ANNEX A

Roulette Wheel Testing

Report on Stage 3.1 of NWML/GBGB Project Proposal

1. Introduction

This is a report on the findings of stage 3.1 of the project proposal submitted by NWML to GBGB on the 24 February 2005.

2. Background

It is understood that a roulette wheel can become "biased", either through wear of the rim or tilting of the wheel, so that the ball will fall towards the centre at a reasonably predictable fixed area of the stationary part of the wheel (known as the "drop zone").

Any wheel will exhibit this "bias" if sufficiently tilted, but the necessary angle of tilt to cause this is not known. As NWML already owns calibrated digital tilt measuring devices (inclinometers) the following proposal was made to test for the effects of tilt on a wheel.

- Adjust the level of the wheel until there is no "bias" (i.e. there is no regular "drop zone").
- Measure the angle of tilt, if any, of the wheel in this position, to determine whether simply levelling the wheel accurately would result in a lack of bias.
- Tilt the wheel from this position, in at least four different directions, until regular "drop zones" are produced.
- Consider whether a spirit level is sufficiently accurate to determine whether an installed wheel will be biased, if simply levelling is found to be sufficient.

3. Method and results

A modern roulette wheel, in excellent condition, was received from TCS Huxley. The roulette wheel was mounted onto a "tilt table" which is normally used for tilt testing of weighing instruments. The table allowed tilting of the wheel in any direction, up to a maximum angle of 1.35°.

The proposed method outlined above was modified slightly such that the tilt table (roulette wheel) was set so as to be "level" (N.B. small angles of tilt could be measured on parts of the table as shown in Annex 1). The outer rim of the roulette wheel was then divided into 8 equal segments (see Annex 1). 176 spins of the ball were conducted, with a record made of which segment the ball fell into on each spin. The ball was introduced to the wheel at the same point (segment 5) for each spin on this test and for all subsequent tests. Table 1 shows the results of this initial test.

Table 1 – Wheel "level"

Segment	Number of times selected
1	23
2	18
3	24
4	22
5	22

6	28
7	18
8	21

By applying chi-square analysis to the results (X^2 = 3.36 with 7 degrees of freedom) it was determined that the probability that the measurement results were down to pure chance (i.e. random) was approximately 85 %.

The tilt table was then tilted to give a maximum tilt of 1.35° in one plane (right to left when viewing the wheel as per Annex 1). The test was repeated, with Table 2 showing the results of this test.

Table 2 – Wheel tilted 1.35° "right to left"

Segment	Number of times selected
1	40
2	37
3	11
4	8
5	10
6	10
7	22
8	38

Chi-square analysis of these results (X^2 = 64.1 with 7 degrees of freedom) indicates a probability of less than 0.1% that these results are down to chance, i.e. there is a greater than 99.9% probability that the results are due to a "bias" on the table.

The angle of tilt was then reduced, to 0.5°, 0.25° and then 0.1°. Again, the tests were repeated at each of these angles of tilt. A chi-squire analysis was made of each set of results. These results are shown in Table 3.

Table 3 – Wheel tilted 0.5°, 0.25° and 0.1° "right to left"

Segment	Number of times selected		
	0.5°	0.25°	0.1°
1	34	39	31
2	48	30	31
3	21	28	28
4	9	6	17
5	16	11	10
6	7	10	19
7	13	14	22
8	28	38	18
Chi-square (7 degrees of freedom)	X^2 = 62.2	X^2 = 55.9	X^2 = 17.8
Probability of "bias"	> 99.9%	> 99.9%	98%

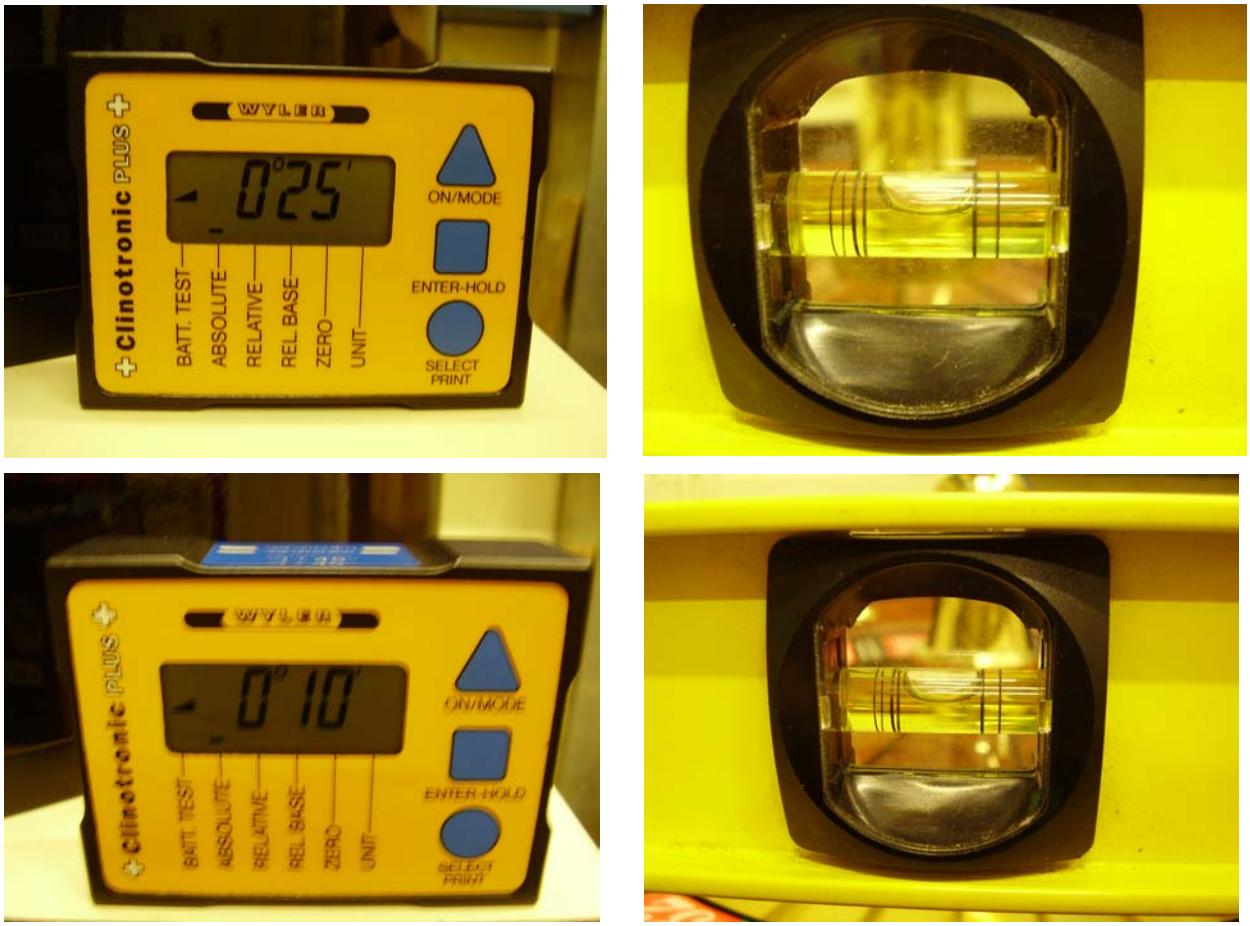
The table was then tilted to an angle of 0.1° in the other three planes. Only 80 spins were conducted for each of these tests. The results are shown in Table 4.

Table 4 – Wheel tilted 0.1° in three other planes

Segment	Number of times selected		
	Left to right	Front to back	Back to front
1	7	6	7
2	9	6	2
3	5	20	4
4	8	18	15
5	21	16	14
6	13	7	8
7	9	3	17
8	8	4	13
Chi-square (7 degrees of freedom)	$X^2 = 17.4$	$X^2 = 32.6$	$X^2 = 21.2$
Probability of “bias”	98%	> 99.9%	99.5%

A check of a typical standard spirit level (obtained from a DIY store) showed that a 0.1° angle equates to the bubble just touching the first indicating line on the bubble window as shown in Figure 1.

Figure 1 – Comparison of inclinometer and spirit level



4. Summary of results

The results indicate that when the wheel was “level” (it should be noted that a certain amount of tilt was discernable on some parts of the tilt table using the digital inclinometer) a figure of 85% probability that the results were down to chance (i.e. random) was achieved. It is possible that this figure could be improved to the more generally accepted 95% level by making very fine adjustments to the tilt table to ensure that it was perfectly level. However, it was decided not to “chase perfection” as these initial results indicated a good benchmark with which to compare the results of the tilt testing.

Tilting the wheel to 1.35° led to a greater than 99.9% probability that the results were the result of a “bias” on the wheel. Reducing the angle of tilt reduced the probability figure, but even at an angle of only 0.1°, a probability of 98% that the wheel was “biased” was still obtained. The results in the other three planes gave repeatable results, with the lowest probability still in the region of 98%. An analysis of the peak segment numbers also indicates that the “bias” appears to move in relation to the plane in which the table is tilted.

5. Conclusions

It appears from the results of testing that an angle of as little as 0.1° (the first line on the bubble window of a standard spirit level) will introduce a “bias” into the wheel. It can also be seen that the “bias” will vary according to the plane in which the wheel is tilted.

A tilt of only 0.1° could be easily introduced if the wheel is not mounted correctly, if the mounting and/or the table is not stable over time, or by leaning on the table on which the wheel is mounted if it is not sufficiently rigid. It therefore appears essential from these initial findings that particular attention should be given to the tables in the casinos onto/into which the roulette wheels are mounted. It is suggested that calibrated digital inclinometers be used when mounting the wheels (although it can be seen that a standard spirit level can indicate, quite clearly, a tilt of 0.1°). The tables should be sufficiently rigid and stable over time and not be liable to tilting by someone leaning on the table. Stability over time could be ensured by regular checks of the level and adjustment if necessary.

As it can be seen how easily a “bias” can be introduced, the next two stages of the project can now be undertaken. These will begin upon receipt of the roulette prediction device and software from Michael Barnett.

Paul Dixon, NWML
08 July 2005

Annex 1 – Roulette wheel segments and initial tilt measurement

Segments 1 and 5 are not shown.