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Research on the work performance improvement of the disabled in product lines based on the learning curve

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Abstract. Under different national and historical conditions, the specific content of social security system are not consistent. However, there is a common point that multilevel security projects are correspondingly arranged for meeting multilevel needs of social individuals. At present, to fulfill social responsibilities and avoid paying employment funds for the disabled, many enterprises have recruited a significant number of disabled employees. Given the fierce competition, employees' work efficiency is the lifeblood of enterprises development. It's an urgent problem for global enterprises how to improve the work performance of disabled employees. In this paper, it introduces a special factor which distinguishes the handicapped from the normal based on the traditional learning curve model, According to the double-factor learning curve model, it builds a learning curve model for the disabled. By comparing the results calculated by the traditional learning curve with that of the improved learning curve, it founds that the latter is more accurate and reasonable. This study puts forward specific solutions to enhance the work performance of the disabled. Meanwhile, it can also provide references for the same type enterprise decision-makers.

Key words. Work performance, two-factor learning curve model, special factors, the disabled learning curve model.

1. Introduction

With economy developing rapidly, social security system is gradually completed by promoting public welfare level and improving the quality of national life. However, it becomes a significant and ineluctable problem to safeguard and promote employment for the disabled. National governments put too much emphasis on the security of the handicapped, and give increasing investments annually. In China, the law of safeguarding the disabled expressly stipulates that state agencies, enter-

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prises should arrange proper jobs for the disable people. By contrast, the enterprises not employing the disable persons or the number of disable workers being less than stipulated ratio should pay proper employment funds for the disable persons. For security of the disabled, American administration also put forward the disability insurance(DI) program, and facilitate the employment of a portion of disable persons[1].Under this social background, the enterprises reached a consensus gradually about the employment security of the disabled that enterprises have recruited a mass of disable employees successively.

As for enterprises, work efficiency has always been the core issue of the production operation management research. Some scholars made a survey about work performance, the result of which demonstrated there was different work performance in various companies [2], and a study tested a model of the link between psychological strain and work performance [3]. Przemyslaw Korytkowski developed a competences-based analytical model of the performance of multi-skilled workers undertaking repetitive tasks, taking into account learning and forgetting, meanwhile, by binding together hierarchical competences modeled as a weighted digraph together with a learning and forgetting curve model to express individual learning rates [4]. Xiao Qianqiao took the dynamic reactive of employee learning curve on production process into consideration, to research the dynamic relationship between human machine resource and employee learning capacity in which the production-cost, production-time and production quality were taken as the optimal objects of workshop lean production. The optimized allocation solution was obtained. In order to improve the teaching effect and students' participation enthusiasm, Wu Boliang put forward the optimization tactics of campus production practice combining with the theory of learning effects. Guo Li ey al combined with the regression analysis theory and learning curve model, analyzed the cumulative average workload and unit training time, and established the learning curve equation, effectively evaluated the actual welder training of the employees in learning ability and work ability. After all, the disabled is a special group, from the view of efficiency, the disable workers are much less than normal staffs. TA. Grossi use self-operated auditory prompting system to improve the work performance of blind employees, and partly to solve the employment problem of disable persons [5]. The scholar Zhang Ran did research on disabled persons' job performance, and found that the feeling of organizational justice does not influence their task performance formally stated in job description, but the contextual performance that are not required by job roles and can not be identified in organizations' formal reward system, therefor, as organization leaders, to take related measures to construct a justice work atmosphere and improve job embededness, is an effective approach to improve and ameliorate of job performance of the vulnerable group in workplace. Recently, behavioral experimental research methods were regarded as a focus of attention by the international operation management. People emphasized that behavioral approach has great impact on performance improvement again, but the learning curve is characteristic function describing the improvement of production performance due to the learning and the accumulation of experience.

The learning curve theory was proposed by Wright firstly, majored in the aircraft

manufacturing, in subsequent decades this theory is widely used in other areas [6]. Lately, Zhixiang Chen et al have summed up the related research of the learning curve in the industrial production operation, and summarized their expressions and characteristic. The learning curve was introduce into the implementation research of ERP, to describe the law which enterprises work efficiency change with project time. In the perspective of science and technology, using the learning curve model can not only predicate the relation between profits and costs in the process of semiconductor manufacturing [7] as well as the electronic mechanical systems reliability [8], but also be applied to medical technology improvement [9]. With the further research and development of the learning curve, existing studies combined learning with forgetting effect to evaluate staffs' training time and work performance improvement. As far as energy costs are concerned, Amy J.C. Trappey et al explored the determinants of photo-voltaic system cost with the learning curve hierarchical model [10].Since the multi-factors learning curve index model had been put forward, the application of this theory got into a new stage. A research used LCM, respectively from personality, learning attitude and learning skills, to synthetically evaluate the team-learning performance [11]. JunHua Li et al broke through the limitations of traditional single-factor learning curve, and established a double-factors measure model for organization technology learning. Combining with the above academic researches, few scholars apply two-factor learning curve model to study enterprise employees' production performance improvement, and even it's still rare that there is research on production performance for the disabled. On behavioral learning, there exist differences between the normal and the handicapped, traditional learning curve model cannot estimate precisely the production performance improvement of disable employees. On the basis of traditional learning curve, this study attempts to establish a two-factors learning curve model for the disabled.

2. Establishing the learning curve model for disable workers

The traditional learning curve only consider a factor that affects the production progress, its model is described as follow:

$$Q_x = kx_n^b \tag{1}$$

where the variables are defined as follows:

Q_x: product hours at x_{th} production for the normal staffs;

k: constant, product hours at the initial production for normal staffs;

x_n: cumulative number of products for the normal;

b: learning constant, a simpler expression is introduced as a progress ratio,$r = 2^{-b}$.

Cobb-Douglas multi-factor [12] index model was found in the article of Bemis et al., which was expressed as follows:

$$Q = b_0 x_1^{b_1} x_2^{b_2} \cdots x_n^{b_n} \varepsilon \tag{2}$$

where Q is the cost; $b_0$is constant, and initial value;b_i(i=1,2...n) is learning coefficient of the i_{th} factor;$x_i$is the i_{th}independent variable, the i_{th}factor; and ε is the error term, which is typically omitted in real applications.

In fact, human behaviors have significant influence on productivity, the typical learning curve describes a characteristic function that the normal improve their work performance on account of their study and experience accumulation, and yet neglect work performance improvement for the disabled. Compared with normal workers, factors having an impact on the work performance of disable employees are more than production progress factor, also include blocking factors, such as inconvenient behaviors, psychological difference and the like. In this paper, the above factors are called comprehensive obstructive factors. That is to say comprehensive obstructive factors are adverse to disabled workers' production performance improvement. Therefore, this paper combines with the multi-factor index model and the single-factor model, introducing a new, special factor $x_s$into the learning curve for the normal, and reconstruct a characteristic function describing the work performance improvement of the handicapped. Certainly, this model is also based on three assumptions the same as the learning curve for normal. It's expression as follows:

$$Q_s = k^{'} x^{-b^{'}} x_s^{-b_s} \tag{3}$$

Q_s: product hours at x_{th} production for the disable employees;

k': constant, product hours at the initial production for disable staffs;

x_d: cumulative number of products for the disable;

b': cumulative production learning constant, only related to the progress rate r,$r = 2^{-b^{'}}$;

x_s: accumulative difference, comprehensive obstructive factor,$x_n - x_d$;

b_s: accumulative difference learning constant.

The progress rate$r$means the percentage of cumulative learning experience and progress achievement, namely, when output increase double, the cost of new products (man-hours, costs or other units of measurement) cut down at certain proportion, and the proportion is called for progress rate. Put another way, the lower progress rate is, the higher work performance (UPH or productivity) become.

To calculate this model conveniently, the study utilize multiple linear regression (MLP) to analyze learning curve model for the disabled. Firstly, taking logarithm on both sides of eq. (3) at the same time, it can be obtained as follows:

$$\ln Q_s = \ln k^{'} - b^{'} \ln x - b_s \ln x_s \tag{4}$$

Finally, it can be attained by fitting eq.(4),as follows:

$$Y = B_0 - B_1 X_1 - B_2 X_2 \tag{5}$$

where Y denotes $\ln Q_s$;$B_0$is $\ln k^{'}$;B_1,B_2 respectively denote $b^{'}$,b_s;X_1,X_2 denote $\ln x$,$\ln x_s$ separately.

3. Empirical case study

The group F is a high-tech enterprise specializing in three Cs products research and development , including computer, communications, consumer electronics, which widely involved in digital content, automotive components, path, cloud computing services as well as the development and application of new energy, new materials. To undertake social responsibilities and promote the employment of disable people, the group F has set up a sun family production line, where there are majority of the deaf and a few employees with dwarfism. In this study, it intends to use the capacity data of sun family production line to test the new learning curve model for the disabled.

In Table1, there are 18 groups capacity data from the F group staffs' practical UPH.

Table 1. The practical UPH of F group staffss

Days	UPH of the disable	UPH of the normal	Days	UPH of the disable	UPH of the normal
1	160	176	10	255	300
2	172	200	11	262	300
3	184	250	12	268	300
4	197	275	13	268	300
5	200	290	14	270	300
6	219	295	15	281	300
7	231	295	16	290	300
8	246	300	17	294	300
9	251	300	18	300	300

Through calculating and disposal data of Table1, cumulative UPH and cumulative differences of the disable staffs can be obtained, as shown in Table2.

Table 2.The values of cumulative UPH and differences

Days	The normal sum UPH x_n	The disabled sum UPH x_d	The cumulative differences x_s
1	176	160	16
2	376	332	44
3	626	516	110
4	901	713	188
5	1191	913	278

Table 2.The values of cumulative UPH and differences (next)

6	1486	1132	354
7	1781	1363	418
8	2081	1609	472
9	2381	1860	521
10	2681	2115	566
11	2981	2377	604
12	3281	2645	636
13	3581	2913	668
14	3881	3183	698
15	4181	3464	717
16	4481	3754	727
17	4781	4048	733
18	5081	4348	733

According to the relationship between the variables in eq.(5) and the corresponding variables in eq.(4), it uses Excel software to calculate average work hours of each product for the handicapped, after that it takes logarithm of y,x and x_s in Table2 respectively, and marks Y, $X_1$and X_2, analysis results as shown in Table3.

Table 3.The values of each variable in regression equation

Days	Cumulative time(s)	y s/unit	X_1	X_2	Y
1	3600	22.500	5.075	2.773	3.114
2	7200	21.687	5.805	3.784	3.077
3	10800	20.930	6.246	4.700	3.041
4	14400	20.196	6.569	5.236	3.006
5	18000	19.715	6.817	5.628	2.981
6	21600	19.081	7.032	5.869	2.949
7	25200	18.489	7.217	6.035	2.917
8	28800	17.899	7.383	6.157	2.885
9	32400	17.419	7.528	6.256	2.858
10	36000	17.021	7.657	6.339	2.834
11	39600	16.660	7.774	6.404	2.813
12	43200	16.333	7.880	6.455	2.793
13	46800	16.066	7.977	6.504	2.777
14	50400	15.834	8.066	6.548	2.762
15	54000	15.589	8.150	6.575	2.747
16	57600	15.344	8.231	6.589	2.731
17	61200	15.119	8.306	6.597	2.716
18	64800	14.903	8.377	6.597	2.702

Where y is the average working hours of each product for the disable; X_1,X_2 is shown for $\ln x$,$\ln x_s$;Y is $\ln y$.

Through data in above table, this paper firstly uses the traditional learning curve model to calculate learning curve for normal persons and handicapped workers respectively, as follows:

$$Q_t^n = 44.7x^{-0.150} \tag{6}$$

Eq.(6) shows the learning curve model of normal workers, and by above equality, the progress rate of normal employees can be obtained,$r_n = 90.11\%$,and the initial product man-hour is 44.7s;

$$Q_t^d = 48.4x^{-0.1372} \tag{7}$$

Similarly, eq.(7)shows the learning curve model of disable staffs, and the progress rate of the disabled is 90.92%, the first product labor-hour for disable workers is 48.4s.Obviously, $90.92\% > 90.11\%$, so it's unreasonable that the progress rate of the disabled is higher than that of normal persons. Based on this issue, this study takes the improved two-factor model to reappraise the learning curve of disable workers in this case.

The correlation analysis of X_1,X_2,Yin Table3 are conducted by SPSS, the fol-

lowing results are presented in Table4.

Table 4.Correlation intensity among X_1, X_2 and Y

Correlation level coefficient				
		X_2	X_1	Y
X_2	Pearson Correlation	1	.965**	-.894**
	Sig. (Both-sides)		.000	.000
	N	18	18	18
X_1	Pearson Correlation	.965**	1	-.979**
	Sig. (Both-sides)	.000		.000
	N	18	18	18
Y	Pearson Correlation	-.894**	-.979**	1
	Sig. (Both-sides)	.000	.000	
	N	18	18	18
.The correlation is significant at 0.01 level(Both-sides)				

According to the result in Table4, the correlation coefficients of variable X_1, X_2 and dependent variable Y are respectively -0.979,-0.894.It can be seen variables X_1, X_2 all have a negative correlation with Y, moreover, the correlation of X_1 is more stronger than X_2.The present study apply SPSS software to take regression analysis on the corresponding data in Table3.A regression equation can be obtained, as follows

$$Y = 4.09 - 0.235X_1 + 0.0871X_2 \tag{8}$$

Meanwhile,by the above eq.(8), it's sure that the learning curve for disabled of the F group sun-family production line can be attained, as the eq.(9) shown:

$$Q_s = 59.74x^{-0.235}x_s^{0.087} \tag{9}$$

There into, the progress rate of the disabled can be obtained by the above equation,$r_d^{'} = 84.97\%$, and then initial product man-hour is 59.74s. Because of $r_n > r_d^{'}$, in fact, the progress rate for the disable people inferiors to that of the normal. Therefore, comparing to the traditional learning curve model, this improved model for disable persons is more reasonable, more practical and accurate.

4. Results and discussion

Finally, based on Table2, comparing with the calculative UPH of normal workers and the cumulative UPH of the disabled, it exhibits as the below Figure1 shown:

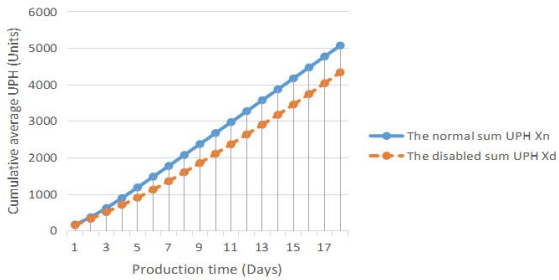

Fig. 1. The compared result of the normal cumulative UPH and the disabled cumulative UPH

Combining with the factor of learning curve in seven aspects, this study explores and analyzes how to enhance staffs' work performance. To find out the sub-factors of x_s, it excludes the common factors between the normal and the disable. The Figure 2 includes four sub-factors of x_s, as follows:

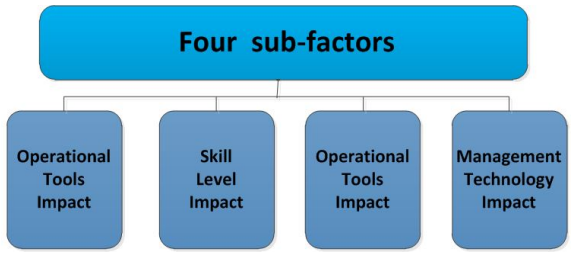

Fig. 2. The special factors of the learning curve for disable workers

Basing on above four sub-factors, the research have further analysis on work performance of the disable, and put forward specific solutions.

Proposal A: Unskilled operation result from unreasonable worker training among disable employees. Aim at this problem, the enterprises need to set up a training model which is special for the disable workers, such as audio-visual mode. At first, using sign language to explain operating standards; secondly, the input of sign language-visual teaching, deepening operation expression; last, it can utilize the whiteboard training, to make the skill level of disable workers more standard.

Proposal B: The lack of special auxiliary tools causes the inconvenience of disable workers' behavior. It's an essential way to improve work performance for handicapped workers. For instance that the semiautomatic chair set specifically for the dwarfism, or nearby the workbench the alarm devices can be installed to remind of deaf-mutes.

Proposal C: Unreasonable post arrangement about the disabled. According to each worker's capacity level and job characteristics, the enterprise should arrange proper job for suitable workers, in the meantime, in accordance with post characteristics, and keep every workers in a comfortable workplace at the most extent, for example, some positions requesting workers' stature cannot arrange the dwarfism.

Proposal D: Compared with the normal, there are double difficulties in manage-

ment technology, it is respectively communication and psychological problems. As communication mode between disable employees and normal workers is not unified, it's inconvenient for communication among workers, and also feedback information not in time, resulting in decreasing workers' performance. For communication problems, it's necessary to unify gesture language and encourage normal workers to learn this kind language. At working time, staffs can use card to talk with each other. In the aspect of psychology, disable workers is not so good as the normal. They need more care and encouragement, therefore, an enterprise should arrange regular psychological counseling for disabled employees, managers should regularly inquire their greeting. As a matter of fact, communication not only can keep employees in pleasure, also is conducive to alleviating psychological pressure. Good psychological quality is a guarantee to improve job performance.

5. Conclusion

Based on the traditional single factor learning curve, in this paper, it inputs a special variablex_s that is cumulative difference, and analyzes the relationship among cumulative productions, cumulative differences and production times, and seeks out existing rules, eventually, establishes a learning curve model for the disabled. The study applies practical data to exam the feasibility of new learning curve model, and alculates the learning curve equation of this line for the disable staffs.

In accordance with four sub-factors of x_s, this study proposes four kinds of solution to certain extent, it can provide gists for the enterprises. At present, there are many questions deserving to study and explore further in detail, which are related to the learning curve model for the disable. For example, how to study the model for disable persons on the basis of learning-forgetting effect, to decide disable workers' optimal training time on which their work performance is greatest. Moreover, this paper mainly focus on the work performance of disable employees in production industry. Thus, more attention should be paid to service industry even widely.

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