Survey and Analysis of the Actual Condition of the Walking Time from the Road to the Working Spot

——Study Cases of the Shiga Forest Corporation and the Kyoto University Wakayama Forest——

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道路から現場までの歩行時間に関する現状調査と分析

——滋賀県造林公社と京都大学和歌山演習林における調査例——

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Summary

In order to make clealy and quantitatively the effect of roads on the forest working, we surveyed the actual conditions of the walking time from the road to the working place. We obtained 10 data of Forest Corporation in Shiga Prefecture, and 3 data of Kyoto University Forest in Wakayama Prefecture. We divided these each data into some partial walking data. And we analyzed mainly Shiga data by means of the Multiple Regression Analysis. According to the results, for explaining the walking time it is enough following three variables; the horizontal distance, the mean gradient and the other bad conditions. Then we studied deeply how these variables had influence on the walking time. According to this analysis, we obtained that the horizontal distance is the largest influence on the walking time, and the mean gradient is the second. Moreover the influence of the mean gradient is much less than that of the horizontal distance. From these things we could consider that the horizontal distance is directly connected with the walkingtime, but the mean gradient is indirectly connected with the walking time. Well, we studied the walking speed. Then we obtained the regression equation between the walking speed and the mean gradient, and comfirmed the propriety of the equation (B) as the linear regression. And we presume the most suitable mean gradient by means of this equation as a simple approach.

要　旨

道路が森林作業に与える効果を数量的に明らかにするために，道路から作業現場までの歩行時間を現場調査した。そして，滋賀県造林公社にて10事例，京都大学和歌山演習林にて３事例を得

た。この各々の事例を数区間に分けて区分データを作った。そして，主に滋賀県造林公社の資料を用いて，重回帰分析を行った。この結果，歩行時間を説明するためには，水平距離，平均勾配，その他悪条件の 3 つの変数で十分であることがわかった。そこで，これらの変数が歩行時間に対してどのように影響を与えているのか，より深く究明してみた。その結果，歩行時間に対して一番大きな影響を与えているのは水平距離であり，平均勾配はその次であることが明らかになった。しかも，平均勾配のその影響は，水平距離の影響に比べてはるかに小さいことも判明した。これらの事を通して，水平距離は歩行時間に対して直接的に関係しているが，平均勾配の方は間接的なものであることが推測された。一方歩行速度についても分析を試み，歩行速度と平均勾配の回帰式を得た。そして，その回帰式（B）の直線回帰としての妥当性を確認した。またこの回帰式を使って最も適当な平均勾配を単なる参考程度のものとして推察をこころみた。

Introduction

In recent years, the circumstances of surronding the forest labor in Japan have been getting worse. For example, the decrease and the deterioration of the forest worker, the outflow of the forest successor, the rise of the wages, and the many planted forest which does not have complete adjustments of forest roads. Under these conditions we think that planning the adjustment of the road network is very important subject as a productive foundation of the forestry. So we have studied is order to look for the road network which brings the enough labor environment to work easily and to administer carefully.

In the previous report[1], we investigated the effect of the road on the weeding work by the questionnaire. The objects of the investigation were 24 University Forests and 17 Private Forests. According to the results we obtained following two considerations. Firstly the increase of commuting hours by car has a tendency to reduce working hours, and to increase the working efficiency (ha/man, hour). Secondly the increase of commuting hours by walk has a tendency to reduce the working efficiency, and to increase rest hours. It is the latter case that involves the serious problem about the improvement of the working conditions. The increase of commuting hours by walk may bring the physical burden of workers. Well commuting hours by walk is, saying it differently, the walking time from the road to the working spot. So we use the walking time from now on.

Then we try to study the process of the walking time from the road to the working spot in detail. And we try to estimate quantitatively the effect of the roads. In this report, we surveyed the actual condition of the walking time in following two areas. Firstly in Shiga Prefecture we obtained 10 data of a contracted weeding work of the Forest Corporation. Secondly in Wakayama Prefecture we obtained 3 data of a weeding work under direct operation of Kyoto University Forest. We analyzed about the walking time by means of the Multiple Regression Analysis. In that time we used mainly Shiga data. And we used Wakayama data comparatively when we discussed about the analytic results. While we studied the walking speed, and we obtained the regression equation. According to studying these results a few properties of the walking time became evident, so here we reported in this paper.

We should like to express our grateful thanks to the Forest Corporation in Shiga Prefecture, Tanabe Forestry Group and the Kyoto University Wakayama Forest. And we are also deeply indebted to the members of the forest engineering laboratory of Kyoto University for their helpful advice. Particularly we are indebted to Mr. H. Ishihara, Mr. T. Ishikawa, Mr. T. Hashimoto and Mr. S. Fujita for their considerable assistance with the actual survey.

Surveying Procedure

As we wanted for the actual data of the walking time, we walked from the road to the working spot together with the workers early in the morning. That is, we surveyed when they were going to their daily work, so there was no request from our side. While we were walking together, we observed the time required, their personal effects and the walking circumstances. Then we checked the remarkable points such as the change of the gradient and small rest in walking, too. After arrival the working spot, we observed the temperature, the humidity, the rest time and their physical condition of working. And on our way back, we measured the distance and the gradient of the walking course. In our laboratory we adjusted these data, and we obtained the walking time, the horizontal distance and the mean gradient. And then we also made partial data how to divide those each data into some sections by the remarkable point as before.

In Shiga Prefecture we surveyed Kawakami group of the Tanabe Forestry group which contracted the weeding work for the Shiga Forestry Corporation. This group was composed of 8 persons (6 men, 2 women). The mean age of this group was about thirty. They worked on the piece basis. So they went out for a work at 5:30 a. m. everymorning. And they went back at about five o'clock. And they had not a regular holiday because they didn't show up for work in such as rainy day. This area were very steep and had few forest roads. So they had to walk about 1000m to their working spot on an average. Their working spots existed at the Ashibi and the Ega valley on Katsuragawa in Ōtsu city.

In Wakayama Prefecture we surveyed the staff of the Kyoto University. This group was composed of 5 men. The mean age of this group was about fifty. They worked under payment by the hour. So they went out for a work at 8:00 a. m. every morning, and went back until 5:00 p. m. This area were also very steep and had scarcely forest roads. So it is common that they walked about 2000m. Their working spots existed at Chikai of Kamiyukawa on Shimizu in Arita district.

When we analyzed these data, we used SPSS and SAS Program Packages. SPSS (Statistical Package for the Social Sciences) is the program package that is born in Stanford University, and grew in Chicago University, and then is added some Japanese programs. SAS (Statistical Analysis System) was developed in North Carolina University, and particularly has various program about the Multiple Regression Analysis. These works were supported by FACOM M-200 computer at Data Processing Center Kyoto University.

Results and Discussion

I. Total Walking Data

We showed the total walking data in Table 1. From S1 to S10 are the Forest Corpo-

Table 1. Total Walking Data

NO	TOTAL WALKING				HILLSIDE WALKING				REST
	MG %	HD m	WT min	WS m/min	MG %	HD m	WT min	WS m/min	min
S 1	13.3	1242	28	44	33.6	176	9	20	28
S 2	24.2	1081	28	39	35.2	661	21	31	31
S 3	16.1	414	9	46	0.0	0	0	0	29
S 4	23.9	1185	30	39	28.1	771	22	35	41
S 5	26.1	1259	34	37	30.9	845	25	34	31
S 6	27.0	1145	36	32	33.2	731	28	26	38
S 7	25.9	1023	29	35	32.5	610	21	29	37
S 8	19.9	1172	31	38	38.5	369	12	31	36
S 9	17.2	1027	24	42	33.4	279	9	31	32
S10	25.4	945	23	41	32.6	531	15	35	31
W 1	5.0	800	12	67	0.0	0	0	0	20
W 2	13.0	1533	30	51	35.0	643	19	34	33
W 3	8.0	2322	39	60	15.8	222	8	28	21

ration's data in Shiga Prefecture, and from W1 to W3 are the Kyoto University Forest's data in Wakayama Prefecture. Table 1 is composed of three parts, total, hillside and rest. Then the hillside walking is contained in the total walking, because the total walking is divided in the hillside walking and the valley walking. The total and hillside parts are composed of 4 factors; the Mean Gradient of walk (MG), the Horizontal Distance of walk (HD), the Walking Time (WT) and the Walking Speed (WS).

The following two things can be seen from Table 1. Firstly the hillside HD is in inverse proportion to the total WS. For instance, in case of much hillside walking the mean total WS is 39.1m/min. But in case of few hillside walking is 49.5m/min. The difference between the two is 10.4m/min. Even if only Shiga data are calculated, the former case is 42.5m/min, the latter case is 37.2m/min and their difference is 5.3m/min. Secondly the hillside HD is in proportion to the rest time. For instance, in case of much hillside walking the mean rest time is 34.6min. But in case of few hillside walking is 27.7min. The difference between the two is about 7 min.

According to these findings, the hillside walking has a bad influence on the walking speed and the rest time. Then the walking speed is closely connected with the walking time. And there is an inverse proportion between the two. The increase of the walking time and the rest time reduces the actual working time. Therefore we can consider that the hillside walking has a adverse effect on the actual working time.

Now, we obtained mutual coefficients of correlation among these 10 factors by means of SPSS Program Package. The significant correlations are the following; the total HD and the total WT (0.684), the total WT and the hillside WT (0.706), the total MG and the hillside WT (0.868), the hillside WT and the hillside HD (0.942).

According to this we can consider two things: Firstly the horizontal distance is deeply connected with the walking time. Secondly the hillside walking has an important effect on the total walking time. This is an agreement with the former consideration. There is a near connection between the hiliside walking and the mean gradient. Therefore it seems that the horizontal distance and the mean gradient have some closely influence on the walking time.

Table 2. Partial Walking Data

NO	SECTION	INDEXES		VARIABLES							
		WT min	WS m/min	MG %	HD m	BC	SUN	TEM deg	HUM %	ETC	NP men
S 1	S 1-1	19	56	10.0	1066	N	N	18	80	N	8
	S 1-2	9	20	33.6	176	N	N	18	80	Y	8
S 2	S 2-1	7	60	6.8	419	N	N	26	80	N	7
	S 2-2	15	30	39.9	451	N	Y	26	80	N	7
	S 2-3	6	35	25.0	210	N	Y	26	80	N	7
S 3	S 3-1	9	46	16.1	414	Y	N	22	80	N	6
S 4	S 4-1	8	52	16.1	414	N	N	22	87	N	7
	S 4-2	18	34	32.5	610	N	N	22	87	N	7
	S 4-3	4	40	11.6	161	Y	N	22	87	N	7
S 5	S 5-1	9	46	16.1	414	N	N	24	77	N	5
	S 5-2	17	36	32.5	610	N	N	24	77	N	5
	S 5-3	8	29	27.0	236	Y	N	24	77	Y	5
S 6	S 6-1	8	52	16.1	414	N	N	23	79	N	6
	S 6-2	14	28	32.5	396	N	Y	23	79	Y	6
	S 6-3	7	31	32.4	214	N	Y	23	79	N	6
	S 6-4	7	17	37.0	121	Y	Y	23	79	Y	6
S 7	S 7-1	8	52	16.1	414	N	N	21	82	N	4
	S 7-2	15	26	32.5	396	N	N	21	82	Y	4
	S 7-3	6	37	32.4	214	N	N	21	82	N	4
S 8	S 8-1	9	46	16.1	414	N	N	18	76	N	4
	S 8-2	8	49	6.3	390	N	N	18	76	N	4
	S 8-3	7	22	42.9	157	N	N	18	76	N	4
	S 8-4	5	42	35.3	212	Y	N	18	76	N	4
S 9	S 9-1	8	52	16.1	414	N	N	19	81	N	6
	S 9-2	7	48	5.0	335	N	N	19	81	N	6
	S 9-3	9	31	33.4	279	N	N	19	81	N	6
S10	S10-1	8	52	16.1	414	N	N	22	74	N	8
	S10-2	5	25	55.5	126	Y	Y	22	74	N	8
	S10-3	10	41	25.5	405	Y	Y	22	74	N	8
W 1	W 1-1	12	67	5.0	800	S	N	—	—	N	4
W 2	W 2-1	8	75	− 3.3	600	S	Y	—	—	N	5
	W 2-2	19	34	35.0	643	S	N	—	—	N	5
	W 2-3	4	73	− 1.6	290	S	N	—	—	N	5
W 3	W 3-1	31	68	7.1	2100	S	N	—	—	N	5
	W 3-2	8	28	15.8	222	S	N	—	—	N	5

Then in order to clarify the process of the walking time in detail, we tried to analyze the partial walking data.

II. Partial Walking Data

The partial walking data is each data of the section which the total walking data is divided by the large change of the gradient. We showed it in Table 2. This is composed of 4 parts; the number of the total walking data, the section of the total walking data, the indexes of this analysis and the variables. The indexes are the Walking Time (WT) and the Walking Speed (WS). The variables are the following; the Mean Gradient (MG), the Horizontal Distance (HD), the existence of the Bush Cutter (BC: Yes, No, Sickle), the existence of the direct rays of the sun (SUN: Yes, No), the temperature (TEM), the humidity (HUM), the other bad conditions (ETC: Yes, No) and the number of person (NP). The other bad conditions are the case that the most steep gradient is beyond 50 % and its horizontal distance is beyond 100m, and the other case that the bad condition troubles doing the general analysis. For example a very strong wind and a very heavy bush, and so on.

Firstly we calcuated mutual coefficients of correlation among these 10 factors. The significant correlations are as follows; the walking speed and the mean gradient (−0. 838), the walking time and the horizontal distance (0. 790), the walking speed and the horizontal distance (0. 530), the walking speed and the other bad conditions (−0. 595). Things to be emphasized among them are the close connection between the walking speed and the mean gradient, and between the walking time and the horizontal distance. The effects of the other variables on these two indexes are not very important. Therefore we can consider the following two things. Firstly it is the horizontal distance that has direct effect upon the walking time. Secondly the mean gradient is directly connected with the walk-

Table 3. The optimum combination of variables

R-SQUARE	VARIABLES				
0. 02272	ETC				
0. 12557	BC				
0. 62469	HD				
0. 66147	HD	SUN			
0. 74660	HD	ETC			
0. 81259	MG	HD			
0. 82332	MG	HD	BC		
0. 83145	MG	HD	HUM		
0. 88100	MG	HD	ETC		
0. 88500	MG	HD	TEM	ETC	
0. 89517	MG	HD	HUM	ETC	
0. 89606	MG	HD	BC	ETC	
0. 89863	MG	HD	HUM	ETC	NP
0. 90095	MG	HD	BC	TEM	ETC
0. 90605	MG	HD	BC	HUM	ETC

ing speed, so the mean gradient has indirect effect upon the walking time.

Well, as W1-1, W2-1 and W3-1 are the data of walking on the forest road, their walking speed is much higher than the others.

Now, we tried the Multiple Regression Analysis for the walking time. Firstly we studied the proper number of the variables and its combination in order to explain the walking time by means of SAS-R.SQUARE. This is the program that if we fix the number of the variables calculates the square value of the coefficient of multiple regression (R. SQUARE) about all combinations of variables in that number. And this program shows these R. SQUARE in order of size. We showed this results in Table 3. This is composed of the combinations of variables about only best three R. SQUARE in each number from 1 to 5. According to studying Table 3, the change of this R. SQUARE is much until 3 variables, but few beyond 4 variables. That is, the combination of the three variables is the most suitable for explaining the walking time. Moreover, the combination of the mean gradient, the horizontal distance and the other bad conditions is considered the best. Here we find the mean gradient and the horizontal distance in this combination. Well, how do these two variables have influence on the walking time?

Then, secondly we tried to analyze this combination and the walking time by means of SAS-STEPWISE. This program takes a variable into the stage of the multiple regression analysis in order of the high F value. But if the F value goes down in the calculating, that variable is turned out from the stage of the analysis. In this way this program finds the most proper combination of variables in each number of variables. We should this result in Table 4. Reading the F value of each variables, we can consider that the horizontal distance (180. 15) is the largest influence on the walking time, and the mean gradient (28. 24) is the second. This results surprised us a little. For certain, according to PROB F (0. 0001) in Table 4, the influence of the mean gradient is significant. But it is much less than that of the horizontal distance. It seems that the walking time is influenced mainly by the horizontal distance. Now, reconsidering the coefficients of correlation once more, there is not significant correlation between the walking time and the mean

Table 4. The result of SAS-STEPWISE

STEP 3	VARIABLE ETC ENTERED			R SQUARE=0. 88100	
				C(P)	=8. 13447
	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB F
REGRESSION	3	389. 58463	129. 86154	61. 70	0. 0001
FRROR	25	52. 62226	2. 10489		
TOTAL	28	442. 20689			
	B VALUE	STD ERROR	TYPE II SS	F	PROB F
INTERCEPT	−5. 10162				
MG	0. 13176	0. 02479	59. 43243	28. 24	0. 0001
HD	0. 02157	0. 00160	379. 20557	180. 15	0. 0001
ETC	2. 85145	0. 75219	30. 24801	14. 37	0. 0009

THE ABOVE MODEL IS THE BEST 3 VARIABLES MODEL FOUND.

gradient. The mean gradient is closely connected with the walking speed. And then the walking time is the horizontal distance divided by the walking speed. As before, the mean gradient is indirectly connected with the walking time. It seems that this thing is shown clearly in Table 4. We can understand this as follows. If the mean gradient decreases, naturally the walking speed increases. Only in case of the fixed horizontal distance, also the walking time decreases. But this influence is less than the influence of the horizontal distance. About this reason we can consider the following two things. Firstly the change of the horizontal distance is much wider than that of the mean gradient. In case of the mean gradient, the range of change is actually from -50% to 50%. Certainly the gradient of the ground may be beyond 100%. But in case of actual man's walking, the gradient of walking way may be until about 50%. While the horizontal distance has a very wide range from 0 m to 2000m. 2000m's walking is very long. Generally the long walking distance is a little over 1000m. This case is one of Wakayama data (W3-1). It is the data of walking on the forest road. And particularly we requested the workers to walk. Usualy they go to by car. So it is paticular case. Though the walking distance has a wide range from 0 m to a little over 1000m. The difference of these ranges may have large influence on the multiple regression analysis. Secondly the steeper the mean gradient is, the shorter the horizontal distance is. According to reading Table 2 this is evident. For instance, in case that the mean gradient is beyond 30% the mean horizontal distance is 329m. In case of under 30% it is 502m. The difference of the two is 173m. In particular in case of beyond 40% it is 142m. According to this we can consider that the horizontal distance of the steep gradient is very short in this analysis. Even if the mean gradient is very steep, in case that the horizontal distance is very short, the demerit of steep gradient has little influence on the walking time, and according to circumstances has no influence on also the walking speed. Because the workers are apt to walk up steep gradient at a breath in case of the short horizontal distance. If the horizontal distance were the more longer, the workers could not walk up at a breath, and their walking speed went down. Then the walking time will be influenced considerably, and this result of SAS-STEPWISE may be changed. But actually it is few case that the steep gradient such as beyond 40% continues the long distance such as beyond 1000m. So we need not to think deeply the case as a particular case.

Well, we show the regression equation of the walking time as follows. See Table 4. The B VALUE is the coefficient of each variables, and the INTERCEPT is the constant of this equation.

(The Walking Time) =0.132*(The Mean Gradient)

+0.0216*(The Horizontal Distance)

+2.85*(The other bad conditions) −5.10

These coefficients are not standardized. So if we change the unit of variables, the coefficient is changed in itself.

III. The Analysis of Walking Speed

As before, there is a high correlation between the walking speed and the mean gradient(−0.838). So we showed this correlation map in Fig. 1. The vertical axis is the walk-

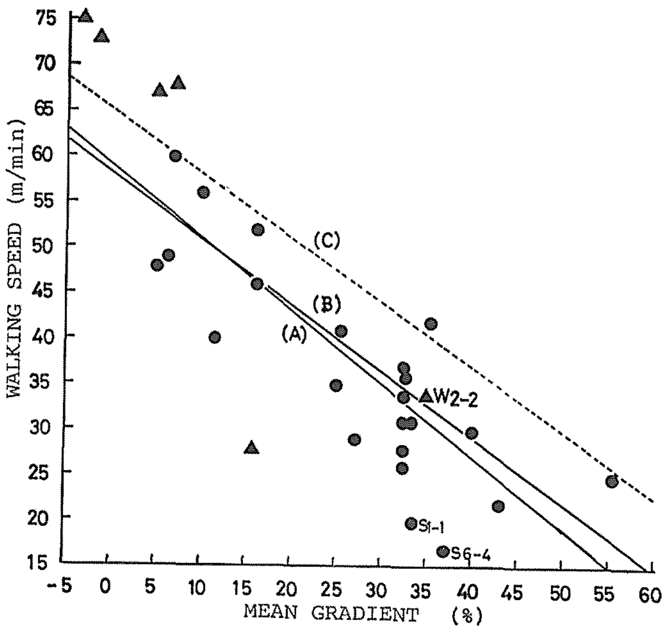

FIG. 1 SCATTERGRAM OF WS MG

ing speed, and the transverse axis is the mean gradient. The Shiga data are indicated ● mark, and the Wakayama data are indicated ▲ mark. All these data are the partial walking data. Now, except the Wakayama data we obtained the regression equation of the walking speed as follows. We showed this as the (A) line in Fig. 1.

Equation (A): (The Walking Speed) =58.9−0.798*(The Mean Gradient)

But in these data there are paticular cases of general analysis. So we excluded these cases (S1-1, S6-4), and obtained the regression equation again. We showed this as the (B) line in Fig. 1.

Equation (B): (The Walking Speed) =58.2−0.730*(The Mean Gradient)

The constant of each equation indicates the walking speed when the mean gradient is 0%. The walking speed that the two constants indicate, about 58m/min, is slower than the mean walking speed of Japanese[2], about 80m/min. While accoring to seeing the ▲ mark in Fig. 1, it seems that the walking speed of 0% had better be more fast. But this set of ▲ marks in the left-upper part of Fig. 1 is the data of walking on the forest road. When actual hillside walk, even if the mean gradient is 0%, we can never walk as if on the forest road or a flat ground. There are many obstructions on our way. For instance, many small ups and downs, stones and rocks, weeds and bushes, crossing swamps and log briges, and so on. Here is a regression equation of the walking speed which is obtained by the same former analysis.[3] We showed it as the (C) line in Fig. 1.

Equation (C): (The Walking Speed) =65.2−0.708*(The Mean Gradient)

According to this constant we study that the walking speed of 0% is not so fast. See Fig. 1. W2-2 is the only hillside walking data of Wakayama data. This point is very near by the (B) line. So we can consider that the regression equation (B) can be used under limited conditions. But there is the same problem when we analyzed the walking time. That is, in case of the steep gradient the horizontal distance is generally short, and the walking speed is not influenced very much by the demerit of the steep gradient. We think that the two dimentional regression is more adiquate in this case. Though in this analysis we discuss mainly the actual case in Japan as before. So we don't touch this problem.

Well, if we are given a relative height from a road to a working spot, we try to presume the mean gradient and the horizontal distance that the workers can walk in the shortest time by means of the regression equation (B). Then the relative height is fixed, so as follows.

MG: the mean gradient HD: the horizontal distance
WT: the walking time WS: the walking speed
RL: the relative height

$$MG*HD=100*RL$$

Whereupon the walking time is as follows.

$$WT=HD/WS=100*RL/(WS*MG)$$

Then we substitute the regression equation (B) for this.

$$WT=100*RL/(MG*(58.2-0.730*MG))$$

Here 100 *RL is a constant, so in order to minimize the walking speed the denominator must be maximum. Then we differentiate the denominator by the mean gradient.

(The denominator) $=Y=MG*(58.2-0.730*MG)$

$$Y'=58.2-1.46*MG$$

When $Y'=0$, the function Y reaches a maximum. So as follows.

$$MG=39.9$$

$$HD=100*RL/MG=2.5*RL$$

According to this however the relative height changes, the most suitable mean gradient is 39.9% constant. 39.9% is worthy of 21.7 DEG. But if we use the other equation, as a matter of course the mean gradient changes. For reference, in case that we use the equation (C), the most suitable mean gradient is 46.0%, and the horizontal distance is 2.1 times of the relative height. But both 39.9% and 46.0%are, so to speak, the steep gradient that we have treated until now. In case of these steep gradient there is no data of the long horizontal distance. So there are some problems when we presume such things by means of the linear regression equation. Though we can consider these value as a standard when we think the maximum mean gradient. The long slope of about 40% may increase the physical burden, and the walking speed may be reduced. So if we relieve the mean gradient too much, the horizontal distance decreases very much, and the walking time may be more longer as before. As for this details, we shall wait to see what the future holds. Here we regard these values as a simple approach.

Conclusions

In order to make clear quantitatively the effect of roads on the forest working, we have studied the side of the commuting walking from the road to the working spot. In this report, we surveyed the actual conditions of this walking, and studied mainly the walking time by means of the multiple regression analysis. Certainly this research is none other than one of the case study in Shiga and Wakayama Prefectures. But according to considering the results, we obtained a few general properties about the walking time and the walking speed.

Firstly we are going to mention about the walking time. In studying total walking data, we noticed that the horizontal distance and the mean gradient have some closely influence on the walking time. But we could not study beyond this thing because the number of total walking data is few. So we studied partial walking data by means of the multiple regression analysis. According to the results we obtained that the most suitable combination of variables for explaining the walking time is the horizontal distance, the mean gradient and the other bad conditions. Then we studied deeply how these variables had influence on the walking time. According to the results we obtained that the horizontal distance is the largest influence on the walking time, and the mean gradient is the second. Moreover the influence of the mean gradient is much less than that of the horizontal distance. After reconsidering the coefficients of correlation, we could consider that the horizontal distance is directly connected with the walking time, but the mean gradient is indirectly connected with the walking time.

Secondly we studied the walking speed. Then we comfirmed the propriety of our equation as the linear regression. And we presume the most suitable mean gradient by means of this equation as a simple approach.

There are some problemes on the property of data in this research. Firstly in case of the steep gradient such as beyond 40%, its horizontal distance is mostly short. So workers are apt to walk up at a breath. And they recover their fatigue received on that part while walking on the following part of the gentle gradient. Therefore the influence of the steep gradient is not indicated evidently on the walking speed and the walking time. This thing is obvious in the result of partial walking data, and in the regression equation of the walking speed. Certainly, the linear regression may be unsuitable theoretically in case of studying the walking speed. But in actual conditions the steep gradient has never so long distance. And there is few case that the mean gradient is steep in itself. Because the foot path is made the gradient to be easy to walk. So we can use these results in this research under the condition of the actual walking.

Secondly the number of total walking data is not enough for studying quantitatively. So we divided one total walking data into some partial walking data, and then we began to analyze. As a matter of fact, these partial walking data is composed of many small parts of various gradient. Now, our presented problem is the total walking time. Even if the partial walking time increases or decreases, there is no problem as far as the total walking time does not changed. So we need not to analyze as deeply as very small parts. But the rough partial data, for example the valley and the hillside walking or the gentle and the steep gradient, are very useful in order to study the formative process of the walking time. In this research, it is the analysis of partial walking data that we can obtain the quantitative results. If we had enough total walking data, we could study more quantitatively and the process of the walking time might be evident. That is our only regret. But it is very difficult that we try to obtain many walking data of various cases by means of such an actual survey. There are the limitation of time and place in this. So we estimate the meaning of these data highly as one of the standard to infer the actual condition.

In this research, the results may be summarized as follows: For explaining the walking time it is enough three variables, the horizontal distance, the mean gradient and the other bad conditions. The other variables do not seem to have the important influence on the walking time. And the difference of the influences between the horizontal distance and the mean gradient becomes clear a little quantitatively. So we can consider that the walking time is influenced directly by the horizontal distance and indirectly by the mean gradient.

From now on, we will proceed with this resarch on the basis of the results in this report. We must make more clear and quantitatively the influence of both the horizontal distance and the mean gradient so that we can estimate the walking time. And we must study more deeply the other bad conditions, too. Then we must look for the most suitable equation of the walking speed by means of the two dimentional regression analysis. In order to study these problems, we should perform close experiments. Perhaps many problems will happen when we expect the universality in these experiments. So before this, we need to investigated and analyze the state of the situation between the road and the working spot in wide areas.

References

1) Yamada, Y. and Sasaki, I.: A quantitative analysis of the influence of using forest road on weeding work. Bulletin of the Kyoto University Forests **54**, 164-171 (1982)
2) Akutsu, K.: Walk and health of person. The Science of Labor, **30**, No. 3, 34-39 (1976)
3) Kitagawa, K. and Kamiiizaka, M.: Effects of forest roads network on working time in forestry. Trans. 79rd Meet. Jap. For. Soc., 265-266 (1968)