

Research on Association with Freight Transit Period and Forwarding Time base on Logistics conditions

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Abstract—The whole process of freight forwarding includes multiple links. The consumption time of every link and its operational efficiency may affect the entire freight forwarding time, which can influence the transit period of freight, as well as the formulation and achievement of the transportation organizations scheme and the transportation contract. In order to analyze the existed problems in present calculation method of railway transit period, and the effects of logistics on forwarding time, on the basis of investigating and literature, Railway freight forwarding process and factor of logistics on railway freight forwarding time were analyzed, and average speed of through train, ordinary through train and high-speed train, and daily average running tariff kilometer and time were analyzed, and statistical results were examined by adopting χ^2 testing method, finally, daily average running tariff kilometer and time of logistics developed and under-developed area were comparative analyzed, from which daily average running tariff kilometer and time were obtained. The analytical results show that the average speed, daily average running tariff kilometer and time respectively obeys normal distribution, the maximum difference value between the transit period calculated by present method and the practical forwarding time of freight is four 4.5 days, which show that the method can not objectively responds the freight forwarding time of each kind of freight transport product under logistics condition.

Index Terms—Forwarding time, Transit Period, logistics, Probability distribution, Statistical analysis

I. INTRODUCTION

With the adjustment of railway productivity distribution, the needed operation links of railway freight delivery decrease gradually, and the parameters having influences on θ vary to different degree, of which v_{pl} increase constantly, t_z and t_x decrease gradually, while t_y and t_w change slightly.

In the context of railway productivity distribution adjustment, average speed of non-through train, ordinary through train and fast freight train as well as daily average running tariff kilometer are analyzed, and the statistic results have been carried out χ^2 test. The analyzing results show that: both the

average speed of each kind of train and the daily average running tariff kilometer obey normal distribution respectively. Finally, the daily average running tariff kilometers of freight trains before and after railway productivity distribution adjustment have been comparatively analyzed, which shows that the timeliness of railway freight forwarding improves constantly in the context railway productivity distribution adjustment.

The whole process of freight forwarding includes multiple links. The consumption time of every link and its operational efficiency may affect the entire freight forwarding time, which can influence the transit period of freight, as well as the formulation and achievement of the transportation organizations scheme and the transportation contract[1]. In recent years, a series of measures which involve in merging railway station and segment, shutting down the small intermediate station, developing strategic loading or unloading location, carrying out long locomotive routing, etc. have been taken to adjust railway productivity distribution. The implementation of above measures has been greatly promoted Chinese railway's transport capacity resource optimization allocation, realized the systematic speed raising of existing railway, and constantly upgraded the timeliness of freight forwarding, in the meantime, booming logistics have affect railway transportation product, and the whole process of railway freight forwarding is simplified, and freight forwarding time is shorten. Based on the research achievement of relative references[2-5] and investigating analysis, adopting random process and mathematical statistics theory, in this paper the influences of railway productivity arrangement on freight forwarding time is analyzed, relationship between the railway freight forwarding time and transit Period which can provide a theoretical basis to further determining freight transit period and transportation organization scheme[3].

II. ANALYSIS OF RAILWAY FREIGHT FORWARDING PROCESS

Railway freight transit period is defined as the time is taken for transporting freight from origination to destination with corresponding organization methods.

$$T = t_f + t_y + \sum t_t \quad (1)$$

Among them

$$t_y = l/l_r \quad (2)$$

Where T represents freight transit period; t_f represents transmission operation time; t_y represents transportation time; $\sum t_t$ represents additional time of special operation; l_r represents daily average running tariff kilometer; l represents kilometrage for charging rates.

At present, the value of parameter t_f is 1d; the value of parameter l_r is 250 kilometers (for general freight) or 500 kilometers (for express freight), and current freight transit period is calculated from the second day of acceptance of carriage. $\sum t_t$ mainly refers to the special operation time in transport for part load, such as container of 1t(5t ro 6t) , refrigerator car, car load freight, and standard mile gauge exchange, etc.

The organization process of railway freight includes operation in loading station, technical station ,unloading station and general stations along the line. Operation efficiency and time consuming in each station may affect delivery time which is likely to impact on transit period finally. So, it is doubtful that with delivery time to analyzing the current transit period, it is really shows the railway transport equipment, technology level and organization efficiency.

Supposing the number of obligatory operation link that transport freights from departure station to arrival station is n . According to present railway equipping technology, the transportation organization level, the load level of transportation equipment, and relative reliabilities, etc., set the time of finishing link i is I_i , and the consumption of standard operating time is $\tau(I_i)$ ($i=1,2,\dots,n$), then the total operating time consumed by each link before the moment of I_s is

$$T(I_{i=s}) = \sum_{i=1}^s \tau(I_i)$$

Taking into account the complexity and unpredictability of the transport organization, the actual consumption time by link s is

$$\tau_s(I_s) = \tau(I_s) \pm \Delta\tau(I_s)$$

So the total time which were actually consumed by all the operating links is the freight forwarding time represented by θ

$$\theta = T_s(I_{i=n}) = \sum_{i=1}^n \tau(I_i) \pm \sum_{i=1}^n \Delta\tau(I_i) \quad (3)$$

According to the process of railway freight transportation organization, freight forwarding time T mainly includes the freight operation remain time in loading station t_z , the freight operation remain time in unloading station t_x , the technical operation remain time in technical station $\sum t_{js}$, and the running time on the way $\sum t_{tz}$. That is

$$\theta = t_z + \sum t_{js} + \sum t_{tz} + t_x \quad (4)$$

Among them

$$\sum t_{js} = n_y t_y + n_w t_w \quad (5)$$

$$\sum t_{tz} = l/v_{pl} + t_{zl}$$

In the formulation: t_z and t_x respectively represents the freight operation time remain in loading station and unloading station; t_y and t_w respectively represents the remain time of trains which have shunting operation or not in technological station; n_y and n_w respectively represents the number of shunting operation or non-shunting operation in technological station; $\sum t_{tz}$ is the train running time on the way; l is freight tariff kilometer, and for the acceptance freight, it's a constant value. v_{pl} represents average traveling speed of train; t_{zl} represents abnormal residence time.

According to the whole process of railway transportation organization operation, association point between the transit period T calculated by present method and the practical forwarding time θ is $T = \theta$, if considering complexity of railway transportation organization operation, and supposing calculation method of freight transit period not only reflect existing equipment technology and transportation organization level, but also possess certain reliability and practicability, and let

$$\theta \leq T \leq T_r, \text{ and } \min\{T - \theta\} \quad (6)$$

Where T_r is the permitted freight transit period.

III. INFLUENCE ANALYSIS OF LOGISTICS CONDITIONS ON θ

In recent years, a series of measures which involve in merging railway station and segment, shutting down the small intermediate station, developing strategic loading or unloading location, carrying out long locomotive routing, etc. have been taken to adjust railway productivity distribution. The implementation of above measures has been greatly promoted Chinese railway's transport capacity resource optimization allocation, realized the systematic speed raising of existing railway, and

constantly upgraded the timeliness of freight forwarding, in the meantime, booming logistics have affect railway transportation product, and the whole process of railway freight forwarding is simplified, and freight forwarding time is shorten.

A. Analysis of the Major Parameters which Influence θ

The consumption time of every link and its operational efficiency may affect the entire freight forwarding time, which can influence the transit period of freight, as well as the formulation and achievement of the transportation organizations scheme and the transportation contract.

Based on above analysis, the factors that influence θ mainly include $t_z, t_x, t_y, t_w, n_y, n_w, v_{pl}, t_{pl}$, etc.

Under the precondition of satisfying the load level of railway transportation devices, the labor intensity of workers, the reliability and connectivity of each link operation, the value-choosing standards of these parameters should be determined according to the level of rail transport organization, technical equipment and operational efficiency in a certain period.

In recent years, Chinese railway productivity distribution has been widely adjusted. On the one hand, through the development of new freight products, the organization-mode adjustment of package freight transportation, and the development of strategic loading and unloading location, the process of freight traffic organizations has been optimized. On the other hand, the transportation organization level has been improved by constantly optimizing the distribution of locomotive, vehicle, transport, engineering and power devices, reducing the number of marshalling yards, implementing extended locomotive routing and crew shifting system, as well as by optimizing the wagon flow path and the train formation plan, and improving the technology of equipment. So that the operation links of freight forwarding constantly reduce, meanwhile v_{pl} constantly increases, t_z and t_x constantly decrease, while t_y and t_w change less (see figure 1).

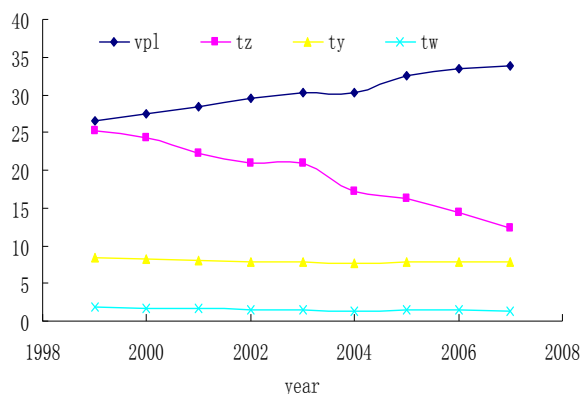


Figure1. Changing trend of each major parameter which influences θ

B. Statistical analysis of the Major Parameters which Influence θ

Although the parameters influencing θ occur different degree of changes with the adjustment of the railway productivity distribution, θ is influenced by very complex factors. The value of θ varies from the same freight in the different shipping and receiving stations with the same travelling distance, even the same shipping and receiving stations, it may be different. It is difficult to describe θ with a definite function relation[4].

Therefore, according to the statistic of daily average running tariff kilometer t_{pl}^d and average travelling speed v_{pl} , and then the daily average running tariff kilometer of freight trains be obtained to reflect the current situation of freight forwarding time θ in the background of railway productivity distribution adjusting.

Set X, μ and δ^2 respectively represent whole, average value and variance. According to sampling standard, δ^2 is unknown to the index of t_{pl}^d , but

$$S^2 = \frac{1}{n-1} \sum_{i=1}^n (X_i - \bar{X})^2$$

is the unbiased estimate of δ^2 . So

$$T = \frac{\bar{X} - \mu}{S/\sqrt{N}} \sim t(n-1)$$

and it can be approximated by normal

distribution when $n > 45$, that is $t_{\alpha/2}(n-1) \approx Z_{\alpha/2}$, $\Delta_x / (S/\sqrt{n}) \approx Z_{\alpha/2}$. On the other word, $n = Z_{\alpha/2}^2 S^2 / \Delta_x^2$ can be used to check whether the sample size meet with requests or not[5].

1) Statistical analysis of t_{pl}^d and v_{pl}

The whole process of freight forwarding includes multiple links. The consumption time of every link and its operational efficiency may affect the entire freight forwarding time, which can influence the transit period of freight, as well as the formulation and achievement of the transportation organizations scheme and the transportation contract. The implementation of above measures has been greatly promoted Chinese railway's transport capacity resource optimization allocation, realized the systematic speed raising of existing railway, and constantly upgraded the timeliness of freight forwarding, in the meantime, booming logistics have affect railway transportation product, and the whole process of railway freight forwarding is simplified, and freight forwarding time is shorten.

Through the investigation on Wuhan railway Bureau, Xi'an Railway Bureau and Taiyuan Railway Bureau, the statistic values of daily average running tariff time t_{pl}^d and average traveling speed v_{pl} are got. The statistic values of average traveling speed are respectively gathered according to average traveling speed of non-through train t_{pl}^d , ordinary through train t_{pl}^d and fast freight train t_{pl}^d . The statistical analysis and data fitting

are shown in table I. (limited by the space, only the statistical results of t_{pl}^d are given.)

TABLE I.
DISTRIBUTION ANALYSIS STATISTIC RESULT OF t_{pl}^d

k	class	n_i	$\frac{n_i}{n}$ %	$\frac{n_i}{n \cdot h} (h = 1)$	$\sum \frac{n_i}{n}$ %
1	0~8	21	0.74	0.74	0.74
2	8~10	117	4.1	4.1	4.84
3	10~13	506	17.8	17.8	22.64
4	13~15	1567	55	55	77.64
5	15~17	513	18	18	95.64
6	17~18	105	3.7	3.7	99.4
7	18~	18	0.6	0.6	100

The maximum likelihood estimation results of heavy wagons' daily average running tariff kilometer t_{pl}^d , non-through trains' average traveling speed v_{npl}^d , ordinary through trains' average traveling speed v_{opl}^d , and fast freight trains' average traveling speed v_{fpl}^d are shown in table II.

TABLE II.
THE RESULTS OF MAXIMUM LIKELIHOOD ESTIMATION

	t_{pl}^d	v_{npl}^d	v_{opl}^d	v_{fpl}^d
mean value	13.623	25.13	30.13	51.25
mean square error	6.05	9.36	7.13	8.04

According to Pearson Theorem[6]

$$\chi^2 = \sum_{i=1}^k \frac{f_i^2}{np_i} - n \tag{7}$$

Where f_i is the observation frequency of the i -th range, while p_i is the probability that falls into the i -th range on the basis of the hypothetic theoretical distribution.

In the χ^2 distribution, parameters just relate to degree of freedom R .

$$R = r - s - 1 \tag{8}$$

Where r is grouping number and s is the number of the unknown parameters that is needed to estimate the sample observation value in the theory distribution.

Given significance level α , if the statistics value χ^2 and $\chi_{\alpha}^2(r-s-1)$ meet the condition[9]

$$\chi^2 < \chi_{\alpha}^2(r-s-1) \tag{9}$$

Then accept the hypothesis test.

Divide the statistical data into k intervals as $(0, a_1]$, $(a_1, a_2]$, \dots , $(a_{k-2}, a_{k-1}]$, $(a_{k-1}, +\infty)$, and note $a_0 = 0, a_k = +\infty$.

According to the *Sturges* formula which is used to estimate interval number.

$$k = 1 + \lg n \tag{10}$$

Where k represents interval number, n represents sample size.

Then the interval number is determined seven at last. Taking t_{pl}^d as example, its χ^2 testing results of fitting validity are shown in table III.

TABLE III.
 χ^2 TESTING DATA OF THE FITTING VALIDITY OF t_{pl}^d

k	Class	Observed Number f_i	Observed Frequency $\frac{f_i}{n}$	Estimated Probability p_i	np_i	$\frac{f_i^2}{np_i}$
1	0~8	21	0.007376185	0.01	28.47	15.49
2	8~10	117	0.04109589	0.04	113.88	120.205
3	10~13	506	0.177730945	0.17	483.99	529.011
4	13~15	1567	0.550403934	0.56	1594.32	1540.15
5	15~17	513	0.180189673	0.17	483.99	543.749
6	17~18	105	0.036880927	0.04	113.88	96.8124
7	18~	18	0.006322445	0.01	28.47	11.3804

Thus, $\chi^2 = 9.19, \chi_{0.05}^2 = 16.143$. Therefore, it obeys normal distribution. Similarly, it can conclude that v_{npl}^d, v_{opl}^d and v_{fpl}^d also obey or approximately obey normal distribution. The conclusion is consistent with reference [10].

2) Statistical analysis of daily average running tariff kilometer l_{ir}

The organization process of railway freight includes operation in loading station, technical station, unloading station and general stations along the line. Operation efficiency and time consuming in each station may affect delivery time which is likely to impact on transit period finally. So, it is doubttable that with delivery time to analyzing the current transit period, it really shows the railway transport equipment, technology level and organization efficiency.

According to Chinese railway freight product structure, logistics development condition, and the effects of logistics on railway freight transportation organization, based on the investigation on Beijing railway Bureau, Chengdu Railway Bureau and Guangzhou Railway Bureau, and random drawing freight of through train, ordinary through train, high-speed train, and rate-limiting train respectively 2847 groups, and railway freight transit period and forwarding time of corresponding freight are analyzed.

According to result of statistical analysis, all of the drew railway freight can arrive station of destination, furthermore ,the transit period of most drew railway freight is greater than forwarding time of the corresponding freight, and the maximum differentials value between the transit period calculated by present method and the practical forwarding time of corresponding freight is 3.5 days.(see figure 2)

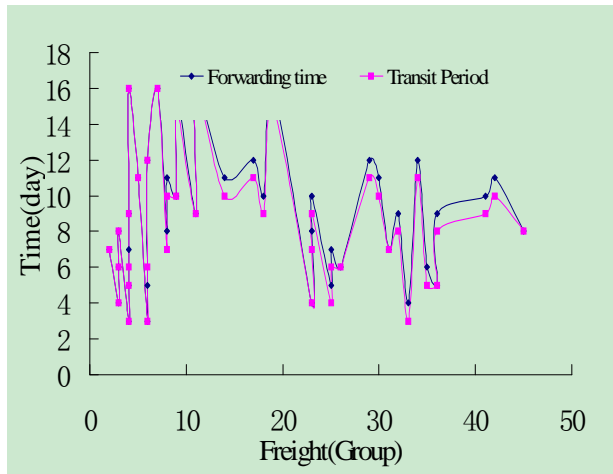


Figure 2. Comparative analysis between θ and T

According to figure 2, Chinese existing computational method and theory of railway freight transit period is simplified, and can not adapt to Chinese railway freight product structure, and can not adapt to Chinese logistics development, at the same time, the major parameters which influence θ have adjusted in various degrees with Chinese logistics development , transformation of railway freight product structure and adjusting of railway productivity distribution.

For this reason, freight transit period T of existing railway can not reflect the current situation of freight forwarding time θ in the background of Chinese logistics development and transformation of railway freight product structure.

Due to railway freight transportation organization operation is detailed and complicated, section quantity required of each railway freight product in railway freight transportation organization operation is certain unlikeness, furthermore, and spent time of each section in railway freight transportation organization operation is distinction.

Reference [10] only have statistical analyzed distribution about spent time of each section of railway freight transportation organization operation, in this paper daily average running tariff kilometer l_{ir} ($i=1,2,\dots$) of every category train are statistical analyzed based on Chinese logistics development and adjusting of transformation of railway freight product structure.

Supposing separately daily average running tariff kilometer of through train, ordinary through train, high-speed train and rate-limiting train is l_{1r} , l_{2r} , l_{3r} and l_{4r} , and daily average running tariff kilometer of every category train is analyzed.

According to maximum likelihood estimation, statistical result of daily average running tariff kilometer for through train, ordinary through train and high-speed train and rate-limiting train are shown in table IV, table v and table VI.

TABLE IV. STATISTICAL RESULT ON l_{ir}

l_{ir}	Number of statistical	Mean value μ	Mean square error σ
l_{1r}	2847	674.5697	43.462
l_{2r}	2847	400.1011	30.248
l_{3r}	2847	309.8174	17.811
l_{4r}	2847	254.9138	8.927

TABLE V. χ^2 TESTING RESULT ON PARAMETER l_{1r}

Serial number	Section	Observed Number f_i	Estimated Probability p_i	np_i	f_i^2 / np_i
1	0~550	21	0.01	28.47	15.4900
2	550~600	117	0.04	113.88	120.2050
3	600~650	506	0.17	483.99	529.0110
4	650~700	1567	0.56	1594.32	1540.1500
5	700~750	513	0.17	483.99	543.7490
6	750~800	105	0.04	113.88	96.81240
7	>800	18	0.01	28.47	11.3804

TABLE VI. χ^2 TESTING RESULT ON PARAMETER l_{2r}

Serial number	Section	Observed Number f_i	Estimated Probability p_i	np_i	f_i^2 / np_i
1	0~300	8	0.003	8.37	7.6464
2	300~340	87	0.030	83.70	90.4301
3	340~380	413	0.140	390.60	436.6850
4	380~420	1752	0.650	1813.50	1692.5900
5	420~460	448	0.150	418.50	479.5790
6	460~500	78	0.026	72.54	83.8710
7	>500	4	0.001	2.79	5.7348

It can be seen from above-mentioned statistical analysis, for arbitrary l_{ir} , in given conditions that significance level 0.05, χ^2 and $\chi^2_{\alpha}(r-s-1)$ meet the requirements of formula(6), conclusion is showing no difference with references [7].

According to formula(6), and results of inspection is calculate, and shown in table VII.

TABLE VII.
SUMMARY OF THE TESTING RESULT

l_{ir}	mean value μ	mean square error σ	χ^2	$\chi^2_{0.05}$	Testing Result
l_{1r}	674.5697	43.462	9.19	16.143	normal distribution
l_{2r}	400.1011	30.248	6.53	16.143	normal distribution
l_{3r}	309.8174	17.811	8.04	16.143	normal distribution
l_{4r}	254.9138	8.927	9.78	16.143	normal distribution

According to TABLE VII of statistical and testing result about daily average running tariff kilometer of each category train $l_{ir} (i=1,2,\dots)$, considering reliability, computational convenience and railway track condition of different transportation territory, Respectively objective value of parameter l_{1r}, l_{2r}, l_{3r} , and l_{4r} is 650 km, 400 km, 300 km and 250km.

Supposing T_{1i} represents the transit period of the i -th group freight calculated by present method, θ_i represents the practical forwarding time of the i -th group freight, and T_{2i} represents the transit period of the i -th group freight calculated by computational method of adjusted parameter $l_{ir} (i=1,2,\dots,4)$.

And T_{1i}, T_{2i} and $\theta_i (i=1,2,\dots,4)$ of the 2847 groups railway freight are analyzed. (see TABLE VII). The relationship between transit period T_{1i} of the i -th group freight calculated by present method and the practical forwarding time θ_i of the i -th group freight is shown in Figure3, and the relationship between the transit period T_{2i} of the i -th group freight calculated by computational method of adjusted parameter and the practical forwarding time θ_i of the i -th group freight is shown in Figure4.

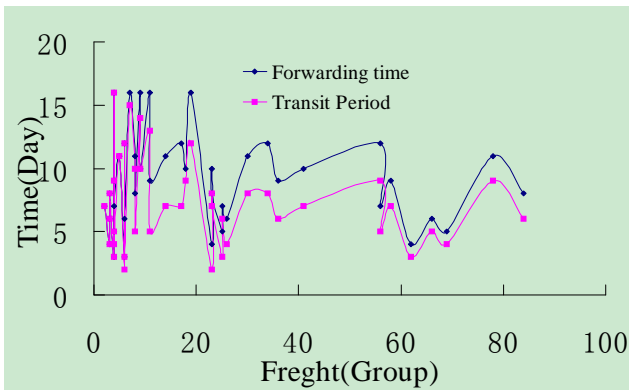


Figure 3. Comparative analysis between θ and T

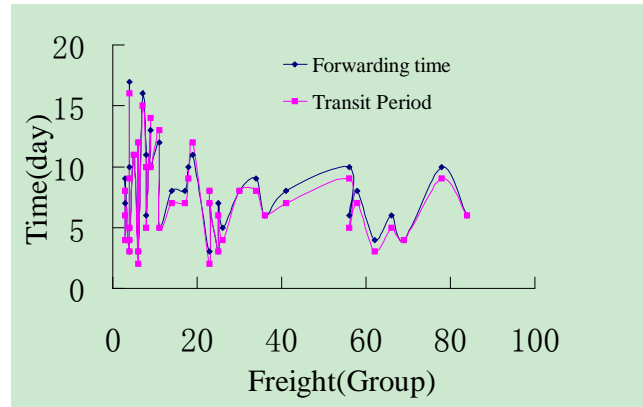


Figure 4. Comparative analysis between θ and T

It will be seen from this that the maximum difference value between the transit period calculated by present method and the practical forwarding time of freight is 4.5 days, while it is only 0.8d by adopting new calculation method, which show that the method objectively responds the forwarding time of each kind of freight transport product under speed-raising condition. Consequently, relationship between T_{1i} and θ_i is worse, while relationship between T_{2i} and θ_i is excellent.

According to Figure 3 and Figure 4, result of the statistical analysis(see TABLE VII), Respectively objective value of parameter $l_{1r}, l_{2r}, l_{3r}, l_{4r}$ is 650 km, 400 km, 300 km and 250km.

C . Statistical analysis of the Major Parameters which Influence θ

According to the analysis, t_{pl}^d obeys normal distribution and independent of each other. For the linear combination of two or more independent normal random variables is still the normal variable, θ also obeys normal distribution. Suppose the transit period of certain freight is k days, then probability density function and distribution function that this batch of freight can be delivered within k days are respectively as

$$f(y) = \frac{1}{\sqrt{2\pi} \sqrt{\sum_{i=1}^n \sigma_i^2}} e^{-\frac{(y - \sum_{i=1}^n \mu_i)^2}{2(\sum_{i=1}^n \sigma_i^2)}}$$

$$F(Y \leq y) = \frac{1}{\sqrt{2\pi} \sqrt{\sum_{i=1}^n \sigma_i^2}} \int_{-\infty}^y e^{-\frac{(y - \sum_{i=1}^n \mu_i)^2}{2(\sum_{i=1}^n \sigma_i^2)}} dy \quad (11)$$

Suppose $T=k$, then the probability is

$$F(\theta \leq k) = \frac{1}{\sqrt{2\pi}\sqrt{\sigma_s^2}} \int_{-\infty}^k \exp\left\{-\frac{(t_s - \mu_s)^2}{2\sigma_s^2}\right\} \quad (12)$$

$$\sigma_s^2 = \sum_{i=1}^m \sigma_i^2, \mu_s = \sum_{i=1}^m \mu_i$$

Where σ_i^2 expresses the variance of the i -th link, μ_i expresses the mean of the i -th link, and m is the total amount of operations.

Therefore, θ also obeys or approximately obeys normal distribution. According to the statistical analysis result, daily average running tariff kilometers of non-through trains, ordinary through trains, and fast freight trains are shown in table IV.

TABLE VIII.
DAILY AVERAGE RUNNING TARIFF
KILOMETERS OF EACH KIND OF TRAIN

Trains	Non-through trains	Ordinary through trains	Fast freight trains
t_{pl}^d	342.35	410.46	698.18

From the daily average running tariff kilometer of railway freight transportation l_r between 1979 and 1997(see Figure 2), it can be seen that the daily average running tariff kilometer of railway freight transportation in this period still has a certain gap compared to the requirement of the current railway freight transit period, which is 250km (or 500km) . According to the sampling survey and analysis in reference[3] on railway freight transportation situations in 1999, the daily average running tariff kilometer is 250.3km when the tariff kilometer is more than 1500km, while that has a certain gap compared with the requirement of the current transit period when the tariff kilometer is less than 1500km.

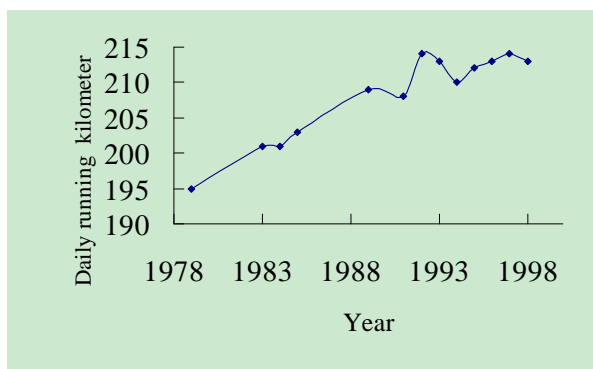


Figure2 Daily average running tariff kilometers of railway freight transportation from 1979 to 1997

IV. CONCLUSIONS

With the adjustment of railway productivity distribution, the needed operation links of railway freight

delivery decrease gradually, and the parameters having influences on θ vary to different degree, of which v_{pl} increase constantly, t_z and t_x decrease gradually, while t_y and t_w change slightly.

In the context of railway productivity distribution adjustment, average speed of non-through train, ordinary through train and fast freight train as well as daily average running tariff kilometer are analyzed, and the statistic results have been carried out χ^2 test. The analyzing results show that both the average speed of each kind of train and the daily average running tariff kilometer obey normal distribution respectively. Finally, the daily average running tariff kilometers of freight trains before and after railway productivity distribution adjustment have been comparatively analyzed, which shows that the timeliness of railway freight forwarding improves constantly in the context Chinese railway productivity distribution adjustment, logistics development and railway freight product structure. It will be seen from this paper that the maximum difference value between the transit period calculated by present method and the practical forwarding time of freight is four 4.5 days, while it is only 0.8d by adopting new calculation method, which show that the method objectively responds the forwarding time of each kind of freight transport product under speed-raising condition. Consequently, relationship between T_{1i} and θ_i is worse, while relationship between T_{2i} and θ_i is excellent.

ACKNOWLEDGMENT

We would like to thank Chinese Shanghai railway Bureau, Wulumuqi Railway Bureau and Lanzhou Railway Bureau etc, This project is supported by Spring sunshine plan of Ministry of education(Z2005-1-62008).

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