intensity for lean production, enterprise profitability and enterprise development ability has not passed the test. Future research can make more in-depth analysis and discussion for different subdivided industries to enrich the existing theories (Qin et al. 2018).

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Cite this article:

LI SHIGEN (2022). Empirical Study of the Optimization of the Lean Production System in China. *International Journal of Science and Business, 8*(1), 58-67. doi: https://doi.org/10.5281/zenodo.5895906

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