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The Effect of Different Methods to Determine Log Volume and Their Impacts to Veneer Recovery

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Abstract: Veneer production has not been determined precisely from the log consumption due to plywood production varies from year to year. This research has studied the influence of various factors: stem diameter, water content, density and form quotient on veneer recovery. In addition to these factors, it is assumed that different methods to determine the volume of logs can produce different veneer recovery. Model from the analysis of factors influencing the veneer recovery is very useful to predict the number of veneers produced, as well as to predict the amount of plywood produced from the amount of raw materials available.

Allegedly, the determination of the volume of different methods will produce different veneer recovery. Determination of the volume with Brereton and Integral formula were selected as the best estimate for veneer recovery by chi square test. Chi square test showed that the volume of log and veneer recovery by Brereton and Integral were not different.

Key words: log volume, veneer recovery

1. Introduction

As veneer is the raw material for plywood making, it is required to estimate the number of veneers produced from raw material available. Veneer yielded from log consumption is expressed in veneer recovery. The emphasis of this study is to determine the volume of logs as an input factor by Brereton and Integral formula to determine the veneer recovery by measuring the diameter and length of the log. It is known that different methods to determine volume can produce different results of volumes [1]. Among others, the methods of Brereton and Integral can be used in this case. Allegedly, different methods to state the volume will result in different veneer recovery. Results of previous studies mention that the factors that affect veneer recovery are log diameter, moisture content, density, and form quotient [2]. However, in this research, only the effect of different methods to determine log volume and veneer recovery was investigated.

Allegedly, the determination of the volume by different methods will produce different log volumes and veneer recovery. Chi-square test for the significant rate of 5% and 1% was done to establish whether different methods to state log volumes will result in different veneer recovery.

The purpose of this research was to study whether there were differences in volume and veneer recovery due to the different methods of volume determination by Brereton and Integral. The benefits of this research were to understand the various methods to determine log volume and its affect on veneer recovery and to predict the amount of plywood from raw materials available.

2. Materials and Methods

2.1 Materials, Place, and Time of Study

Materials used in this research were 30 pieces of log of White Meranti (*Shoreaspp*), Matoa (*Pometia*

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piñata), and Binuang (*Octomelessumatrana*) ready for peeling. This research was conducted at The Plywood Industry, PT. Wainibe Wood Industry, Buru Regency, lasted for a month in December 2013.

2.2 *Methods for Data Collection*

Data collection included:

(1) Measuring the diameter and length of the logs, and then calculating the volume based on the Brereton and Integral formulas.

(2) Calculating the volume by Brereton formula:

$$I = 0.7854D^2L/10{,}000 \text{ (input)} \quad (1)$$

Where: I = volume of logs in m^3; D = diameter of the logs in cm; L = length of logs in m^3.

(3) The Calculation of the Volume by Integral:

Bears and Karal (1976) [3] suggested a formula to calculate the volume of a cone, which is:

$$V = \int_0^H \pi R^2 (t - \frac{t}{H})^2 dt, \text{ or} \quad (2)$$

$$V(t) = \pi \int_0^H R^2 (t - \frac{t}{H})^2 dt - \frac{1}{3}\pi Ø^2 (H - t), \text{ (input)} \quad (3)$$

Where:

V = volume; 0 = lower height limit of the pyramid; H = upper height limit of the pyramid; t = height or length of the log; Ø = Radius of above plane; R = radius of the base plane; V(t) = stem volume

(4) Veneer Volume Measurements

Veneer volume is the number of veneer sheets × length × width × thickness (output)

(5) Veneer recovery was calculated bythe formula:

$$\text{Recovery} = \text{output/input} \times 100\% \quad (4)$$

(6) Needs of Veneer Amount Persheet of Plywood can be seen on Table 1.

2.3 Data Analysis

The statistical analysis used was the chi-square test [4, 5] with the formula:

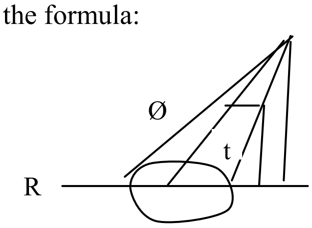

Fig. 1 A pyramid.

Table 1 Needs of total veneer persheet of plywood.

Plywood (veneer core)	∑ core veneers/ sheet plywood	∑ Face/Backveneers/sheet plywood
3-ply	1	2
5-ply	2	3
7-ply	3	4

$$fe = \frac{\sum \text{row x} \sum \text{column}}{\sum \text{observations}} \quad (5)$$

$$X^2\text{Cal} = \sum \frac{(f0 - fe)^2}{fe} \quad (6)$$

where:

fe = expected value; fo = the value of the observation

$$\text{If } X^2 \text{ Cal} \begin{cases} < X^2 \text{ Table, receive } H_0 \\ > X^2 \text{ Table, reject } H_0 \end{cases}$$

3. Results and Discussion

The study was conducted on 30 pieces of log, in which measurements of length and diameter of log follow the Regulation of the Director General of Forestry Production No. P.14/VI-BIKPHH /2009 [6].

This paper examined different log volumes by Brereton and Integral formulas. The data in Appendix 1 shows that the volume obtained by the integral is 0.8610 m^3 and by Brereton is 0.8691, while on Appendix 2 shows that the veneer recovery based on volume by integral is 56.5211% and by Brereton is 56.0029%.

Chi-square test shows that X^2 calculation of volume and veneer recovery are smaller than X^2 Table (Appendix 1 and 2), so it can be concluded that the volume by Brereton is not differentiation with the one by integral, this affects to veneer recovery. Veneer recovery is a ratio between volume of veneer as input factor to volume of log as input factor.

The highest veneer recovery occurred on Matoa (67.13%) and the lowest one occurred on Benuang (42.41%). Data of veneer recovery, volume veneer Face/Back and veneer cores per stem for interval class diameter can be seen in Table 3.

Table 2 The veneer recovery, volume face/back and core/stem for different wood species.

No.	Wood sp	∑ pcs	Average Ø (cm)	Recovery (%)	Vol. Face/Back (m^3)	Vol. Core (m^3)
1	Binuang	4	68	42.41	0.266	0.139
2	Matoa	4	76	67.13	0.350	0.405
3	White meranti	22	63	55.55	0.311	0.169
Average			66	56.00	0.3105	0.1961

Table 3 Recovery, volume and the number of face/back and core veneer for interval class diameter.

No.	Interval class Ø	∑ pcs	Average Ø (cm)	Recovery (%)	Vol. Face/Back/log (m^3)	Vol. Core/ log (m^3)	Tot sheet Face/Back	Tot sheet core
1.	41-50	6	47	38.40	0.121	0.048	484	60
2.	51-60	4	56	57.13	0.252	0.102	671	92
3.	61-70	4	64	64.38	0.321	0.188	856	156
4.	71-80	15	75	59.36	0.383	0.269	3830	840
5.	81-up	1	83	69.12	0.554	0.404	369	84
Tot		30		1675.99	9.3162	5.8828	6211	1233
Av			66	56.00	0.31105	0.1961	207	41

Data in Table 3 reveals that the greater the diameter the greater the veneer recovery except on the diameter class of 71 cm-80 cm. This means that the veneer recovery was not only influenced by the diameter but also by many other factors [7].

3.1 Factors Affecting Veneer Recovery

Factors that affect the level of veneer recovery are wood species, wood diameter, and volume resulted from different determination methods [1, 2] as explained below:

3.1.1 Wood Species

Different wood species has different physical properties includes density [8], but it has little influence on veneer recovery [9]. Kewilaa (2007) stated that each species has specific physical properties and form quotient that lead to different volume and impact to veneer recovery [2, 7]. Martawijaya et al. (1981) and Kewilaa (2009) suggested that wood species which has a specific gravity ranging from 0.40-0.70 is suitable for plywood [8, 10].

White Meranti (*Shoreaassamica* and *Shoreavirescens*) have a specific gravity ranging from 0.38 to 0.62, so that those species are classified as a good species for veneer face and back [8]. The data in Table 2 shows that the average volume of veneer Face/Back is bigger than the volume of veneer cores per stem.

Matoa has a specific gravity ranging from 0.50-0.99 [8], so it is classified as unfavorable for plywood. The data in Table 2 shows that the average volume of veneer face and back per stem is smaller than the volume of veneer core per stem. This means that veneer generated by matoa has a low-quality.

Benuang has a specific gravity ranging from 0.16 to 0.48, so that it suitable when used only for core veneer [11]. Table 2 shows that the average volume of veneer face and back is bigger than the average volume of veneer core per stem. The data in Table 2 also shows that veneer recovery of Binuang is lower than White Meranti while Matoa is the highest.

3.1.2 Wood Diameter

The data in Table 3 shows that log diameter is positively correlated with veneer recovery, unless the diameter class of 71-80. Feng et al. (2013) stated that log diameter had significant influence on veneer recovery [9]. Kainama (1997) and Sari (2009) stated that the greater the diameter of log, the greater the veneer recovery [12, 13].

3.1.3 Volume by Different Method

Data on Appendix 1 reveals that volume obtained by the integral is smaller than by Brereton. These results are in accordance with the opinion of FAO (2010) [1], that the volume obtained from different methods can be different, and it has impact on veneer recovery.

Brereton Metric Method is a method applied in Indonesia [6], but Integral method is so difficult to understand by those who are not mathematician, so it requires the preparation of a table to facilitate the reading and use.

Some formulas assume that the log according to geometric shapes such as cylinders, cones, or paraboloid can be used to estimate the volume [1]. Some of these formulas generally do not give the same results in terms of the average diameter of the base and the end of the log, so that each has a bias of the real volume, depending on how many different geometric shapes assumed of the actual form log. Smalian formula assumes that the geometric shape of log is paraboloid. Huber formula assumes that the average cross-sectional area is at the midpoint of the log. Formula subneiloid became the rules of Brereton. Bear and Karal (1976) assumed that the log is a cone shape geometry [3].

Below are the formulas of Smalian and Huber

$$\text{Smalian } V = f\,(ds^2 + dl^2)\,L/2 \quad (7)$$

$$\text{Huber } = f\ dm^2\ L \quad (8)$$

Compared to the formulas of Brereton and integral, Brereton formula assumes that the average diameter is: D log = ½ $((d_1+d_2)+(d_3+d_4))/2$ and $I = 0.7854 \times D^2 \times L$.

The diameter measurement by Brereton is the same as Smalian, i.e., the measurements are conducted on diameter at the base and the end, but the calculation is similar with Huber, i.e., only calculates median diameter (D). Integral Method assumes the geometry shape as a cone and the volume calculation is the same as Smalian, but using a variable radius and not the diameter.

Veneer volume resulting from the peels is generally smaller than the volume of log. Therefore, generally, output/input is usually expressed as veneer recovery. Many factors that are thought to affect the veneer recovery, however, on this occasion only investigated the influence of different methods, namely the method of Brereton and Integral on veneer recovery. Chi square test showed that the determination of the volume by these methods are not different, as well as veneer recovery. It is showed that the differentiation between volume in Appendix 1 (0.8691-0.8610 m^3 = 0.0081 m^3) and veneer recovery by Brereton and integral method in Appendix 2 (56.5211 – 56.0029% = 0.5182%), both are near to zero..

3.2 Total Plywood Produced

Data in Appendix 2 show that the sheets number of face and back veneer that are produced as many as 6211 sheets while the core are 1233 sheets. The analysis is based on the data in Table 1 it can be predicted realization of the number of plywood as follows:

Table 4 Actual amount of plywood produced from 30 pieces logs.

Type of plywood	∑ sheet core veneer	∑ sheet Face/Back veneer	∑ sheet plywood
3-ply	1233	2466	1233
5-ply	1232	1848	616
7-ply	1233	1644	411

It can be concluded that from 30 pieces logs, it can be generate 1233 plywood type 3-ply or 616 plywood type 5-ply or 411 plywood type 7-ply (Table 4). This means that there is an excess amount of veneer Face/Back of 3745 sheets that must be prepared by providing at least 1872 pieces veneer cores again for 3-ply. This amount can be prepared by providing a low density of raw materials or inferior sp to provide the core veneer.

4. Conclusions

Log volume obtained by the integral is smaller than by Brereton, but the chi-square test showed that both the volume and veneer recovery generated by these two methods were not different. From 30 pieces of logs, 1233 sheet plywood type 3-ply or 616 sheet plywood type 5-ply or 411 sheet plywood type 7-ply can be generated. There is an excess amount of veneer Face/Back of 3745 sheets that must be prepared by providing at least 1872 pieces veneer cores again for 3-ply. This amount can be prepared by providing a low density of raw materials or inferior sp.

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Appendix 1 Chi square test on different in volume by Brereton and Integral method.

N0	Ø2 (X1)	Ø1 (X2)	Avr. Ø	Length	V.Brereton (Y)	H=Pj*R2/ (R2-R1_	H-t	V(H)	V(H-t)	V pred Integral	Y+ Ypred	feY	fe Ypred	(f0-fe)2/ feVol	(f0-fe)2/ feV.Pred	Total Chi Square	Diff. Volume
1	44	38	41	2.50	0.3301	18.3333	15.8333	0.9195	0.5923	0.3272	0.6572	0.3302	0.3271	0.00000003	0.00000003	0.00000005	0.003
2	50	44	47	2.49	0.4320	20.7500	18.2600	1.3438	0.9158	0.4280	0.8600	0.4320	0.4280	0.00000000	0.00000000	0.00000000	0.004
3	50	46	48	2.50	0.4524	31.2500	28.7500	2.0238	1.5759	0.4479	0.9003	0.4522	0.4480	0.00000005	0.00000005	0.00000009	0.004
4	53	43	48	2.50	0.4524	13.2500	10.7500	0.9642	0.5149	0.4493	0.9016	0.4529	0.4487	0.00000064	0.00000064	0.00000128	0.003
5	50	48	49	2.49	0.4696	62.2500	59.7600	4.0315	3.5668	0.4647	0.9342	0.4693	0.4649	0.00000014	0.00000014	0.00000028	0.005
6	56	44	50	2.50	0.4909	11.6667	9.1667	0.9478	0.4597	0.4881	0.9789	0.4917	0.4872	0.00000154	0.00000156	0.00000310	0.003
7	57	45	51	2.50	0.5107	11.8750	9.3750	0.9995	0.4918	0.5077	1.0184	0.5116	0.5068	0.00000144	0.00000146	0.00000290	0.003
8	60	52	56	2.49	0.6133	18.6750	16.1850	1.7416	1.1337	0.6079	1.2212	0.6134	0.6077	0.00000003	0.00000003	0.00000007	0.005
9	61	53	57	2.50	0.6379	19.0625	16.5625	1.8375	1.2052	0.6323	1.2702	0.6381	0.6321	0.00000003	0.00000003	0.00000005	0.006
10	62	58	60	2.49	0.7040	38.5950	36.1050	3.8432	3.1463	0.6969	1.4009	0.7037	0.6972	0.00000013	0.00000013	0.00000026	0.007
11	68	56	62	2.50	0.7548	14.1667	11.6667	1.6970	0.9478	0.7492	1.5039	0.7555	0.7485	0.00000067	0.00000067	0.00000134	0.006
12	69	57	63	2.50	0.7793	14.3750	11.8750	1.7729	0.9995	0.7735	1.5528	0.7800	0.7728	0.00000062	0.00000063	0.00000125	0.006
13	65	63	64	2.50	0.8042	81.2500	78.7500	8.8927	8.0968	0.7959	1.6001	0.8038	0.7963	0.00000026	0.00000026	0.00000053	0.008
14	69	61	65	2.48	0.8229	21.3900	18.9100	2.6381	1.8228	0.8153	1.6383	0.8230	0.8153	0.00000000	0.00000000	0.00000000	0.008
15	76	66	71	2.49	0.9858	18.9240	16.4340	2.8315	1.8544	0.9771	1.9629	0.9860	0.9769	0.00000004	0.00000004	0.00000009	0.009
16	73	69	71	2.49	0.9858	45.4425	42.9525	6.2732	5.2975	0.9757	1.9616	0.9854	0.9762	0.00000023	0.00000023	0.00000045	0.010
17	76	68	72	2.50	1.0179	23.7500	21.2500	3.5536	2.5454	1.0082	2.0261	1.0178	1.0083	0.00000001	0.00000001	0.00000002	0.010
18	77	69	73	2.49	1.0422	23.9663	21.4763	3.6810	2.6487	1.0322	2.0744	1.0420	1.0324	0.00000001	0.00000001	0.00000003	0.010
19	76	70	73	2.48	1.0380	31.4133	28.9333	4.7003	3.6726	1.0277	2.0656	1.0376	1.0280	0.00000011	0.00000011	0.00000023	0.010
20	78	70	74	2.50	1.0752	24.3750	21.8750	3.8416	2.7767	1.0650	2.1402	1.0751	1.0651	0.00000002	0.00000002	0.00000003	0.010
21	78	70	74	2.50	1.0752	24.3750	21.8750	3.8416	2.7767	1.0650	2.1402	1.0751	1.0651	0.00000002	0.00000002	0.00000003	0.010
22	79	71	75	2.50	1.1045	24.6875	22.1875	3.9913	2.8974	1.0939	2.1984	1.1043	1.0941	0.00000002	0.00000002	0.00000004	0.011
23	79	71	75	2.50	1.1045	24.6875	22.1875	3.9913	2.8974	1.0939	2.1984	1.1043	1.0941	0.00000002	0.00000002	0.00000004	0.011
24	79	73	76	2.50	1.1341	32.9167	30.4167	5.3217	4.1990	1.1228	2.2569	1.1337	1.1232	0.00000014	0.00000014	0.00000028	0.011
25	80	72	76	2.50	1.1341	25.0000	22.5000	4.1448	3.0216	1.1232	2.2574	1.1339	1.1234	0.00000003	0.00000003	0.00000005	0.011
26	81	73	77	2.50	1.1642	25.3125	22.8125	4.3022	3.1492	1.1530	2.3171	1.1640	1.1532	0.00000003	0.00000003	0.00000006	0.011
27	81	73	77	2.50	1.1642	25.3125	22.8125	4.3022	3.1492	1.1530	2.3171	1.1640	1.1532	0.00000003	0.00000003	0.00000006	0.011
28	86	74	80	2.49	1.2516	17.8450	15.3550	3.4190	2.1782	1.2408	2.4924	1.2520	1.2404	0.00000013	0.00000013	0.00000026	0.011
29	80	74	77	2.48	1.1548	33.0667	30.5867	5.4822	4.3389	1.1433	2.2981	1.1544	1.1437	0.00000015	0.00000015	0.00000030	0.012
30	87	81	84	2.50	1.3854	36.2500	33.7500	7.1077	5.7362	1.3715	2.7569	1.3849	1.3720	0.00000022	0.00000022	0.00000044	0.014
∑	2080	1852	1966	74.86	26.072	814.214	739.354	104.438	78.6085	25.839	51.902	26.072	25.8299	0.00000679	0.00000685	0.00001364	0.242
Av	69	62	66	2.495	0.8691	27.1405	24.6451	3.4813	2.6203	0.8610	1.7301	0.8691	0.8610	0.00000023	0.00000023	0.00000045	**0.008**

$$X^2 \text{ Cal. (Vol)} = 0.000014 \begin{cases} \leq & X^2(0.05;29) = 42.6 \\ \leq & X^2(0.01;29) = 49.6 \end{cases}$$

Appendix 2 Chi square test on different in veneer recovery based on volume by Brereton and integral method.

N0	sp	Ø2 (X1)	Ø1 (X2)	Aver. Ø	Length m3	Vol.Bre-reton (Y)	Vol. Int	Vol. Vnr	∑sht F/B	∑sht core	Recov. (%)	Recov. Pred	Recov. + Rec.Pred	fe Recovery	ferecv. Predict	(f0-fe)2/ ferecov	(f0-fe)2/ fe Rec Pred	Total Chi Square	Diff Rec.
1	M	44	38	41	2.50	0.330	0.327	0.133	65	7	40.204	40.581	80.785	40.207	40.579	0.000000	0.000000	0.000000	0.38
2	M	50	44	47	2.49	0.432	0.428	0.143	70	8	33.032	33.341	66.373	33.034	33.340	0.000000	0.000000	0.000000	0.31
3	M	50	46	48	2.50	0.452	0.448	0.153	75	9	33.842	34.174	68.017	33.852	34.165	0.000003	0.000002	0.000005	0.33
4	M	53	43	48	2.50	0.452	0.449	0.149	70	9	32.958	33.207	66.165	32.930	33.235	0.000024	0.000023	0.000047	0.25
5	B	50	48	49	2.49	0.470	0.465	0.160	70	12	34.011	34.344	68.355	34.020	34.335	0.000002	0.000002	0.000005	0.33
6	M	56	44	50	2.50	0.491	0.488	0.277	135	15	56.389	56.721	113.110	56.295	56.816	0.000158	0.000157	0.000315	0.33
7	M	57	45	51	2.50	0.511	0.508	0.291	142	16	57.019	57.323	114.342	56.908	57.434	0.000218	0.000216	0.000434	0.30
8	M	60	52	56	2.49	0.613	0.608	0.306	137	28	49.830	50.263	100.093	49.816	50.277	0.000004	0.000004	0.000007	0.43
9	M	61	53	57	2.50	0.638	0.632	0.381	167	27	59.661	60.222	119.882	59.665	60.217	0.000000	0.000000	0.000001	0.56
10	M	62	58	60	2.49	0.704	0.697	0.437	225	21	62.028	62.654	124.683	62.054	62.628	0.000011	0.000011	0.000021	0.63
11	M	68	56	62	2.50	0.755	0.749	0.483	202	37	63.980	64.473	128.452	63.930	64.522	0.000038	0.000038	0.000076	0.49
12	M	69	57	63	2.50	0.779	0.773	0.510	216	39	65.455	65.990	131.445	65.420	66.025	0.000019	0.000019	0.000038	0.53
13	M	65	63	64	2.50	0.804	0.796	0.500	212	38	62.132	62.776	124.909	62.167	62.742	0.000019	0.000019	0.000038	0.64
14	M	69	61	65	2.48	0.823	0.815	0.543	226	43	65.958	66.601	132.560	65.975	66.585	0.000004	0.000004	0.000008	0.64
15	M	76	66	71	2.49	0.986	0.977	0.570	235	45	57.778	58.301	116.079	57.772	58.307	0.000001	0.000001	0.000001	0.52
16	B	73	69	71	2.49	0.986	0.976	0.429	182	32	43.476	43.914	87.389	43.494	43.896	0.000007	0.000007	0.000015	0.44
17	M	76	68	72	2.50	1.018	1.008	0.663	273	53	65.086	65.724	130.811	65.104	65.706	0.000005	0.000005	0.000010	0.64
18	M	77	69	73	2.49	1.042	1.032	0.589	253	35	56.488	57.045	113.533	56.505	57.028	0.000005	0.000005	0.000010	0.56
19	Mt	76	70	73	2.48	1.038	1.028	0.648	183	78	62.391	62.996	125.387	62.405	62.982	0.000003	0.000003	0.000006	0.61
20	B	78	70	74	2.50	1.075	1.065	0.717	287	60	66.666	67.305	133.971	66.677	67.294	0.000002	0.000002	0.000004	0.64
21	M	78	70	74	2.50	1.075	1.065	0.467	203	34	43.470	43.887	87.358	43.478	43.880	0.000001	0.000001	0.000002	0.42
22	M	79	71	75	2.50	1.104	1.094	0.736	295	61	66.602	67.239	133.842	66.613	67.229	0.000002	0.000002	0.000003	0.64
23	M	79	71	75	2.50	1.104	1.094	0.737	297	61	66.747	67.386	134.133	66.758	67.375	0.000002	0.000002	0.000003	0.64
24	M	79	73	76	2.50	1.134	1.123	0.626	293	39	55.224	55.770	110.994	55.241	55.752	0.000006	0.000006	0.000011	0.55
25	Mt	80	72	76	2.50	1.134	1.123	0.722	214	84	63.644	64.274	127.918	63.665	64.254	0.000007	0.000007	0.000013	0.63
26	Mt	81	73	77	2.50	1.164	1.153	0.773	245	85	66.383	67.025	133.408	66.397	67.011	0.000003	0.000003	0.000006	0.64
27	B	81	73	77	2.50	1.164	1.153	0.566	255	38	48.653	49.124	97.777	48.663	49.114	0.000002	0.000002	0.000004	0.47
28	M	86	74	80	2.49	1.252	1.241	0.701	325	45	56.040	56.519	112.559	56.020	56.538	0.000007	0.000007	0.000014	0.48
29	Mt	80	74	77	2.48	1.155	1.143	0.876	292	91	75.820	76.605	152.425	75.862	76.564	0.000023	0.000023	0.000046	0.79
30	M	87	81	84	2.50	1.385	1.371	0.958	369	84	69.119	69.847	138.965	69.163	69.803	0.000028	0.000028	0.000056	0.73
∑		2080	1852	1966	74.860	26.072	25.829	15.240	6211	1233	1680.087	1695.633	3375.720	1680.087	1695.633	0.000603	0.000597	0.001200	15.55
Avr		69	62	66	2.495	0.869	0.861	0.508	207	41	56.0029	56.5211	112.5240	56.0029	56.5211	0.000020	0.000020	0.000040	**0.52**

$$X^2\ Cal = 0.0012 \begin{cases} \leq & X^2(0.05;29) = 42.6 \\ \leq & X^2(0.01;29) = 49.6 \end{cases}$$