Factors Affecting Construction Labor Productivity in China: A Case Study of Chongqing

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ABSTRACT
Labor productivity is an important indicator of Chinese construction industry development, so it has a positive influence on study the factors affecting construction labor productivity for the sustainable development in construction industry. Since Chongqing became one of Chinese municipality in 1997, construction industry had a rapid development. But the construction labor productivity in Chongqing is still low. Thus, this paper selects construction labor productivity data in Chongqing as the research object, and indicates labor productivity is affected by eight specific factors from economy, technology, capital, labor and management aspects. Based on the data, this paper uses principal component analysis (PCA) method and multiple linear regression (MLR) to analyze the relationship between labor productivity and affecting factors. The result reveals labor productivity in Chongqing is affected by the average wage in construction industry, GDP and construction and installation engineering investment. Meanwhile, a low labor productivity in Chongqing dues to a lack of technological innovation.

KEYWORDS
Construction industry, labor productivity, affecting factors, PCA, MLR, Chongqing

INTRODUCTION
Following the fast development of Chinese economy, government attaches importance to a sustainable development by transformation and upgrading of industry, productivity improvement and innovation driven. As well, construction industry plays an important role in Chinese economic growth. According to National Bureau of Statistics (2014), construction industry constitutes 7.03 percent of GDP in China with a total construction value of 44,725 billion Yuan in 2014, providing 15.98 percent of Chinese total employment. Although value of construction output keeps increasing tendency, the growth rate of construction output value decreases. Thus, this paper focuses on how to improve construction industry.

Construction belongs to labor-intensive industry, and due to labor costs accounting for nearly 30-50% of the total cost is the dominant productive resource in construction industry (Li X, 2015). Therefore labor productivity plays a key role in determining the financial success of a

project (Liu and Ballard, 2008). Labor productivity is a kind of the single factor productivity, which can evaluate the developing potential and the international competitiveness of a country or an industry. According to The American Association of Cost Engineers International, labor productivity in construction industry is defined as the "rate of output per unit of time or effort, usually measured in labor hours" (AACE International, 2004). Namely, Construction labor productivity can be also explained mathematically by the following equation (Li X, 2015):

$$\text{Construction labor productivity} = (\text{Unit output})/(\text{Labor inputs}) \quad (1)$$

Any promoting in labor productivity will contribute a high deal to the improvement of whole performance in construction industry. There are many researches for identifying the factors affecting labor productivity in construction projects. Welfare is a factor affecting the efficiency of workers directly, Ailabouni N et al. (2009) stated that welfare coupled with efficient management styles to control work activities is essential to achieve a high productivity. Moreover, Shamil G N. (2015) identified four main components as to the main causes of low productivity in UK, including technical, social, managerial and contractual. Hiyassat M A et al. (2016) conducted a questionnaire survey in developing countries, and indicated that the top three ranked dimensions affecting labor productivity are experience increases, financial incentives, trust and communications between managers and workers.

Confronting with the challenge of construction industry fast developing, Chinese government also published many policies to stimulate the development of construction industry. Due to improve construction labor productivity is an efficient way to increase the construction profit with low cost, some previous studies in China have been conducted to find out the factors affecting Chinese labor productivity. Zhu Y E et al. (2008) conducted an input-output model and identified that the productivity growth rate has a strong correlation with the technological progress rate. And Yao and Zeng (2012) suggested that labor cost has incentives on labor productivity and Chinese wage level is currently within the reasonable incentive scope based on the analysis of the provincial panel data of China. Then Mao and Pan (2012) stated that capital stock per labor, industry structure and city scale have a significant influence to promote labor productivity based on 1995-2010 China mutual ground and above city dataset.

Concluding a plenty of previous research on labor productivity, the factors affecting labor productivity can be divided into five aspects with economy, labor, technology, capital and management. However, compared to American and UK, Chinese labor productivity still maintained at a low level. The development of construction labor productivity should keep the same development degree of economic. Under the fast growth of Chinese labor costs, labor productivity also should be promoted. Since Chongqing became one of municipality in the west of China in 1997, Chongqing has turned into one of the most developed city in China. However, Chongqing's construction labor productivity still remains a low level, which is contradictory with the fast economic development. So it can also provide a guiding function for other cities in China to study on how to improve Chongqing's construction labor productivity. Therefore, with fully consideration, this paper selected Chongqing as a typical case to identify main factors affecting construction labor productivity in China.

RESEARCH METHODOLOGY

Factors affecting labor productivity

Given the factors concluded by above literature reviews, a summary of the main factors affecting on labor productivity in construction industry is presented in table 1. This paper will adopt eight accessible factors from these five aspects.

Table 1 Summary of the factors affecting labor productivity.

Category	Factors
Economy	Industry structure and city scale (Mao and Pan, 2012)
Labor	Wage (Ailabouni N et al., 2009, Yao and Zeng, 2012)
	The motivation of laborers (Shamil G N. 2015)
	Experience increases (Hiyassat M A et al., 2016)
Technology	Planning of the resources and building design (Shamil G N. 2015)
	Technological progress (Zhu Y et al., 2008)
Capital	Financial incentives (Hiyassat M A et al., 2016)
	Capital stock per labor (Mao and Pan, 2012)
Management	Procurement method (Shamil G N. 2015)
	Trust and communications between managers and workers (Hiyassat M A et al., 2016)

Principal Component Analysis (PCA) method

PCA is an efficient dimension-reducing technique, which is frequently used for multivariate time series (MTS) dimensionality reduction. Its goal is to extract the important information from the data table and to express this information as a set of new orthogonal variables called principal components (Abdi H and Williams L J, 2010). This paper will adopt eight different multivariate time series of Chongqing as the research target. Nevertheless, there are some correlations between the eight factors. Thus, in order to eliminate the correlations of these factors, this paper uses PCA to reduce the dimension of the factors.

Multiple Linear Regression (MLR)

MLR is applied to establish a model between labor productivity and its affecting factors as a target to recognize the main factors affecting labor productivity. Wiedermann W and Von E A (2015) concluded that the present contribution extends the direction of dependent methodology to a multiple linear regression setting by analyzing distributional properties of residuals of competing multiple regression models. Based on the consequence of PCA, this paper applies MLR to conduct the model between labor productivity and its affecting factors.

RESULT AND DISCUSSION

Data collection

In order to guarantee the accuracy of the conclusion, this paper will use the data of labor productivity calculated by the added value of the construction industry in China. As for the data, this paper analyzes the correlation between labor productivity (LB) and the data collected from the statistics yearbook, with the consideration of the external and internal

aspects, this paper decides to adopt eight data shown as table 2 from the five aspects classified in table 1. Since Chongqing became the only municipality in the west part of China in 1997, the data from 1998 to 2014 are typical to reflect the change of Chongqing's construction industry, this paper decides to adopt the statistics from 1998 to 2014 shown in table 3. All the data are collected from National statistics yearbook and Chongqing statistical yearbook. In order to analyze the tendency of LB and its factors presented in figure1, this paper uses Statistical Product and Service Solutions (SPSS) to standardize the statistics shown in table 3.

Table 2 Data selected for analysis

Aspect	Economy	Technology	Capital	Labor	Management
External	GDP		CIEI	NEP	EN
Internal		TEC	ITE	EDU	WAGE

a) GDP——Gross domestic product.
b) TEC——Technical equipment rate.
c) CIEI——Construction and installation engineering investment.
d) ITE——The input of technical equipment.
e) NEP——Number of employed persons in construction industry.
f) EDU——Education calculated by the proportion of college degree or above.
g) EN——Enterprise number can reflect the influence of competition situation.
h) WAGE——Personnel average wage in construction industry.

Table 3 Statistics of labor productivity and affecting factors in Chongqing from 1998 to 2014.

Year	LB	GDP	TEC	CIEI	ITE	NEP	EDU	EN	WAGE
Unit	Yuan	100 million Yuan	Yuan/ Person	100 million Yuan	100 million Yuan	Ten thousand people	%	Piece	Yuan/ Person
1998	10245	1440.56	3942	125.67	31.72	80.46	1.15	1655	6354
1999	11656	1491.99	4580	385.12	34.55	75.43	2.09	1735	7181
2000	12859	1603.16	5070	165.54	37.09	73.16	2.80	1785	7239
2001	14526	1765.68	6059	198.20	50.87	83.96	1.80	1721	8648
2002	13636	1990.01	8190	295.98	66.86	81.64	3.14	1778	8865
2003	15246	2272.82	8156	387.85	66.72	81.8	3.80	1760	10028
2004	18571	2692.81	7758	851.50	67.42	86.91	3.86	2442	11194
2005	20763	3070.49	7518	1075.9	62.35	82.94	4.35	2310	12860
2006	22123	3491.57	7747	1364.1	67.09	86.6	4.33	2455	15018
2007	24999	4676.13	7411	1846.2	71.73	96.79	3.62	2486	17898
2008	30167	5096.66	7626	2410.7	80.26	105.25	4.05	2483	20658
2009	41902	6530.01	7334	3181.6	87.11	118.78	5.21	2465	23741
2010	43878	7925.58	6085	4137.3	84.72	139.22	10.99	2467	27730
2011	36359	10011.37	6882	5310.9	92.43	134.31	9.48	2530	32064
2012	49010	11409.60	6756	6041.5	95.18	140.88	9.39	2575	35581
2013	58598	12783.26	5906	7389.5	94.55	160.09	8.86	2578	43375
2014	69164	14262.60	6265	8748.6	104.56	166.9	12.17	2591	46036

(Statistic source: National statistics yearbook and Chongqing statistical yearbook)

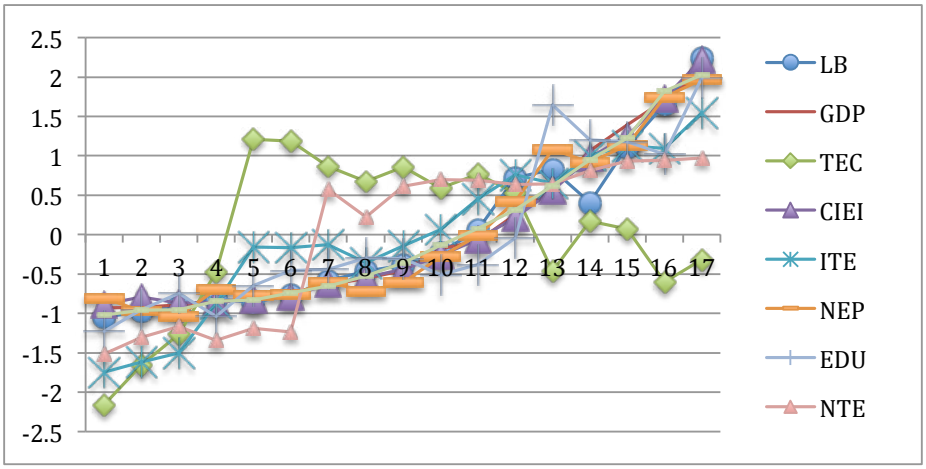

Figure 1. The tendency of factors based on the standardized statistics from 1998-2014.

In figure1, labor productivity almost has similar tendency with other eight factors. Therefore, labor productivity and its factors can be analyzed by MLR. There is no correlations between independent variables is the premise using MLR. In order to eliminate the correlations between the eight factors, this paper adopts PCA method to process these statistics.

PCA method

By SPSS analyzing, the consequence of the correlation matrix is shown in table 4. It is obvious that the eight factors have strong correlations. In order to guarantee these data can be used for PCA, this paper uses Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity to check the availability of these data. The consequence is presented in table 5. And the results demonstrate these data are appropriate to apply PCA method (KMO=0.695 > 0.5 and Sig.=0.000 < 0.05). Subsequently, according to table 6, a cumulative variance of 85% was chosen as the PCA's principal component. It can be seen the sample point 2's principal components number and their accumulative confidence level is 96.752%, respectively are the first principal component (PC1) and the second principal component (PC2). It means that PC1 and PC2 already include 96.752% message of the original factors. From table 7, PC1 and PC2 can be expressed as following equations:

$$PC1=0.982GDP+0.160TEC+0.975CIEI+0.939ITE+0.975\ NEP+0.945EDU + 0.837EN+0.987WAGE \quad (2)$$

$$PC2=-0.156GDP+0.975TEC-0.189CIEI+0.315ITE-0.182\ NEP-0.092EDU +0.325EN-0.124WAGE \quad (3)$$

Table 4 Correlation matrix

	GDP	TEC	CIEI	ITE	NEP	EDU	EN	WAGE
GDP	1	.014	.997**	.876**	.984**	.927**	.751**	.997**
TEC	.014	1	-.020	.469	-.016	.075	.384	.042
CIEI	.997**	-.020	1	.857**	.983**	.923**	.736**	.995**
ITE	.876**	.469	.857**	1	.872**	.855**	.843**	.890**
NEP	.984**	-.016	.983**	.872**	1	.933**	.732**	.986**
EDU	.927**	.075	.923**	.855**	.933**	1	.724**	.920**

EN	.751**	.384	.736**	.843**	.732**	.724**	1	.775**
WAGE	.997**	.042	.995**	.890**	.986**	.920**	.775**	1

(** represents there is a significant correlation under the level of 0.01)

Table 5 KMO and Bartlett's Test(a)

Kaiser-Meyer-Olkin Measure of Sampling. Adequacy		.688
Bartlett's Test of Sphericity	Approx. Chi-Square	300.280
	df	28
	Sig.	.000

Table 6 Total Variance Explained

Comp -onent	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.341	79.262	79.262	6.341	79.262	79.262
2	1.272	15.902	95.164	1.272	15.902	95.164
3	.243	3.033	98.197			
4	.109	1.367	99.564			
5	.028	.355	99.919			
6	.004	.047	99.966			
7	.002	.023	99.989			
8	.001	.011	100.000			

Table 7 Principal Component Analysis.

		GDP	TEC	CIEI	ITE	NEP	EDU	EN	WAGE
Principal	1	.982	.160	.975	.939	.975	.945	.837	.987
Component	2	-.156	.975	.189	.315	-.182	-.092	.325	-.124

MLR model

Based on the reduction of dimension, this paper uses MLR model by SPSS to analyze the relation between PC1, PC2 and LB. The consequences are presented in table 8 and table 9.

Table 8 MLR model and coefficient

Model	Nonstandardized Coefficient		Standardized Coefficient	t	Sig.
	B	Standard error			
(Quantity)	-1.958E-16	.053		.000	1.000
PC1	.972	.054	.972	17.870	.000
PC2	-.118	.054	-.118	-2.178	.047

Table 9 The Anova[a] of MLR model

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	15.337	2	7.669	162.038	.000b
	Residual	.663	14	.047		

Total	16.000	16	

In general, the larger the F value, the better the model fits the tendency of the statistics. The F value of 162.038 shown in table 8 indicates that the MLR model does an excellent fitting job. Moreover, The MLR model has an adjusted R^2 value of 0.959, which indicates the correlation and the variation in the data have a good agreement. The results show that the MLR model is reliable and accurate, and can be explained as the equation below from table 8.

$$LB=0.972PC1-0.118PC2 \quad (4)$$

Thus, the final model is expressed in the eight affecting factors by the following equation.

$$LB=0.973GDP+0.040TEC+0.970CIEI+0.875ITE+0.969NEP+0.930EDU+0.775NTE+0.974WAGE \quad (5)$$

From the equation (5), it is obvious that although all factors have a positive impact on labor productivity in Chongqing, there are still some differences. The sorts according to influence degree on labor productivity are economy, labor, capital, management, and technology. In general, the greater the coefficient of the factor, the more influence on labor productivity. Therefore, the coefficients in equation (5) indicate GDP, construction and installation engineering investment, the average wage in construction industry pose the biggest impact on labor productivity in Chongqing. Wage is a factor affecting enthusiasm of workforce directly, so it is natural that wage poses a strong positive effect on labor productivity. GDP and labor productivity are two factors interact with each other, especially construction industry is the pillar industries in China. The development of labor productivity will improve GDP directly, similarly, the improvement of GDP will bring a remarkable positive impact on labor productivity. Improving construction and installation engineering investment will form a similar effect on labor productivity like GDP. However, labor productivity in Chongqing is still on a low level in China. Although construction and installation engineering investment is abundant, the investment on technological innovation in Chongqing construction industry is still very poor. This also can be found in equation (5), improving rate of technical equipment does a little use on labor productivity with the value of 0.04. According to the second time science research and development (R&D) test resources inventory in Chongqing, R&D funding of construction industry in 2010 is 13.22 million Yuan, accounting for all R&D funding is just 0.17%. That is to say, the government and enterprise need pay more attention to improve techniques and lay emphasis on technological innovation in construction industry, like the application of BIM and housing building industrialization.

CONCLUSION

This paper has proposed a method using principal component analysis (PCA) and multiple linear regressions (MLR) for analyzing the time series data of labor productivity and its affecting factors. Given above results, labor and capital aspects should be focused on to stimulate the development of construction industry. Particularly, labor productivity in Chongqing is affected by GDP, construction and installation engineering investment, the average wage. The result also reflects improving technical equipment rate just brings a little benefit on labor productivity in Chongqing, obviously, labor productivity is not affected by a pure input of technology, it is more important to emphasize technology innovation.

This paper comes up with some effective suggestions for Chongqing to improve its labor productivity. Firstly, to promote technological innovation definitely brings an obvious improvement of construction labor productivity. Technological innovation can improve labor efficiency and save labor cost, so technological innovation can help to increase labor productivity effectively. Besides that, improving the average wage can be an efficient way to stimulate enthusiasm of labors based on considering labor cost. Finally, improving investment pose a direct effect on labor productivity, while improving GDP pose an indirect effect. And these suggestions also can be used in other cities in China or other countries, which still remains a low level of construction labor productivity when the economy has been promoted.

This paper provides some useful suggestions for government and enterprise to improve construction labor productivity. However, data in this paper may not be very comprehensive with available consideration. Thus, additional studies are required to take more data into consideration. Moreover, additional studies on labor productivity in other regions in China should be included in future studies.

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