EVALUATION OF OPTIMAL STRATEGIES
FOR THE GAME OF BLACKJACK

BY

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ABSTRACT

A generalized blackjack strategy evaluator has been programmed. It has shown that the game of blackjack can be beaten. It also tells what the expectations are for a given strategy.

In addition to providing support for the expectations previously suggested for Thorp's basic strategy, the evaluator gave positive expectations for all counting strategies, indicating frequent occurrences of situations favoring the player.

The high-low index was found to be the more accurate partial deck evaluation function than the tens ratio method.

The ideal playing conditions were assumed in all computations. Nevertheless, the evaluator can be easily modified to accept any set of standard casino rules. Then different strategies may be simulated until an acceptable strategy has been found.

THESIS TITLE: Evaluation of optimal strategies for the game of blackjack.

AUTHOR: Aleksandar D. Lekic

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INTRODUCTION

The first thing to understand about blackjack is that the game was not set up originally with specified odds against the player. In this important sense, it is vastly different from craps, roulette, and the other games in which the basic odds are easy to figure. Blackjack evolved from other card games. To be sure, the casinos have regularly made plenty of money with it. But this is because the general gambling public has played a very poor game of blackjack, and not because it cannot be beaten. Until recently there has never been a detailed scientific analysis of the proper strategy for playing this game. Instead, there has been a bewildering miasma of misinformation and confusing notions. Veteran blackjack dealers have given all sorts of conflicting advices.

In the mid fifties, with the development of high speed computers, there was an awakening of interest among persons with scientific training who possessed the ability to analyze the game correctly. We have reached the point now, where the game of blackjack is well understood. There have been many claims of winning strategies.\(^1,2,3,4,5\) This paper will attempt to evaluate some of the more promising ones in terms of the bet expectation value, where

\[
\text{BET EXPECTATION} = \frac{\text{NET WINNINGS}}{\text{TOTAL BETS}}
\]

Before going through the simulator program, I think that a thorough understanding of the rules of blackjack is
important. The rules vary slightly from casino to casino. The rules given in Appendix A are most commonly used in Las Vegas casinos, and the strategy evaluator was implemented with that particular set.

As it may be seen from the rules, at various times the player is called upon to make such strategic decision as how large his bet should be, whether to insure his hand when the dealer shows an ace, whether to split a pair, whether to double down, and whether to stand or draw on a given total. These decisions may be expressed in the form of a flow chart as in Fig.1. One might want to think of a particular strategy as being a three-dimensional boolean array having the player's cards as one dimension, dealer's up card as the other, and the type of decision requested as the third. Then, the value of any cell in the array will contain an answer 'true' or 'false', meaning: 'stand' or 'draw', or 'split' or 'don't split' etc.

The bet expectation value depends on the particular strategy used by the player. It varies from -10% and below for mediocre strategies like "Imitate the Dealer" or "Never Bust" to +0.1% for Basic Strategy (section III) to 1.5% and more for some of the counting strategies (section IV).

The preliminary analysis of the game shows several advantages and one large disadvantage for the player:

ADVANTAGES: 1. Player is paid 3:2 on blackjack (natural)
2. Player may double down in favorable situations.
FIGURE 1. - PLAYER'S DECISIONS
3. Player may split a pair.

4. Player sees one of the dealer's cards and uses this information in deciding how to play.

5. The house strategy is known in advance.

DISADVANTAGES: 1. Player must draw before dealer does.

2. There is a fixed maximum bet size.

The good strategy not only maximizes the effects of the advantages, but can also turn the disadvantage of drawing before the dealer into a highly favorable situation.
THE EVALUATOR PROGRAM

I shall here describe the procedure by which my computer simulation was done. Two programs were written: one in Fortran (WATFIV) which was ran on IBM 370/168, the other in Algol60, ran on PDP11/45 minicomputer. The former was the main blackjack play program, while the latter was a backup program used for testing the algorithms and debugging in general. Both were constructed in a highly modular form, the decision portions being located outside the main block, as subroutines or procedures. This provides numerous advantages. The complexity of the evaluator is absorbed in the main program, so the subroutines are very easy to write. They are also quite short. This means that a given strategy can be usually implemented as a subroutine in a time comparable with the time it takes to describe the strategy.

Card Generation

The dealing algorithm can be represented by the flowchart of fig.2. No initialization was shown because this occurs at the beginning of the main program. Each time this subroutine is called, it "deals" a card, adds it to the "next deck" and eliminates it from the "current deck". When the current deck has been depleted of cards, the "next deck", which now contains all 52 cards becomes the "current deck".

In order to change the program to play under different rules such as using more than one deck of cards or not dealing to the bottom of the deck, one need only change the
call for a card

K=0?

yes

set "next deck" equal to "current deck"

no

pick N

take card from Nth position

put it in 53-Nth position of "next deck"

K=K-1

Return

(In case of counting strategies only)

perform counting

K = number of cards left in "current deck"

N = random number between 1 and K

FIGURE 2.
portions of the main program corresponding to initialization and a few steps in this subroutine.

The random number generator used here was a GGL routine of the IBM 370 Math Support Library. It gives a uniformly distributed real number in the region \(0 < n < 1\). In the process of testing, 2000 decks were generated and 10 cards dealt from "top" of each deck. The results showed no necessity to develop a different algorithm. (1554 aces were dealt, for example, while theory predicted 1538, 6122 tens vs. 6154 predicted, etc.)

**Pair Splitting**

The splitting algorithm can be represented by the flow chart of fig.3. The subprogram is entered only if the player has a pair and the strategy calls for splitting. If the cards drawn are of the same value as the original ones, the hand is split again. (This does not apply to split aces). The split hands are upon exit from this subprogram treated as separate games. Doubling, standing, and other decisions are therefore applied to each split hand separately.

**Doubling**

The doubling subprogram is entered only if the strategy calls for hard or soft doubling. A single card is dealt to the player, and the "double down flag" is set. The control is then transferred to the bet settling subprogram.

**Standing and Drawing**

The flow chart for this subprogram is shown in fig.4. The running count of aces (which have the value of 11) is
Enter here
iff player has
pair & wants to
split

$I = 2$
$K = 1$

$I = I + 1$

$I = I + 1$
$K = K + 1$

$P(I) = \text{card}$
← deal one card

$P(I) = P(I-1)?$
← is it of the same value as the two in the pair?

no

$K = K + 1$

$\text{Total}(K) = P(K) + \text{card}$
← deal second card to each of the effective hands

no

$K > I$?

yes

from now on,
treat split hands as two separate players

$I =$ number of cards given to player
$K =$ number of hands that are effectively played

FIGURE 3.
n = number of aces which are counted as 11
kept. If this number is greater than zero, we proceed according to soft standing rules and draw until satisfied or until the total exceeds 21 in which case the value of one of the aces is reduced to 1 and the procedure is repeated.

In case there are no aces (or if they are all counted as 1) the hard standing rules are followed. The "bust flag" is set if the player's hard total exceeds 21, in which case the bet is lost and the new game starts. (The dealer does not draw in this case)

**Bet Settling**

If the dealer's bust flag is set, player wins an amount equal to his bet. (If the player's bust flag is set, he loses automatically regardless of dealer's total, as explained above). If the dealer's flag has zero value, the totals are compared and the value of the bet is subsequently added, subtracted, or ignored depending on player's total being greater, less or equal to dealer's total respectively.

The cases of naturals on both sides are settled immediately after the first four cards are dealt and the control then proceeds to the next game.

The doubling subprogram (if entered), effectively doubles the size of the bet so there is no need to inform the bet settling subprogram whether the player has doubled down or not.

Split pairs are treated as separate games, hence the difference between the number of rounds and the number of games in the computer printout.
The overall flowchart of program operation and the listings of the main program, subprograms, and subroutines are given in Appendix B.
BASIC STRATEGY

In 1961, Dr. Edward Thorp, then on the staff of MIT, offered a "favorable strategy for twenty one" at the meeting of the American Mathematical Society in Washington, DC. His method, summarized in table form in Appendix C, revolutionized the approach to the game. He claimed a player expectation value of +0.12% without insuring, and keeping the bet size constant.

I simulated over 1.3 million hands of blackjack using this strategy and came up with the following results:

<table>
<thead>
<tr>
<th># OF HANDS PLAYED</th>
<th>UNITS WON</th>
<th>EXPECTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIRST RUN</td>
<td>510911</td>
<td>2557</td>
</tr>
<tr>
<td>SECOND RUN</td>
<td>511044</td>
<td>2383</td>
</tr>
<tr>
<td>THIRD RUN</td>
<td>364539</td>
<td>273</td>
</tr>
<tr>
<td>Overall:</td>
<td>1.386494</td>
<td>5213</td>
</tr>
</tbody>
</table>

After subtracting 0.00053 from the value of my expectation to correct for multiple splitting, which Thorp did not allow in his original computation, I obtained a bet expectation of 0.00116 which is in good agreement with the value claimed.

The relevance of a positive expectation without memorizing the cards should be pointed out. Essentially, this means that casino counter-measures such as adding packs of cards or not dealing to the bottom of the deck cannot adversely affect the strategy. Furthermore, now that it has
been shown that a positive expectation can be derived, we can explore those strategies pertaining to betting and counting which may increase that expectation.
COUNTING STRATEGIES

The basis of playing a long term winning game lies in counting the cards as they are dealt out. There is a variety of methods for doing this. In general, the more effective a method is, the more details the player must remember, the more computations and decisions he must make during the course of play. This section discusses and presents the results of simulations of some of the better known methods of card counting.

WILSON'S POINT COUNT

Wilson's method uses all Basic strategy rules for decisions, while counting serves for bet variations. The most favorable cards for the player are the aces and tens. If the deck from which hands remain yet to be dealt contains an excess of aces and tens then in general there is a positive expectation and one should increase the bet size. If it contains a deficiency of aces and tens there is a negative expectation and bets should be made as small as possible. These rules were determined experimentally by playing a few thousand games on a computer with excess or deficiency of tens and aces. See for example, Thorp's "Beat The Dealer", pg48.

The system assigns the following values to cards that are used, i.e. the cards which player sees:

Ace:  -4 points
ten:  -1 point
other: +1 point
The bet size is varied according to the following scheme:

<table>
<thead>
<tr>
<th>POINT COUNT</th>
<th>BET SIZE (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>greater than +7</td>
<td>5</td>
</tr>
<tr>
<td>+2 to +6</td>
<td>4</td>
</tr>
<tr>
<td>-1 to +2</td>
<td>3</td>
</tr>
<tr>
<td>-5 to -2</td>
<td>2</td>
</tr>
<tr>
<td>less than -5</td>
<td>1</td>
</tr>
</tbody>
</table>

For the purpose of saving computer time, Wilson's system was run together with the Basic strategy since both use practically the same set of rules. The results are presented below.

<table>
<thead>
<tr>
<th># OF GAMES PLAYED</th>
<th>NET WIN</th>
<th>TOTAL BETS</th>
<th>EXPECTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>First run: 511,044</td>
<td>7382</td>
<td>3,702,106</td>
<td>0.001994</td>
</tr>
<tr>
<td>Second run: 510,911</td>
<td>7385</td>
<td>3,701,754</td>
<td>0.001995</td>
</tr>
<tr>
<td>Third run: 364,539</td>
<td>-703</td>
<td>2,642,858</td>
<td>-0.000266</td>
</tr>
<tr>
<td>Overall: 1,386,494</td>
<td>14064</td>
<td>10,046,718</td>
<td>0.00140</td>
</tr>
</tbody>
</table>

The obtained expectation value, although positive, is disappointingly low (Wilson claimed 0.008 to 0.010) for two principal reasons. Firstly, the strategy does not provide the means for evaluating the "relative" richness of the deck in terms of tens and aces left. That is, if the point count is +5 for example, and the deck is nearly complete, the deck is not as rich in high cards as it is if the point count is +5 and only five cards remain. Yet, the system calls for the
same bet size in both cases. Secondly, Wilson suggests more than the minimum bet even for some cases with negative count: eg. "bet 2 units for count between -5 and -2".

This system in spite of counting gives lower expectation value than the basic strategy. It should therefore be avoided and the more efficient counting systems (to be discussed next) should be used whenever possible.

THORP'S 10 POINT COUNT

This strategy gives the "relative richness" of the unused deck and thus represents a significant improvement over Wilson's method. It calls for continuous computation of the ratio of nontens to tens. With full deck the ratio is:

$$\frac{\text{Non Tens}}{\text{Tens}} = \frac{36}{16} = 2.25$$

For each seen ten we subtract one from the denominator, and for each nonten (aces are included in nontens) one is subtracted from the numerator.

The betting chart, suggested by Thorp, and used for this simulation is shown below:

<table>
<thead>
<tr>
<th>RATIO</th>
<th>BET SIZE(units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>above 2.0</td>
<td>1</td>
</tr>
<tr>
<td>2.0 to 1.7</td>
<td>2</td>
</tr>
<tr>
<td>1.7 to 1.5</td>
<td>3</td>
</tr>
<tr>
<td>1.5 to 1.2</td>
<td>4</td>
</tr>
<tr>
<td>below 1.2</td>
<td>5</td>
</tr>
</tbody>
</table>

The further improvement is introduced by alteration of the basic strategy in terms of the ratio. For example,
basic strategy always calls for drawing with 10 versus 10, but not for doubling down. But if the ratio is 1.9 or less (as compared to average 2.25 to which basic strategy applies) one should double down. The deck is just enough richer in tens to justify a reversal in basic strategy. A converse example is 11 versus 10. Here, basic strategy calls for doubling down. If the ratio is higher than 2.8, however, one should draw and not double down. The depletion of tens at this point is such that the doubling no longer produces a higher expectation. The summarized version of Ten Count Strategy is given in Appendix C.

A deficiency of this method is that the aces are lumped in with the other nontens. Thorp provided the correction factor, however, which is computed separately. He estimated the increment (or decrement) in expectation due to fluctuations in ace content to be:

\[ (\frac{13A}{N} - 1) \times 4\% \]

Here A is the number of unseen aces, and N is the total number of unseen cards. When \( A/N = 1/13 \) the number of aces is average and the formula gives zero percent as it should.

The results of 100,000 simulated rounds are shown below. Only 100,000 were simulated because the expectation value converged rather fast to the region 0.0130 to 0.0145. The value in the table should be considered an upper bound.

<table>
<thead>
<tr>
<th>ROUNDS</th>
<th>GAMES</th>
<th>NET WIN</th>
<th>TOTAL BETS</th>
<th>EXPECTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>100,000</td>
<td>101,639</td>
<td>3448</td>
<td>234,926</td>
<td>0.014677</td>
</tr>
</tbody>
</table>
One of the great advantages of Ten Count Strategy is that it indicates automatically whether the insurance is a favorable bet. Whenever the ratio is less than 2.0 the insurance should be taken.

The ten count method is unquestionably a winning strategy and for those who can master it well enough and do not become easily fatigued or distracted, it should be worth the effort. I personally found this system too complicated to be able to use efficiently under "casino conditions". The added computations for flow of aces (without which the system looses an estimated 0.0055 in expectation value) represented an almost unsolvable problem.

Fortunately, the point count method (below) proved to be not only easier to memorize and use, but also more efficient.
THORP'S "ULTIMATE" POINT COUNT METHOD

As before, this method uses the fact that casino has the advantage when the deck is poor in high cards (10, A) and the player has the advantage when the deck becomes poor in low cards (2, 3, 4, 5, 6).

For each 10 or ace we see, we subtract one, for each 2, 3, 4, 5, or 6 we add one, while for 7, 8 or 9 the count remains unchanged.

To establish the relative richness, the point total is divided by total number of unseen cards. For example, in one deck game, if 5, 5, 3, 8, A fell, the point total would be +2, 47 cards remain (unseen), so we get 2/47 or about 0.04 or 4%. The ratio (in %) is called high-low index:

\[
\text{HIGH-LOW INDEX} = \frac{\text{POINT TOTAL}}{\# \text{OF UNSEEN CARDS}} \times 10^6
\]

The variations of basic strategy rules according to the value of high-low index are given in Appendix C.

The betting scheme as a function of index value suggested by Thorp and used in the simulation is shown below:

<table>
<thead>
<tr>
<th>INDEX</th>
<th>BET SIZE (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 2</td>
<td>1</td>
</tr>
<tr>
<td>2 to 4</td>
<td>2</td>
</tr>
<tr>
<td>4 to 6</td>
<td>3</td>
</tr>
<tr>
<td>6 to 8</td>
<td>4</td>
</tr>
<tr>
<td>above 8</td>
<td>5</td>
</tr>
</tbody>
</table>

The reason for betting no more than 5 units even when
the index is over 10, is simply to avoid potentially harmful
attention of casino employees.

The insurance is taken whenever the index becomes
greater than 8.

The results of 100,000 simulated rounds are presented
below. Here again, only 100,000 rounds were simulated because
the expectation value remained within the region: 0.015 to 0.018
throughout the last two-thirds of simulation.

<table>
<thead>
<tr>
<th>ROUNDS</th>
<th>GAMES</th>
<th>NET WIN</th>
<th>TOTAL BETS</th>
<th>EXPECTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>100,000</td>
<td>101,629</td>
<td>3611</td>
<td>233,934</td>
<td>0.015436</td>
</tr>
</tbody>
</table>

The significant advantages of this strategy are that
it has the highest expectation of all strategies mentioned,
it is easier to use than the tens ratio, and the average bet
size is practically equivalent to the average bet size used in ten count method. For these reasons, the high-low index provides the most powerful and accurate method of predetermining the approximate probability of winning a given hand.
CONCLUSION

After over 1.5 million simulated rounds, (and another half a million or so rounds generated in test runs) I can say with high degree of certainty that:

I- Basic blackjack, in itself is better than a mere even game.

II- Thorp's counting strategies give the player an excellent long run advantage in the vicinity of +1.5%.

The Point Count (or High-Low) Strategy was found to yield the highest expectation. It is also significantly simpler to use than the Ten Count Method, which produces high expectation as well. On the other hand, it is one thing to play blackjack with a computer and quite another to play it in a distracting atmosphere of a casino, with real money, and fatigue reducing the playing accuracy. The theoretical computations are excellent guide to what one can expect to accomplish. But when all is said and done, it is the long term profit produced on the table that determines the actual expectation for the game.
APPENDIX A

THE RULES OF BLACKJACK

Number of Players

Blackjack has a dealer and from one to seven players.

The Deck

One ordinary 52-card pack of playing cards is used. However, most casinos now use from two to four packs shuffled together in order to make card counting more difficult.

The Deal

Before play begins, the cards are shuffled by the dealer and cut by a player. A card is then "burned" (placed face up on the bottom of the deck). This card may or may not be shown. The dealer then deals two cards to himself and to each of the players. The dealer receives one card face up and one face down.

Bets

The players place all bets other than insurance before any cards are dealt. The house establishes a minimum and a maximum bet size.

Numerical Value of Cards

The player can choose either 1 or 11 to be the value of an ace. The numerical value of picture cards is 10, and the numerical value of all other cards is their face value. A hand is called "soft" if it contains an ace and that ace is counted as 11. All other hands are called "hard".
Object of the Player

The player tries to obtain a total which is greater than that of the dealer but which does not exceed 21. Hands which have exceeded 21 are said to have "busted".

Naturals

If the first two cards dealt either to the player or to the dealer consist of an ace and a 10 value card, they constitute a "natural" or "blackjack". If a player has a natural and the dealer does not, the player receives 1.5 times the original bet from the dealer. If a player does not have a natural and the dealer does, the player loses his original bet. If both player and dealer have naturals, no money changes hands.

Drawing

The draw starts at the left of the dealer and proceeds in a clockwise fashion. A player looks at his cards and may decide to "stand"; otherwise, he can request additional cards from the dealer, which are dealt face up, one at the time. If a player busts, he immediately turns up his cards and pays his bet to the dealer.

The Dealer's Strategy

After each player has drawn, the dealer turns up his hole card. If his total is 16 or less, he must draw a card and continue to draw cards until his total is 17 or more, at which point he must stand. If the dealer receives an ace, and
if counting it as 11 would bring his total to 17 or more without exceeding 21, then he must count it as 11 and stand.

**Splitting Pairs**

If the players original cards are numerically identical, they are called a pair. He may choose to treat them as the initial cards in two separate hands. This is known as "splitting a pair". The original bet goes on one of the split cards and an equal amount is placed on the other card. The player automatically receives a second card on each of the split cards. He then plays his two hands, one at a time, as though they were ordinary hands, with the following exceptions. In the case of split aces, the player receives only one card on each ace. Further, if a 10-value card falls on one of the split aces, the hand is not counted as a natural but only as ordinary 21. Similarly, if a player splits a pair of 10-value cards and then draws an ace, it counts only as an ordinary 21.

**Doubling Down**

After looking at his first two cards, a player may elect to double his bet and draw one, and only one more card. This strategy is known as "doubling down". A player who splits any pair except aces may, after receiving an additional card on each of the split cards, double down on one or both of his hands.
Insurance

If the dealer's up card is an ace, an additional wager is allowed before the draw. After checking his cards, a player may put up an additional side bet equal at most to half his original bet. After the player has decided whether or not to do this, the dealer checks his down card. If the dealer has a natural, the side bet wins twice its amount. If the dealer does not have a natural, the side bet is lost and the play continues.

The Settlement

If the player does not go over 21 and the dealer does, the player wins an amount equal to his original bet. If neither player nor dealer busts, the person with the higher total wins the amount equal to the original bet of the player. If the player and the dealer have the same total, not exceeding 21, no money changes hands (This is called a "push").
**APPENDIX C: THE RULES FOR BASIC STRATEGY**

**Pair Splitting**

<table>
<thead>
<tr>
<th>You have</th>
<th>Dealer shows</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.A</td>
<td>2 3 4 5 6 7 8 9 A</td>
</tr>
<tr>
<td>10,10</td>
<td></td>
</tr>
<tr>
<td>9,9</td>
<td></td>
</tr>
<tr>
<td>8,8</td>
<td></td>
</tr>
<tr>
<td>7,7</td>
<td></td>
</tr>
<tr>
<td>6,6</td>
<td></td>
</tr>
<tr>
<td>5,5</td>
<td></td>
</tr>
<tr>
<td>4,4</td>
<td></td>
</tr>
<tr>
<td>3,3</td>
<td></td>
</tr>
<tr>
<td>2,2</td>
<td></td>
</tr>
</tbody>
</table>

[Diagram of split and do not split options]

*Double down except with (6,2).*

**Soft Doubling**

<table>
<thead>
<tr>
<th>You have</th>
<th>Dealer shows</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.7</td>
<td>2 3 4 5 6 7 8 9 A</td>
</tr>
<tr>
<td>A.6</td>
<td></td>
</tr>
<tr>
<td>A.5</td>
<td></td>
</tr>
<tr>
<td>A.4</td>
<td></td>
</tr>
<tr>
<td>A.3</td>
<td></td>
</tr>
<tr>
<td>A.2</td>
<td></td>
</tr>
<tr>
<td>A.A</td>
<td></td>
</tr>
</tbody>
</table>

[Diagram of double down and do not double down options]

*Double down with (A,A) only if Aces cannot be split.*

**Hard Doubling**

<table>
<thead>
<tr>
<th>You have</th>
<th>Dealer shows</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>2 3 4 5 6 7 8 9 A</td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

[Diagram of hard doubling options]

*Standing Numbers*

<table>
<thead>
<tr>
<th>You have</th>
<th>Dealer shows</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>2 3 4 5 6 7 8 9 10 A</td>
</tr>
<tr>
<td>18</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

[Diagram of soft and hard standing numbers]

*Holding hard 16, draw if you hold two cards, namely (10,6) or (9,7), and stand if you hold three or more cards, for example (6,4,4,2).  
†Stand holding (7,7) against 10.*
### Table 7.1. Using the High-Low Index to Draw or Stand with Hard Hands.

<table>
<thead>
<tr>
<th>You have</th>
<th>Dealer shows</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>DRAW</td>
<td>STAND</td>
</tr>
</tbody>
</table>

The indexes are in per cent. Stand if your index is larger than the appropriate entry in the table. Draw if your index is less than or equal to the appropriate entry in the table. The table assumes that you have already adjusted your index to account for your hole cards and the dealer's up card.

### Table 7.2. Using the High-Low Index to Draw or Stand with Soft Hands.

<table>
<thead>
<tr>
<th>You have</th>
<th>Dealer shows</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>STAND</td>
</tr>
<tr>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td>17</td>
<td>20</td>
</tr>
<tr>
<td>15</td>
<td>24</td>
</tr>
<tr>
<td>14</td>
<td>25</td>
</tr>
<tr>
<td>13</td>
<td>30</td>
</tr>
<tr>
<td>12</td>
<td>35</td>
</tr>
<tr>
<td>11</td>
<td>40</td>
</tr>
</tbody>
</table>

Draw if you have a soft total of 16 or less.

### Table 7.3. HardDoubling Down with the High-Low Index.

<table>
<thead>
<tr>
<th>You have</th>
<th>Dealer shows</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>25</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>9</td>
<td>35</td>
</tr>
<tr>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td>7</td>
<td>45</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>55</td>
</tr>
</tbody>
</table>

Double down if your index is greater than the index in the square. Do not double down if it is less than or equal to the index in the square. Do not double down if a square is blank or if it is not on the table. The table assumes you have already counted your hole cards and the dealer's up card.

### Table 7.4. Soft Doubling Down with the High-Low Index.

<table>
<thead>
<tr>
<th>You have</th>
<th>Dealer shows</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
</tr>
<tr>
<td>A</td>
<td>3</td>
</tr>
<tr>
<td>A</td>
<td>4</td>
</tr>
<tr>
<td>A</td>
<td>5</td>
</tr>
<tr>
<td>A</td>
<td>6</td>
</tr>
<tr>
<td>A</td>
<td>7</td>
</tr>
<tr>
<td>A</td>
<td>8</td>
</tr>
<tr>
<td>A</td>
<td>9</td>
</tr>
<tr>
<td>A</td>
<td>10</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>10</td>
<td>24</td>
</tr>
</tbody>
</table>

Double down if your index is greater than the index in the square. Do not double down if it is less than or equal to the index in the square. Do not double down if a square is blank or if it is not on the table. The table assumes you have already counted your hole cards and the dealer's up card.

### Table 7.5. Using the High-Low Index to Split Pairs.

<table>
<thead>
<tr>
<th>You have</th>
<th>Dealer shows</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>

If a square is shaded, always split.
If a square is blank or omitted, never split.
If a square contains an index number, split if your index is higher. Do not split if your index is lower.

* Split (8,8) against 10 only if the index is below 24.
* Split (4,4) against 8 when the index is greater than 03 only if doubling down is not permitted.
* Split (3,3) against 8 when the index is above 06 and also when the index is below 02.
### Pair Splitting

*Numbers followed by (*) are read in reverse fashion. For example, split (8,8) against a 10 when the ratio is above 1.6 and not otherwise.

Split (4,4) against a 9 when the ratio is 1.1 or less only if doubling down on 8 is not permitted.*

<table>
<thead>
<tr>
<th>You have</th>
<th>Dealer shows</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, A</td>
<td>4.0 4.1 4.5 4.9 5.0</td>
</tr>
<tr>
<td>10, 10</td>
<td>1.3 1.5 1.7 1.9 1.8</td>
</tr>
<tr>
<td>6, 6</td>
<td>2.4 2.6 3.0 3.6 4.1</td>
</tr>
<tr>
<td>5, 5</td>
<td>1.3 1.6 1.9 2.4 2.1</td>
</tr>
<tr>
<td>3, 3</td>
<td>1.1 2.4 4.2 5.3 (*)</td>
</tr>
<tr>
<td>2, 2</td>
<td>3.1 3.8 (<em>) (</em>) (<em>) (</em>)</td>
</tr>
</tbody>
</table>

### Hard Doubling

<table>
<thead>
<tr>
<th>You have</th>
<th>Dealer shows</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>3.9 4.2 4.8 5.5 5.5 3.7 3.0 2.6 2.8 2.2</td>
</tr>
<tr>
<td>10</td>
<td>3.7 4.2 4.8 5.6 5.7 3.8 3.0 2.5 1.9 1.8</td>
</tr>
<tr>
<td>9</td>
<td>2.2 2.4 2.8 3.3 3.4 2.6 1.6 0.9</td>
</tr>
<tr>
<td>8</td>
<td>1.3 1.5 1.7 2.0 2.1 1.0</td>
</tr>
<tr>
<td>7</td>
<td>0.9 1.1 1.2 1.4 1.4</td>
</tr>
<tr>
<td>4, 2</td>
<td>1.0 1.2 1.3</td>
</tr>
<tr>
<td>3, 2</td>
<td>1.0 1.1 1.1</td>
</tr>
</tbody>
</table>

### Standing Numbers

<table>
<thead>
<tr>
<th>You have</th>
<th>Dealer shows</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>3.9 4.5 5.3 6.5 4.6</td>
</tr>
<tr>
<td>18</td>
<td>3.2 3.6 4.1 4.8 4.3</td>
</tr>
<tr>
<td>17</td>
<td>2.7 2.9 3.3 3.7 3.4</td>
</tr>
<tr>
<td>16</td>
<td>2.3 2.5 2.6 3.0 2.7</td>
</tr>
<tr>
<td>15</td>
<td>2.0 2.1 2.2 2.4 2.3</td>
</tr>
</tbody>
</table>

### Soft Doubling

<table>
<thead>
<tr>
<th>You have</th>
<th>Dealer shows</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, 9</td>
<td>1.3 1.3 1.5 1.6 1.6</td>
</tr>
<tr>
<td>10, 10</td>
<td>1.3 1.5 1.7 1.8 2.0 2.0</td>
</tr>
<tr>
<td>6, 6</td>
<td>1.3 1.5 2.2 3.3 3.8 3.5</td>
</tr>
<tr>
<td>5, 5</td>
<td>1.3 1.5 2.2 3.8 4.8 4.8 1.1</td>
</tr>
<tr>
<td>3, 3</td>
<td>1.3 1.5 2.2 3.8 4.8 4.8 1.1</td>
</tr>
<tr>
<td>2, 2</td>
<td>1.3 1.5 2.2 3.8 4.8 4.8 1.1</td>
</tr>
</tbody>
</table>

### Against an Ace

*Against an Ace, the soft standing number is 19 if the ratio is above 2.7. If it is 18 if the ratio is 2.2 or less. The hard standing number against an Ace is 18 when the ratio is above 3.1. It is 17 when the ratio is 3.1 or less.*
APPENDIX B: THE MAIN COMPUTER PROGRAM AND SUBROUTINES

COMMON ICARD (52), IDREF (53), NUM, IX, KFI, IVAL, KDL (11), ITOT (4),
IUP (4), INC (4), IPI (4, 11), ICAZ (4), ISPL (4), IDURL, ISTAT,
PLIST (4), ENB (4), PK, JACE, JEAS (20, 2C, 5), 1HILO, IDLPK, X (2)
10C0 FORMAT ("3X, 'TOTAL' , 4X, 'PPT', 8X, 'RET', 8X, 'GAMES')
7XY, 'GAMES')
10C0 FORMAT (1X, 'COUNT STRATEGY', 25)
1C0 C1M = 1000000
2C0 WITH (6, * 600)
3C0 WITH (6, 10CC)
4C0 WITH (6, 100)
5C0 XY = &42723
6C0 LCH = 0
7C0 NF = 0
8C0 TIPT = 0
9C0 TICE = 0
10C0 TSCI = 0
11C0 TNAC = 0
12C0 NAM = 0
13C0 IC = 1, 13
14C0 TOSY (IC) = TC
15C0 CONTINUE
16C0 DO 20 IC = 1, 39
17C0 IPECK (IC + 13) = IDECK (IC)
20C0 CONTINUE
21C0 IF = 409 J1 = 2, 21
22C0 DO 409 J2 = 2, 11
23C0 IF (J2-10) 411, 412, 413
24C0 JEN (J1, J2, 5) = - 100
25C0 GOTO 409
26C0 JEN (J1, J2, 5) = 100
27C0 GOTO 409
28C0 JEN (J1, J2, 5) = - 100
29C0 CONTINUE
30C0 DO 1401 J1 = 2, 11
31C0 DO 1401 J2 = 2, 11
32C0 JEN (J1, J2, 1) = 100
33C0 CONTINUE
34C0 CONTINUE
35C0 DO 1402 J1 = 17, 21
36C0 DO 1402 J2 = 2, 11
37C0 JEN (J1, J2, 1) = - 100
38C0 CONTINUE
39C0 CONTINUE
40C0 CONTINUE
41C0 DO 1403 J1 = 12, 16
42C0 DO 1403 J2 = 2, 11
43C0 READ (5, 1) JEN (J1, J2, 1)
44C0 CONTINUE
DC 1404 J1=2,12
DC 1404 J2=2,11
JBAS (J1,J2,3) = 100
1404 CONTINUE
DO 1405 J1=2,21
DC 1405 J2=7,11
JBAS (J1,J2,3) = 100
1405 CONTINUE
DC 1406 J1=13,21
DO 1406 J2=2,6
FBAC (5,11) JBAS (J1,J2,3)
1406 CONTINUE
DC 1407 J1=2,4
DC 1407 J2=2,11
JBAS (J1,J2,2) = 100
1407 CONTINUE
DO 1408 J1=12,21
DC 1408 J2=2,11
JBAS (J1,J2,2) = 100
1408 CONTINUE
DC 1409 J1=5,11
DO 1409 J2=2,11
READ (5,11) JBAS (J1,J2,2)
1409 CONTINUE
DC 1410 J1=3,21,2
DC 1410 J2=2,11
JBAS (J1,J2,4) = 100
1410 CONTINUE
DO 1411 J2=2,11
JBAS (2,J2,4) = 100
1411 CONTINUE
DO 1412 J1=4,20,2
DC 1412 J2=2,11
READ (5,9) JBAS (J1,J2,4)
1412 CONTINUE
DO 105 IXYZ=1,JKLM
DC 105 I=1,4
ITOT (I) = 0
IBUST (I) = 0
MACE (I) = 0
IBJ (I) = 0
INS (I) = 0
JBET (I) = 0
DC 105 J=1,11
IPLAY (I,J) = 0
105 CONTINUE
NPLAY=1
NP=NPLAY
ITOT=0
IACF=0
IBJ=0
CALL BFTTR
IBTOT = IBTOT + JBET(NP)
LC 110 I=1,2
CALL DFALA
ITCT(NF)=ITCT(NF)+IVA1
IPLAY(NP,I)=KTR
IF(IVAL-11)110,120,110
120 MACE(NP)=MACE(NP)+1
110 CONTINUE
IF(ITOT(NP)<-21)130,140,150
140 IBJ(NP)=000
GOTO 130
150 ITOT(NF)=ITOT(NF)-10
MACE(NF)=MACE(NF)-1
130 DC 170 J=1,2
CALL DFALA
LTOT=LTOT+IVA1
KLR(J)=KTR
IF(IVAL-11)170,180,170
180 LACF=LACF+1
170 CONTINUE
IF(KLR(1)-1)201,202,201
202 IDLR=11
GOTO 205
201 IF(KLR(1))204,203,203
203 IDLR=10
GOTO 205
204 IDLR=KLR(1)
205 IF(ITOT-21)190,200,210
200 LBJ=999
GOTO 190
210 LTOT=LTOT-10
LACF=LACF-1
190 IF(KLR(1)-1)236,220,230
220 CALL INSUR
INSTOT=INSTOT+INS(NF)
230 IF(LBJ)=240,240,250
240 INSWON=INSWON+INS(NP)
IF(IBJ(NP))260,260,270
270 IBET=IBET+(3*JIBET(NP))/2
GOTO 680
250 INSWON=INSWON+INS(NF)
IF(LBJ-IDB(NP))680,680,280
280 IBET=IBET-JIBET(NF)
GOTO 680
260 NP=1
290 IF(IPLAY(NP,1)-IPLAY(NP,2))300,310,300
310 CALL SPLIT
IF(ISPLIT-1)300,320,360
320 NP=NP+1
NPLAY=NPLAY+1
JPL=JPLAY-NP
DO 330 KAS=1,JPL
I=NPLAYP-KAS
IPLAY(I,1)=IPLAY(I-1,1)
IPLAY(I,2) = IPLAY(I-1,2)
JRT(I) = JRT(I-1)
ITOT = ITOT+JRT(I)

CONTINUE
CALL DEALA
IPLAY(I-1,2) = KTF
IF(IPLAY(I-1,1)-1) 330, 332, 334
IF(330) IPLAY(I-1,1)-10) 334, 335, 336
GOTO 333
ITOT(I-1) = 10
GOTO 333
ITOT(I-1) = 11
MACE(I-1) = 1
ITOT(I-1) = ITOT+ITOT(I-1)
IF(I, IVAL=11) 334, 335, 336
MACE(I-1) = MACE(I-1)+1

CALL DEALA
IPLAY(I,2) = KTF
IF(IPLAY(I,1)-1) 341, 342, 344
IF(341) IPLAY(I,1)-10) 344, 345, 345
ITOT(I) = IPLAY(I,1)
GOTO 343
ITOT(I) = 10
GOTO 343
ITOT(I) = 11
MACE(I) = 1
ITOT(I) = IVAL+ITOT(I)
IF(I, IVAL=11) 290, 370, 290
MACE(NP) = MACE(NP)+1
GOTO 290
IF(NF-NPLAY) 380, 390, 390
NP = NP+1
GOTO 290
DO 531 NP=1, NPLAY
CALL DDLLEN
IF(IUBL-1) 400, 410, 400
IF(TOT=IBTOT+JRT(NP)
JRT(NP) = 2*JRT(NP)
CALL DEALA
IPLAY(NP, 3) = KTF
ITOT(NP) = ITOT(NP)+IVAL
IF(IACP) 441, 441, 440
MACE(NP) = MACE(NP)+1
IF(ITOT(NP)-21) 531, 531, 442
IF(MACE(NP)+1) 490, 490, 443
ITOT(NP) = ITOT(NP)-10
IF(NP) = MACE(NP)-1

K = 2
CALL STRAT
IF(I, ISTRAT=1) 531, 450, 531
CALL DEALA
KIP=KIP+1

ITCT(NP)=ITCT(NP)+1

IF(NF,KIP)=KIP

IF(NF) "570"

IF(ITOT(NP)-21) 640, 660, 670

IF(NF) "580"

MACE(NF)=MACE(NF)-1

ITCT(NP)=ITCT(NP)-10

GOTO 460

IBUST(NP)=1

CONTINUE

KIP=1

DC 591 NE=1, NPLAY

KIP=KIP+1, IBUST(NP)

CONTINUE

IF(KIP-NPLAY) = 591

IF(KP=2)

IF(ITOT-16) = 590

CALL DFAIL

IF(NF) = 594

LACE=LACE+1

ITCT=ITCT+TVAI

KD=KD+1

KIP(KP)=KIP

GOTO 590

IF(LD=2) = 570

IF(NF) = 610

LACE=LACE-1

LACE=ITCT-10

GOTO 590

DC 621 NE=1, NPLAY

IBET=IBET-JBET(NP)

CONTINUE

GOTO 680

DO 621 NP=1, NPLAY

IF(IXST(NP)) = 632

IBET=IBET+JBET(NP)

GOTO 631

IBET=IBET-JBET(NP)

CONTINUE

GOTO 680

DC 679 NE=1, NPLAY

IF(IXST(NP)) = 625

IF(ITOT(NP)-120) = 625

IBET=IBET-JBET(NP)

GOTO 679

IBET=IBET-JBET(NP)

CONTINUE

NCASE=NCASE+1, NPLAY

IBET=IBET

IBET=IBET*1.5

DIOT=ITOT
SUBROUTINE BETT
COMMON ICAE(52), IDLE(52), NUM, IX, KTR, IVAL, KDLR(11), ITOT(4), 
2JBIET(4), INS(4), IPALY(4, 11), MAICE(4), IISPLIT, IDUBL, ISTRAT, 
3IBUST(4), IBIJ(4), NP, K, FACE, JBASE(20, 10, 5), IHILLO, IDLRK(4)
IF(IHILLO-2) 711, 711, 712
712 IF(IHILLO-4) 713, 713, 714
714 IF(IHILLO-6) 715, 715, 716
716 IF(IHILLO-8) 717, 717, 714
718 JBIET(NP) = 10
GOTO 733
717 JBIET(NP) = 9
GOTO 733
715 JBIET(NP) = 6
GOTO 733
713 JBIET(NP) = 4
GOTO 733
711 JBIET(NP) = 2
733 RETURN
END

SUBROUTINE DHLRN
COMMON ICAE(52), IDLE(52), NUM, IX, KTR, IVAL, KDLR(11), ITOT(4), 
2JBIET(4), INS(4), IPALY(4, 11), MAICE(4), IISPLIT, IDUBL, ISTRAT, 
3IBUST(4), IBIJ(4), NP, K, FACE, JBASE(20, 10, 5), IHILLO, IDLRK(4)
IF(MAICE(NP)) 2050, 2060, 2011
2011 IF(JBASE(ITOT(NP)) IDLRK(3) - IHILLO) 2050, 2060, 2060
2060 IDUBL = 1
RETURN
2060 IDUBL = 0
RETURN
END

SUBROUTINE SPLIT
COMMON ICAE(52), IDLE(52), NUM, IX, KTR, IVAL, KDLR(11), ITOT(4), 
2JBIET(4), INS(4), IPALY(4, 11), MAICE(4), IISPLIT, IDUBL, ISTRAT, 
3IBUST(4), IBIJ(4), NP, K, FACE, JBASE(20, 10, 5), IHILLO, IDLRK(4)
IF(ITOT(NP)) 1060, 1070, 1090
1060 IF(JBASE(ITOT(NP)) IDLRK(4) - IHILLO) 1070, 1090, 1090
1070 ISPLIT = 1
RETURN
1090 ISPLIT = 0
RETURN
END
SUBROUTINE DEAL
COMMON ICARD (52), IDECK (52), NUM, IX, KTR, VAI, KDLR (11), IROT (4), 
IQRT (4), IN3 (4), IPLAY (4, 11), MACE (4), ISPLT, IDBL, ISPAT, 
ISUBSE (4), IX, X, IACE, JBASE (20, 4), INH, IBLM, X (2)
IHK = 0
ICAF = 0
I(J) 910, 910, 920
910 PR 000 TK = 1, 5?
ICARD (TK) = IDECK (1K)
CONTINUE
K = 2
NUM = 1
INDEX1 = 0
CALL GGL (IX, X, 2, JLP)
ANUM = NUM
N = ! NUM = IX (1)
N = N + 1
ICARD (N) = ICARD (N)
INDEX (K) = ICARD (N)
INDEX (N) = ICARD (K)
GOTO (930, 941, 941, 941, 941, 941, 941, 941, 950, 950, 960, 970), KTR
930 IF = 1
IVAL = 1
IACE = 1
INDEX1 = INDEX1 - 1
GOTO 990
950 IF = 2
GOTO 960
960 IF = 3
GOTO 980
970 IF = 4
ival = 10
INDEX1 = 2
INDEX1 = INDEX1 - 1
GOTO 990
941 IVAL = KTR
INDEX1 = 1
GOTO 990
942 IVAL = KTP
INDEX1 = 1
INDEX1 = INDEX1 - 1
GOTO 990
940 IVAL = KTP
INDEX1 = 1
INDEX1 = INDEX1 + 1
990 NUM = NUM - 1
K = K - 1
IF (K) 991, 992, 991
991 IHILC = (INDEX1 / K) * 100.
GOTO 993
992 IF (INDEX1) 994, 995, 995
994 IHILC = -50
GOTO 993
SUBROUTINE INSTR

COMMON ICARD(52), IDECK(52), NUM, IX, KTR,IVAL,KDLR(11), ITOT(4),
JFET(4), INS(4), IPLAY(4, 11), MACE(4), ISPLIT, IDBUL, ISTRAT,
3IBUST(4), IFJ(4), NP, K, IACE, JBAS(20, 10, 5),IHILO, IDLRK, X(2)
IF (IHILO-K) 1, 22, 22
1
INS(NF) = JRET(NF)/2
GOTO 3
22
INS(NP) = 0
3
RETURN
END

SUBROUTINE STRAT

COMMON ICARD(52), IDECK(52), NUM, IX, KTR,IVAL,KDLR(11), ITOT(4),
JFET(4), INS(4), IPLAY(4, 11), MACE(4), ISPLIT, IDBUL, ISTRAT,
3IBUST(4), IFJ(4), NP, K, IACE, JBAS(20, 10, 5),IHILO, IDLRK, X(2)
IF (MACE(NF)) 1020, 1020, 1030
1020
IF (JBAS(ITOT(NP), TELRK, 1) - IHILO) 1050, 1050, 1040
1030
IF (JBAS(ITOT(NP), TELRK, 5) - IHILO) 1040, 1050, 1050
1040
ISTRAT = 1
RETURN
1050
ISTRAT = 0
RETURN
END
BIBLIOGRAPHY


