# Kowloon North Rotary Club – William Benter
## The philanthropist from McDonald's Worker to Betting Billionaire

By Herbert K. Lau (劉敬恒) (Rotary China Historian)

11 November 2018

Who is William "Bill" Benter?

If you ask the Google AI Mode, it will give you these answers:

William Benter is an American professional gambler and philanthropist, best known for developing a sophisticated, computer-based algorithm to bet on Hong Kong horse races. His system, which used advanced statistical modeling and data analytics, is estimated to have earned him nearly USD one Billion, making him one of the most successful gamblers of all time.

Key Details

- Background: Benter began by using his mathematical skills for card counting in Las Vegas casinos after reading《Beat the Dealer》, but after being banned, he turned to horse racing.
- The System: In the mid-1980s, Benter and Alan Woods developed an algorithm in Hong Kong to predict race outcomes using over 100 variables, such as past performance, jockey and trainer history, track conditions, and weather.
- Methodology: Benter's system calculated each horse's winning probability using a "Multinomial Logit Model" and determined bet size with the Kelly Criterion, only betting when his model found an edge.
- Success: The system achieved significant success, including a win of approximately $16 million USD on a single bet in 2001.
- Philanthropy and Academia: Benter now focuses on philanthropy through the Benter Foundation and is involved in academia, lecturing and establishing the William Benter Prize in Applied Mathematics.

## Rotary Club President

In Rotary, holding the Classification "Investment Statistician", Bill Benter is better known as President 2000-2001 of the Rotary Club of Kowloon North (九龍北區扶輪社) in the Hong Kong Special Administrative Region of China. Benter came to Hong Kong in the mid-1980s and was a lonely computer expert who focused much on database but with very few friends around. His interaction was entirely with a computer screen. One day his lawyer Gilbert Collins (江偉賢) (President 1995-1996 of Kowloon North Rotary Club) invited him to join Rotary. Accepting the invitation swept him into a philanthropic whirlwind that has been his life since he became a Rotarian in 1996. Benter enjoys Rotary! What he has been doing during his year of Club President? The Club's archive provides some of these information:

"2000-2001 Rotary Year was another excellent year for the Club. Having inherited a Club in good shape from Past President Bruce Stinson, President Bill was able to build on the extraordinary record of service that the Club was fast establishing. Some traditions of the Club were revived, and hopefully a few new ones were begun.

As both the Club's and District 3450's webmaster President Bill was very proactive in Internet matters. The Club website was enhanced and embellished, and the forerunner of what would later become the online《Sampan》first appeared on 31 August 2000 in the form of the first weekly electronic "President's Message", which was sent using the Club's new e-mail list.

Past presidents Gary and Michael Harilela hosted a wonderful club fellowship evening at their home on September 28th, which got the fall season off to a good start. That fellowship evening was following closely on October 14th by another enjoyable evening at the home of Past President M. S. Kalra. Other good news from late September was the approval of two new members: Returned former member Past President Peter Lo, and new Rotarian Howard Davies.

Another technical advance was made on October 20th when President Bill sent a digital photo along with usual e-mail to members. This was the first instance of what later became a common practice with the online version of the《Sampan》.

As usual, in early November the Club supported the annual Terry Fox Run to raise money to fight cancer. The Club was represented by nine members along with eleven Interactors and a group of twenty from Camp Quality. In mid-November, Rotarians Bill, Gilbert, Ramesh and Frank visited Guangzhou with a delegation from Camp Quality.

A bit of mild excitement occurred in mid-November when one of the computers in Past President Joseph Lee's office began sending out hundreds of virus containing e-mails to all of the club members' e-mail addresses. The crisis was soon brought under control by the swift action of the Club Webmaster (President Bill).

December saw the addition of two new members to the Club, Rotarians Dan and Nigel and a recent meeting attendance record was set on December 8th with 24 members present to hear Feng Shui Master Peter Lo making his predictions for the future. The halfway point of the Rotary year was reached with the Club stronger by four members and with a respectable record of service and fellowship.

In January the Club initiated what was to be a month long process of designing a new Club banner. The Club was running out of the old banners, and it was decided that a re-design was in order. Various candidate designs were posted on the Club's website for members' review and comment. The Year of the Dragon drew to a close with the Club in good shape and ready for the New Year.

February saw a Club sponsored Internet training course for Interactors and a tremendous fellowship evening at the Cococabana Restaurant on Lama Island. A junk was hired to transport Club members to and from the event, and a good time was had by all. Most importantly though, the Club had the privilege of naming Professor Patrick Yuen as a Paul Harris Fellow. Professor Yuen is a remarkable man who has devoted his life to the care of children with cancer. As the honorary chairman of Camp Quality, Professor Yuen has rendered service to Rotary and more importantly to the children whom Camp Quality serves.

The new online《Sampan》was first published on March 1st. The Club had gone some years without a regular printed newsletter, but the President's enthusiasm for the Internet and his sense of the tremendous significance of his own musings led him to establish a permanent online record to be preserved for all eternity on the Club's website. A Vocational Service visit to the new Air Traffic Control Centre at the new Chep Lap Kok International Airport was arranged by Past President Michael. Rotarian Albert undertook the Herculean task of cleaning out and re-organizing the Club filing cabinet.

A contingent of five Rotarians from Kowloon North attended the District Conference in April, and a group of ninety-four Camp Quality children attended the District tree-planting day. A serious attempt was made to gather the last of the member's details for a re-publishing of the Club Roster. Sadly, this was never achieved. On the bright side, Honorary Member Past President Uncle George Chu cast the deciding vote and a new club banner design was chosen. During these past months, Uncle George had been in hospital and club members, both in groups and individually, have made numerous visits to his bedside.

In May, a delegation from the Club made a visit to an elderly hostel run by St. James' Settlement, and a "boys' night" fellowship was held which involved a visit to an establishment in Tsim Sha Tsui East. Though there were many lovely distractions at this establishment, members' thoughts never strayed from the Object of Rotary and the Four-Way Test. A day trip was made to an orphanage in Guangzhou and a major visit to Guangxi Province was undertaken to assess the feasibility of the "New School Project". In mid-month, the Club had the pleasure of inducting new Rotarian Nicole. Later, Past President Steve Lan and President Bill paid a visit to Sister Club in Ama, Japan, and were most graciously entertained.

The Club's annual celebration was held in June in the form of a "Rock n' Roll" party which was well attended and included appearances by Bruce "Roy Orbison" Stinson, and Ramesh "Jimmy Hendrix" Chugani. The Club bid farewell to Rotarian Jenny who relocated to Australia. President Bill capped his term as president by attending the Rotary International Convention in San Antonio. Upon returning, he presided over his last meeting as president."

## Contributions to Rotary

During his Rotary life in Hong Kong, Benter might have made monetary contributions generously in many ways to various items including The Rotary Foundation (e.g. US$3 million to End Polio) that we do not know unless he wants to disclose from his mouth. Listing below are some projects that have been involved by or to the knowledge of the author:

(1) R.I. District 3450 Website – That was the first ever website inaugurated in the Year 2000-

2001. Holding the official title of "District Information Coordinator", Benter was the master to provide the engineering in the website construction and maintenance, in addition to his generous sponsorship on the entire operation costs. Collaborated by Herbert K. Lau (劉敬恒), Deputy Coordinator, who was responsible in feeding the content in both Chinese and English languages. (Privately, Lau provided his personal Vocational Service to Benter as his insurance consultant.)

(2) Mongolia – Recommended by Herbert K. Lau, Benter has joined 2 projects of computer education in Ulaanbaatar: (i) In 2001, Benter donated US$25,000 worth of computers to a high school in Ulaanbaatar in setting up the first ever computer teaching room in the country (see photo below). (ii) In 2006, from his personal pocket of US$6,000, Benter joined the international partners of Niislel Rotary Club of Mongolia, Taipei Sun-Young Rotary Club (台北昇陽扶輪社) of Taiwan, and of course The Rotary Foundation to set up another computer teaching room in a high school with special equipment for language learning.

*2001 – An educational project recommended by Herbert K. Lau (劉敬恒) (Tolo Harbour), William Benter donated US$25,000 worth of computers to high school in Ulaanbaatar, Mongolia. Pictured: William Benter points to one of the new computers, while RI Vice President Gary Huang (黃其光) (Taipei) (L1) and District 3450 Governor Johnson Chu (朱梓焜) (Peninsula) (R2) observing. (Photo by: Herbert K. Lau)*

(3) China – During a school project initiated by Macau Rotary Club (澳門扶輪社) to re-build 8 schools, Benter made a donation to restart construction of Du'an Yao Ethnic Experimental Middle School (都安瑤族自治縣民族實驗初級中學), which for years had moldered as a four-storey shell beside a brackish pond because government funding had stalled. The campus, completed in 2005, now houses science and technology laboratories, a multimedia room so well-equipped that it is often booked for government and business functions, and a dormitory bearing Benter's name. (Read more about the project on Pages 15-16.)

(4) Afghanistan – Read the story of refugee relief reprinted on Pages 11-12 as reported by《The Rotarian》magazine June 2002.

What inspired Benter to transfer his betting dividend from the horse-racing to The Rotary Foundation projects? Find the story reported by《The Rotarian》reprinted below on Pages 14-19.


*29 June 2001 – Presiding the Kowloon North Rotary Club regular luncheon meeting, President Bill Benter has the honor of presenting his last banner to Rotarian Bob Pope.*

*2005 – Bill Benter speaks at the completion ceremony of the Du'an Yao Ethnic Experimental Middle School campus, Guangxi Province, China. (Photo credit: Rotary Club of Macau)*

*2005 – Bill Benter presents scholarships to students of the Du'an Yao Ethnic Experimental Middle School.*


*2005 – Bill Benter donated the construction cost of the [Benter House 韋奔達公寓樓] Student Dormitory of Du'an Yao Ethnic Experimental Middle School*


*A staff Christmas party in 2000*

*Bill Benter hired anyone—coders, academics, journalists—who could improve his algorithms.*

*William Benter delivered a Lecture on Gambling at the*

*Macao Polytechnic University – Centre for Gaming and Tourism Studies*

*澳門理工大學 – 博彩旅遊教學及研究中心*

# A sketch of William Benter

## Benter's beginnings

William "Bill" Benter was born in 1957 and grew up in Pittsburgh, Pennsylvania, U.S.A. Raised in a modest, middle-class household, he quickly showed himself to be a mind apart, marked by a fascination with numbers and logic. In 1977 he studied physics and philosophy in Case Western Reserve University. It was during this time that he began to realize how mathematics could be applied to gambling. He came across a copy of the famous gambling bible《Beat the Dealer》by Edward Thorp. Thorp is known to many as "The Godfather of Card Counting", and his methods spoke directly to Thorp's mathematical mind. Benter had an aptitude for the probabilities involved, so got to work memorizing every detail of Thorp's book. Then it was time to put it into action.

## Takes full-time on Las Vegas

In 1979 Benter dropped his studies and to find his treasure on the blackjack tables. He was keen to use his natural mathematic prowess and his newly-learned blackjack and card-counting skills to make a profit. Thorp's approach, as adopted by Benter, is reasonably common knowledge these days. Players gain an advantage by counting cards---keeping track of the number of high and low cards that come of the deck, and therefore knowing the value of the cards that are left in the dealer's deck. From there, it's a matter of waiting for the right time to strike. When there are a high ratio of high-value cards (such as 10s and aces) left in the deck, the chances of drawing a desired card fall into the player's favour. If the player then sticks to the optimal strategy for blackjack---known as basic strategy---the odds are tipped in their favour. It's not a simple process, requiring the player to memorize large amounts of information and then use it to make split-second decisions as cards are dealt. But for those who can master it and play accurately for long enough, the odds say they'll end up in front.

Benter was one who was able to master card counting. As knowledge of card counting grew, the exponents of it became public enemy #1 for casinos! These players were winners, and winners are not welcome in casinos. The houses banned card counting and upped their efforts to quickly identify those doing it---including employing card counters as lookouts. While it's impossible to know just how much he won, Benter spent seven years in Vegas playing full-time. Inevitably, Benter was caught up in the crackdown and was banned by all Vegas casinos.

## Beats roulette?

This part of Benter's tale is very light on evidence, but it is fun speculation all the same. There are stories told that during his time in Las Vegas, Benter developed a system that was actually able to beat the odds at roulette. The system---that he supposedly created in his spare time in between playing blackjack---was said to be able to calculate the speed at which the roulette ball was travelling immediately after release. If a player could memorize the equation to measure the ball's speed, note the ball's entry point and instantly calculate the formula in their head, they would supposedly be able to determine which quadrant of the wheel it would end up in.

Again, it's never been confirmed. But it's some story!

## The McDonald's cleaner met Alan Woods

In 1980 Benter had just applied for a job as a night cleaner at McDonald's when his buddies introduced him to the man who would change his life. Benter met the fellow blackjack professional Alan Woods who was the leader of an Australian card-counting team that had recently arrived in Las Vegas. Woods had studied to be an actuary but was an all-round gambler and a horse racing expert. Predictably, after a while card counting in Monte Carlo, he chose Las Vegas and its myriad of casinos as target. The two joined forces in 1984 and set about turning their success in Vegas into a consistent edge at the racetracks of Hong Kong where is one of the world's biggest horse racing markets. Crucially, there are plenty of casual punters more focused on luck than worrying about winning long-term.

Benter, Woods and a third member, Wally Sommons, worked together on a horse racing system that backed favourites. They quickly discovered that if they bet on overlays they had a decent edge. However, it took some time before their efforts were rewarded. Over the course of two years, the team managed to give away most of their US$150,000 (equivalent to US$453,988 in 2024) starting bankroll. But after another couple of cash injections, they managed to get their system working. They made US$100,000 profit in their third year.

Using his statistical model, Benter identified factors that could lead to successful race predictions. He found that some came out as more important than others. Refining his software, he ended up winning US$600,000 in 1988 and hit US$3 million in profits the following year. Benter later worked with Robert Moore.

## Goes solo

In 1987 the team split up following disputes over money. Benter was determined to continue on his own, taking the early model and building it into something more powerful. The focus of Benter's model was to determine the various factors in racing and then weigh them accordingly.

The tool Benter used for this was known as Multinomial Logit Regression. This tests factors to determine their significance as to the outcome of a race---more specifically, if it leads to the horse winning. The Multinomial Logit Regression model then calculates the weighting of the factors.

In the early days, Benter started out with only 16 form factors to determine the outcome of a race. Many of the factors were calculated manually and databases were created from scratch. Over time the number of factors grew more than 100 as Benter incorporated not only statistics but also video analysis and subjective form factors. Benter's model allows him to determine the 'true odds' of every runner in a race and only bet on overlays. He also uses the same mathematical techniques to bet on the huge exotic pools in Hong Kong. (Read Benter's report on Pages 30-46)

## Supporting higher education

Since 1987 Benter and his team have won incredible amounts in Hong Kong. He was chairman and International CEO of Acusis LLC in Pittsburgh, Pennsylvania. These days he also spent his time lecturing on mathematical probability and statistics at Harvard, Hong Kong and Southampton. Benter was a visiting professor at the University of Southampton Business School, United Kingdom, as part of the Centre for Risk Research and a fellow of the British Royal Statistical Society.

In 2007, Benter founded the Benter Foundation which is a private philanthropic foundation based in Pittsburgh, Pennsylvania, and focuses primarily on advancing a livable Pittsburgh, enhancing the arts, supporting local education, and fostering global connections.

In Hong Kong in 2010, Benter donated an endowment to set up [The William Benter Prize in Applied Mathematics] which is a prestigious biennial award of US$100,000 in the Liu Bie Ju Center for Mathematical Sciences (劉璧如數學科學研究中心), the City University of Hong Kong (香港城市大學). The Prize recognizes outstanding mathematical contributions that have had a direct and fundamental impact on scientific, business, finance and engineering applications.

In 2012, Benter donated USD one million to the University of Pittsburgh, U.S.A.

Mr William Benter (right) presents the first William Benter Prize in Applied Mathematics to Professor George Papanicolaou.

## Philanthropy

Benter is a big contributor to charity and political groups. According to political campaign contribution records, in 2008 Benter and Acusis were listed as donors to Barack Obama's presidential campaign and the Democratic Party of Virginia. In 2010, The Advantage Trust donated to Israeli-based organization [Rabbis for Human Rights]. 《The Atlantic》reported in 2010 that Benter had raised and given at least US$800,000 in support to J Street.

In 2013, *Fox News* reported that Benter donated thousands of dollars for pro-Hagel ads in 《Politico》when he was nominated to be next Secretary of Defense by President Obama. In 2016, 《The Washington Post》reported that Benter raised US$100,000 for [A New Voice for Maryland], a pro-Joel Rubin group for Democratic nomination in Maryland's 8th Congressional District.

## Rotarian Couple

In March 2010, Benter married Hong Kong Rotarian Vivian Fung (鳳慧蓮) in a Tibetan Buddhist rite. In 2015, they had the first child Henry. The Benters are now residing in Pittsburgh.

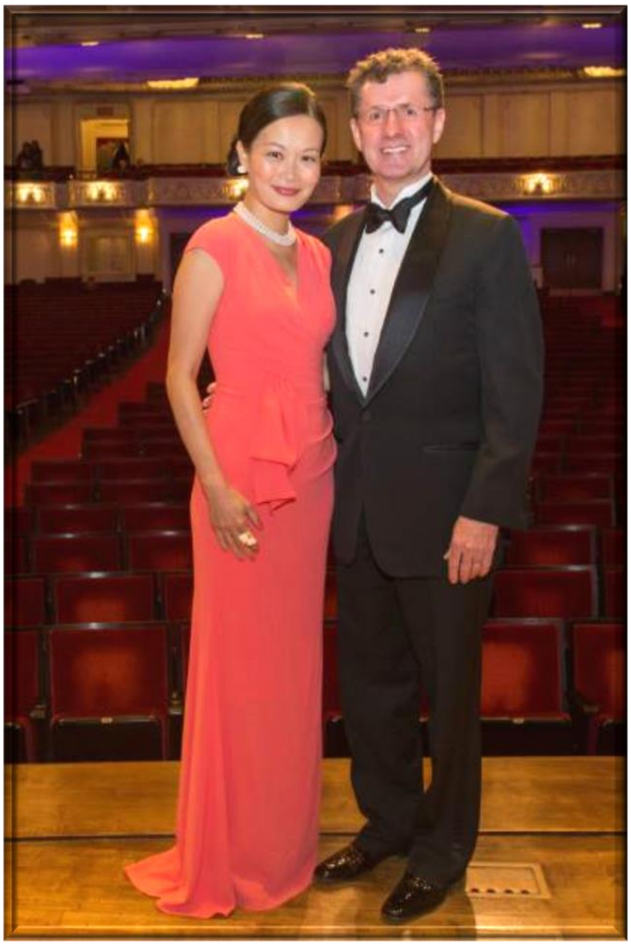
*Rotarian William "Bill" Benter and RotaryAnn Vivian in Pittsburgh*

Rotarian Mrs. Vivian Benter (President 2004-2005 Peninsula Sunrise Rotary Club 半島旭日扶輪社, Hong Kong, Classification "Financial Services") is a prominent philanthropist and community figure in Pittsburgh, known for her work with the Benter Foundation (https://benterfoundation.org), which she co-founded with her husband, Rotarian Bill Benter.

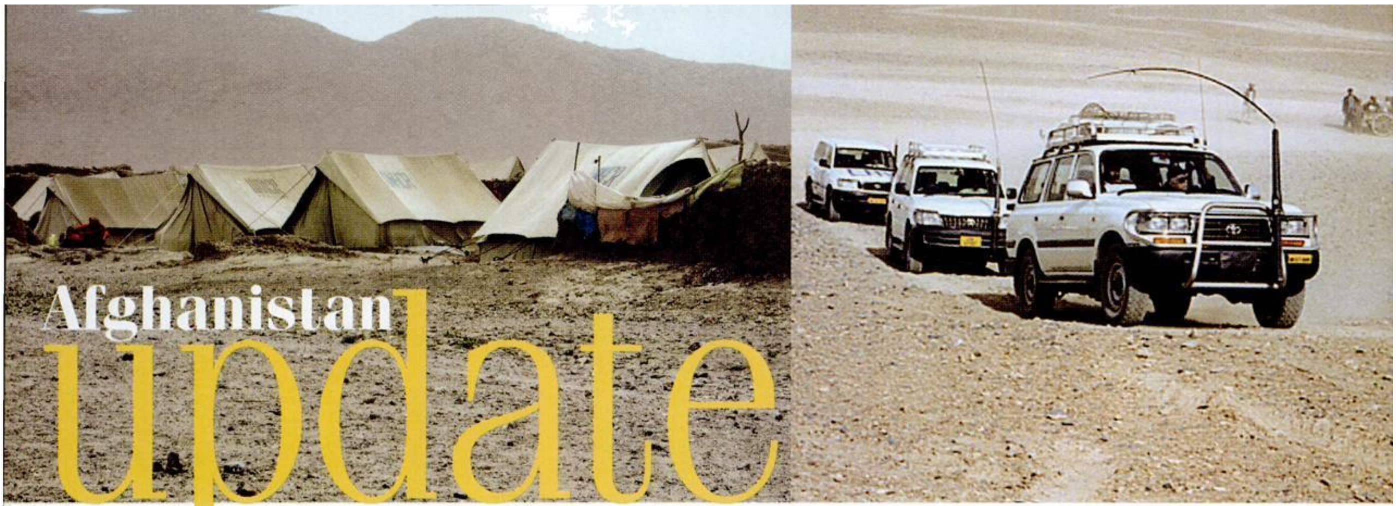
The Benter Foundation is a significant charitable organization in the area, dedicated to "helping communities and individuals thrive" by investing in various local initiatives. Vivian and Bill Benter are noted for their support of:

- The Arts: They are major supporters and hosts of events for local organizations such as the Pittsburgh Opera and the Pittsburgh Ballet Theatre.
- Community and Civic Engagement: The Benter Foundation supports public parks, smart transportation, and global connections and community engagement.
- Education and Human Services: The Foundation provides grants to various non-profit groups and educational initiatives.

Vivian and Bill Benter are active participants in Pittsburgh's social and philanthropic scene, often attending events and galas they've helped make possible through the Foundation's generous grants. She is also described as a "domestic engineer" who lives in the Strip District neighborhood with her family.



*Rotarian William "Bill" Benter and RotaryAnn Vivian in Pittsburgh*



# Afghanistan update

by Ivy A. Walsh

In early April, hope for thousands of Afghans living in the Shalman and Mohammad Khail refugee camps along the Pakistan-Afghanistan border came in the form of necessities: kerosene lamps, blankets, and soap, among other items. The aid, which was purchased, coordinated, and distributed by the RI Afghan Refugee Relief Effort Committee, was the first step in a multipronged attempt to make a significant impact on the lives of the more than 48,000 residents of the two camps.

"The most memorable part of distributing RI aid was seeing the expressions of pleasure on the faces of the refugees," recalls Tariq Akhtar Allawala, a member of the relief committee and of the Rotary Club of Karachi Karsaz, Pakistan. "One refugee even commented, 'This kerosene lamp will be the only source of light for us after the darkness.'"

The relief mission would not have been possible without the support of the office of the UN High Commissioner for Refugees (UNHCR), the United Nations' refugee agency. Led by Chairman Lynmar Brock Jr., Rotary collaborated with UNHCR to aid Afghan refugees. "Just to get to these camps," says Brock, a member of the Rotary Club of Philadelphia, Pa., USA, "you need to travel through dangerous areas where a lot of kidnappings are going on. This wasn't something you do as an amateur. We needed to work with UNHCR; they know which camps need the most help, exactly what the refugees need, and how to get the supplies to them."

The international relief effort also involves another leader with ties to Rotary and UNHCR: Sadako Ogata, former high commissioner and a past Ambassadorial Scholar. She was appointed to represent Japan at the Working Session on the Reconstruction of Afghanistan in November 2001 in Washington, D.C.

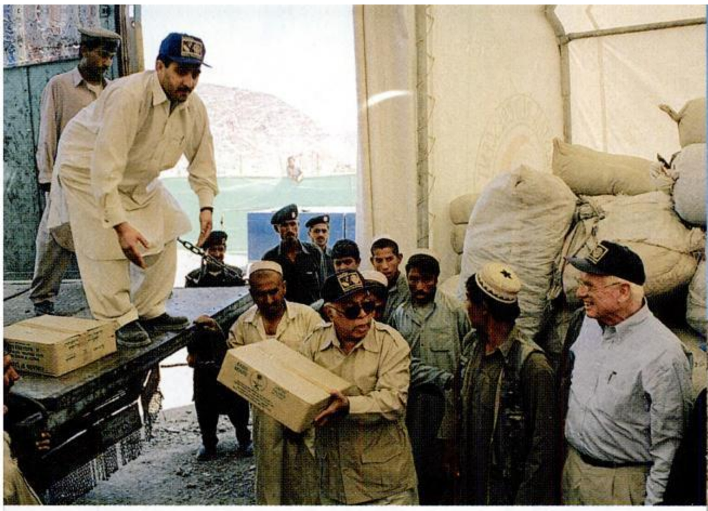
In close cooperation with UNHCR, the RI committee determined in February that the nearly US$1.8 million pledged to RI President Richard D. King's Notice of Disaster could be used most effectively to support the Shalman and Mohammad Khail refugee camps over a 90-day period.

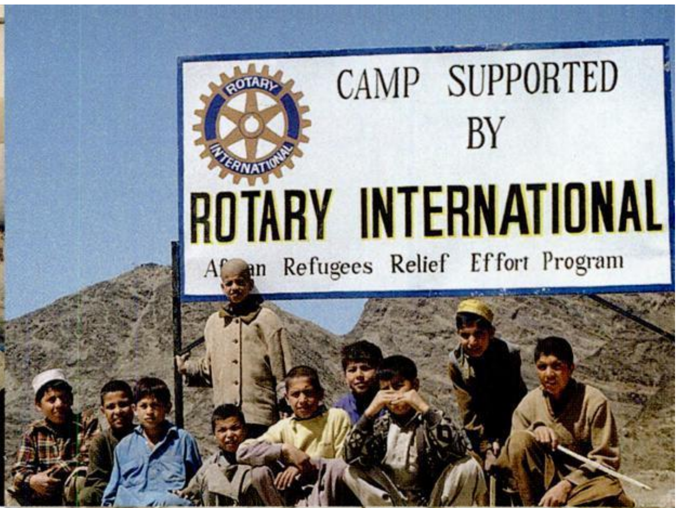
On 3 April, RI committee members; Pakistani Rotarians; William Benter, a past president of the Rotary Club of Kowloon North, Hong Kong; and UNHCR representatives journeyed up the Khyber Pass to Shalman, about 2.5 hours north of Peshawar, to distribute aid. Guards stationed around the Rotary convoy of white SUVs ensured the group's safety through the mountainous terrain. Similar security measures were taken during their passage to Mohammad Khail later that week.

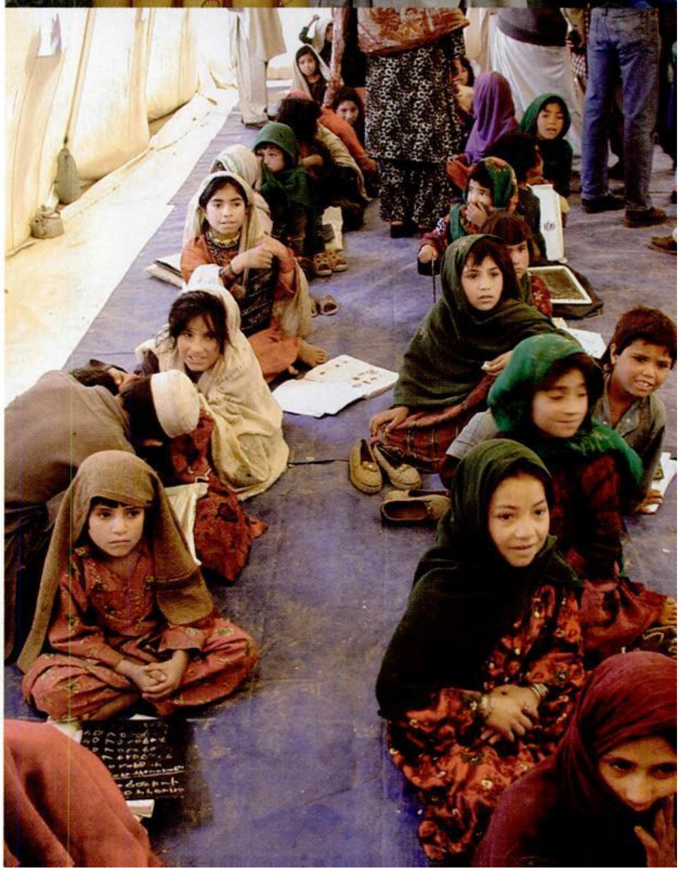
At each camp, the Rotarians first met with tribal elders. Every refugee family then received a package containing tea, dates, biscuits, and sweets. The bulk of the aid, including thousands of shawls, blankets, jackets, shoes, soaps, medical supplies, educational and recreational materials, kerosene lamps, and oil was then distributed en masse by UN volunteers. Every item included a tag that read, in Urdu and English, "Gift of Rotary International." Water tanks were unloaded. Amputees even received artificial limbs. Because the relief committee purchased all of the supplies in Pakistan, Rotary dollars also helped the Pakistani economy.

For the camps' children, the brightly colored soccer balls were an instant hit. Says Chairman Brock, "I realized that something as simple as a ball is useful. Although they don't have a playing field, kids are kids. It's a small gesture, but this is the sort of thing that Rotary does."

The Rotarians met refugees and visited makeshift schools, emergency rooms, and recreational areas. For





Clockwise, from top left: Conditions at the Shalman and Mohammad Khail camps are strikingly bare. The camps are located in isolated and dangerous terrain, which forced the delegation to travel by heavily guarded caravan. Once at the camps, Rotarians helped unload supplies, met camp residents, monitored relief warehouses, and visited UN-operated schools, like this one (bottom right) for girls. Opposite: RI committee members (from left) Sirajuddin Cassim, Muhammad Faiz Kidwai, and Lynmar Brock Jr. and (right) UNHCR representative Montserrat Feixas Vihe gather for an afternoon briefing.

Rotarian Benter, the sprawling size of the refugee camps was striking: "Conditions were spartan, with people living in tents and makeshift stone shelters under desert conditions with extreme temperatures."

The situation was particularly alarming at Shalman, which did not have a permanent source of water. Now that refugees at the two camps have basic supplies, the relief committee is determining what the next priorities should be. For Shalman, the decision is likely to include a water delivery system. UNHCR's objective is to provide at least 15 liters of water per person through deep wells, boreholes, and new supply lines. Because Shalman is located near the Kabul River, fresh water is available, but the basic infrastructure is lacking.

"We are extremely grateful to Rotary International for [its] contribution," says Montserrat Feixas Vihe, assistant representative of UNHCR. "We hope that this is the beginning of a long and fruitful cooperation between Rotary International and UNHCR in Pakistan and throughout the world."

Other priorities include providing vocational training and possibly replacing kerosene-fueled devices with coal alternatives. "While we were visiting, a kerosene stove ignited a tent and killed one person and sent several others to the hospital," Brock recalls. "Kerosene is dangerous, and if UNHCR determines that the switch should be made to coal heat, we will be there to provide the coal."

The ultimate goal, says Chairman Brock, is for the refugees to return to Afghanistan with the vocational skills – and the desire – to rebuild their country. Although achieving peace and stability in Afghanistan won't be easy, international cooperation and aid remain essential to the process.

✦ *Ivy A. Walsh is an assistant editor of* THE ROTARIAN.

# IN THE CARDS

## Because Major Donor Bill Benter played his hand right, The Rotary Foundation won

AS TOLD TO STEPHEN YAFA

I was about to turn 40 when I joined Rotary. The timing was perfect. I'd wandered into a profession, computer software development, where I was disconnected from any community.

I was developing a somewhat complex database program for betting on horse races, based on 70 variables for each horse that enabled me and my colleagues to determine its true odds of winning in any race, once we entered all the data and did our modeling. But we had to key the information into our Kaypro computers – this was way back when, and there were no available online racing databases in the mid-'80s.

My interaction was entirely with a computer screen. We didn't have customers or clients, so I had little opportunity to connect with other humans. And I was living in Hong Kong, a long way from Pittsburgh, my home. There were far fewer horses racing in Hong Kong than anywhere else, I'd discovered, so my business partners and I had packed up our primitive computer equipment and moved there. Our goal was to handicap every Hong Kong racehorse based on past performance, track conditions, and so forth, and place strategic bets based on the results. It was a huge amount of work – but profitable and perfectly legitimate.

By 1996, the business was becoming a substantial success. I was now betting my own money and doing quite well, but unless you're an extremely gregarious person, which I'm not, you don't make that many new friends in foreign surroundings. That was the draw of Rotary for me. Our business lawyer, Gilbert Collins, invited me twice to join the Rotary Club of Kowloon North before I accepted. I must have had some trepidation; I'm not a joiner by nature. But before I knew it, I was on my way to becoming a member. Rotarians respect the dignity and usefulness of all professions. Mine didn't have a service

> I have a fondness and an aptitude for numbers, and, as I discovered through Rotary, a passion for putting my skills to work for causes I believe in.

component, so I felt immensely honored to have been asked to join. In the first year after I became a member, I learned more about the Hong Kong community than in all the time I'd been living there. Looking back, it's not surprising that I would become deeply involved in the club's service projects.

I soon became the club's international service director and was charged with reaching out to join forces with clubs in other locations. Bruce Stinson, past president of the Kowloon North club, had already made friends with Sai-Hong Choi, past president of the Rotary Club of Macau, and had visited impoverished Du'an County in southeast China in 1999. He'd been moved to tears by the condition of many of the area's rural schools – the roofs and walls had collapsed, and there were no desks or seats, he reported. The Macau club lacked funding, and that's where we stepped in.

I knew that it would be something of a gamble to make our way through the Chinese regional bureaucracy and ensure that the money we raised went where it was intended, but I'd been gambling successfully for most of my adult life. In my junior year, I had dropped out of Case Western Reserve University, where I was studying physics and philosophy, and gone to Las Vegas with my friends to play blackjack. I remembered a sign I'd seen as a teenager in an Atlantic City casino: "Professional card counters are prohibited from playing at our tables." That always stayed with me; it meant that if you learned to count, you could win. And that's what we did until we got bounced out of all the Las Vegas casinos. Card-counting improves your odds and is completely legal, but Nevada casinos are private property, and owners can bar anyone they want from entering. In our early 20s, we were averaging about $80,000 each per year at blackjack, which was pretty good back then for young kids.

I never made a serious career choice to become a gambler. My only real interest has been to beat the system and come out ahead. I have a fondness and an aptitude for numbers, which helps – and, as I discovered through Rotary, a passion for putting my skills to work for causes I believe in. As I got to know the Chinese government officials in Du'an, my level of trust increased. They turned out to be sincere and honest and grateful for our help. The government agreed to put up half the money if we put up the other half – a total cost of about $60,000 to rebuild each school. To me, this seemed like a slam-dunk, and thanks to the success of my business, I was able to donate a substantial amount of those costs on my own. The Kowloon North club teamed up with the Macau club on the first three schools in the region, and since then, our district's clubs have been able to fund many more. Putting the money into bricks and mortar assured us that we were creating something of lasting value, that the money wasn't being frittered away. It was my kind of gamble.

For me, one of the most rewarding results of these service projects is to watch my perceptions bump up against reality. I expected China to be a tyrannical place, even brutal. But my Rotarian colleagues and I learned a few things as we watched the Long'an middle school in Du'an being transformed from a dilapidated building into a functional structure. I asked the headmaster about discipline. "Do you spank students?" I wondered. He looked at me incredulously. "Spank students?" He was shocked at the suggestion. Teachers and administrators are forbidden to employ physical punishment, he explained. "They do that in your country?" It was inconceivable to him that we could even think that was possible. So much for my concern about social protectors.

Now, about 11 years after the first schools were rebuilt, Du'an has become a thriving region. When we visited in

2008, schoolchildren no longer looked at our cameras in awe; they snapped digital photos of us with their smartphones. There had been an amazing upsurge in prosperity. Our first school project was dwarfed, in a good way, by high-rises all around.

On that visit, I suggested that because the city centers were booming, perhaps we could help rebuild schools in the surrounding mountain villages, which are still quite primitive. The local authorities told us that they hoped everyone would be able to move out of the villages, because there is no way people can live prosperous lives in those areas. The land is arid; they can raise only a few goats and not really grow anything. With a better education at one of the schools, the officials said, the poor village children may be able to qualify for better jobs.

## Who are we really doing this for? Is it to make ourselves feel good, or to provide genuine help where it's needed?

Our Kowloon North and Macau clubs, with help from other Rotarians, have been able to give children in that region a chance to become educated in a safe environment. Du'an has been the perfect project. We were able to launch it, then eventually step away and applaud the success of the schools from afar. That is an ideal scenario. And there was no donor fatigue, as there can be when funding seems to go on and on with no end in sight and no progress.

That brings up another point about philanthropy that I pay attention to: Who are we really doing this for? Is it to make ourselves feel good, or to provide genuine help where it's needed? I've been supporting a hospital in Haiti that serves a region devastated by the 2010 earthquake, with no visible signs of improvement. The people are as poor as they've always been; there's no end to the deforestation. They're mired, and the moment the funding stops, the hospital will shut down. If we can just keep the hospital going, isn't that enough? I try to remember that service is about serving, not getting something back in return.

For the RI Afghan Refugee Relief Effort, which helped people living in refugee camps along the Afghanistan-Pakistan border, we raised over $2 million; I contributed a lot myself. Again, there was an open-ended need created by internal conflict, and we were able to adopt a few camps along the border to provide basic comforts and food. But there was another kind of reward, too. I visited Pakistan, where there are numerous Rotary clubs, and discovered that many of their problems are the same problems we deal with daily. That's nothing I'd ever have learned sitting in front of a computer screen.

Because of the success of my business, I also was able to give a large gift recently to The Rotary Foundation's Rotary Peace Centers, in support of programs leading to graduate degrees or professional certificates in peace and conflict resolution at eight universities around the world. Our goal on the Rotary Peace Centers Major Gifts Initiative committee is to help raise $95 million to fund the Rotary Peace Centers program in perpetuity, in the hope that peace fellows will rise to leadership positions in their respective countries. The idea is to create a community of graduates so that, when conflicts arise between countries and cultures, these former peace fellows can get together and use their skills to resolve them before the tensions escalate.

Did I ever expect to become involved in so many projects, or to meet my wife, Vivian, in the Rotary Club of Kowloon North – she is a past president of the Rotary Club of Peninsula Sunrise, Hong Kong – and to marry for the first time at age 53? I wouldn't have laid odds on any of those things happening. But computer programs, even mine, have serious limitations. They couldn't have predicted the adventures I've had or the personal rewards that have come my way through Rotary. I donate to The Rotary Foundation because I believe in its mission. ■

# PHILANTHROPY AND THE BRAIN

## WHY DOING GOOD FEELS GOOD

BY LAURENCE GONZALES

IN THE MID-1980S, Bill Benter didn't care about you, or me. He cared about a database program he was writing. The program could process 70 variables for any horse in a horse race. It could then model the race and give the true odds that the horse would win.

He was so absorbed in his project that he left his home in Pittsburgh and moved to Hong Kong, simply because race tracks in that city would give him a better opportunity to develop his idea. There, Benter at last got his payday: He and his partner bet on the results that the computer program spit out. And they began winning. They began winning big. "It was a huge amount of work, but profitable and perfectly legal," Benter recalls. "By 1996, the business was becoming a substantial success."

But Benter had few friends. He was not naturally outgoing, and he was in a foreign country. "I was disconnected from any community," he says. "My interaction was entirely with a computer screen. We didn't have customers or clients, so I had little opportunity to connect with others."

Then his lawyer invited him to join the Rotary Club of Kowloon North. Benter didn't think much of the idea. "I'm not a joiner by nature," he says. But the second time he was asked, Benter accepted.

Accepting that invitation swept him into a philanthropic whirlwind that has been his life since he became a Rotarian in 1996. He calls it "the great magic and mystery of Rotary."

# GRAFMAN'S AND HARBAUGH'S RESULTS PAINT A PICTURE OF PHILANTHROPY AS A POTENT MOTIVATOR THAT CAUSES MEASURABLE CHANGES IN THE BRAIN.

"There is a group of people to appreciate your good works," he says, adding that "the power of example" also contributes to the appeal. "You see this altruistic activity by others throughout the Rotary world." But as he was drawn deeper into his work with Rotary, initially teaming up with the Rotary Club of Macau to build schools in southeast China, he felt himself inexplicably drawn in by a force more powerful than any he had known in his life. It was almost like an addiction. And he was moved to ask, "How is it that Rotary kindles this in people?"

It turns out that this feeling is steeped in science. In the 1980s, at Walter Reed Medical Center, a neuroscientist named Jordan Grafman (now director of brain injury research at the Rehabilitation Institute of Chicago) was puzzling over why some combat veterans who had suffered damage to a certain area of the brain lost their ability to feel empathy. He wanted to learn where in the brain empathy was located. Functional magnetic resonance imaging, or fMRI, had led to new discoveries in neuroscience. It measures brain activity by detecting blood flow, essentially making it possible to watch the brain work. Grafman put fMRI to work on his problem.

He recruited subjects and gave them a list of charities and some money. As they evaluated the charities, they could choose one of three courses: donate the money to an organization, refuse to donate, or deposit some of the money into an account for themselves. Choosing an organization and donating to it, and giving themselves the money, caused the same areas of the mid-brain to become active. These areas are directly involved in seeking food and sex.

But there was also a difference in brain activity: When the subjects gave to charity, another part of the brain known as the subgenual area showed increased blood flow, indicating that it was hard at work. A hormone called oxytocin is processed in that area. Oxytocin is secreted by a mother's pituitary gland during breast-feeding and produces contractions of the uterus during sexual activity and labor and delivery. Oxytocin is also involved in the bonding of people with one another. In a 2007 study conducted at Claremont Graduate University in California, subjects who received a dose of oxytocin donated 80 percent more money to charity than people who received a placebo.

At about the same time, at the University of Oregon, an economist named Bill Harbaugh was studying what made alumni give to their colleges. He found that the nucleus accumbens (where both pleasure and addiction reside) became active when graduates decided to give. The nucleus accumbens releases the neurotransmitter dopamine, which is the chemical centerpiece of the reward system.

Grafman's and Harbaugh's results paint a picture of philanthropy as a potent motivator that causes measurable changes in the brain. Those changes affect feelings of pleasure, much like an addictive drug. Rotarians often attest to the intense positive feelings they derive from good works, from delivering polio vaccine to providing clean water, and the strength of their desire to keep repeating the experience.

In 2013, Harbaugh considered whether we could become addicted to giving. He told Elizabeth Svoboda for her book, *What Makes a Hero?: The Surprising Science of*

# WHEN WE HELP SOMEONE OUT, WE ARE REWARDED WITH MICROEXPRESSIONS THAT ENTER OUR EMOTIONAL SYSTEM BELOW THE HORIZON OF CONSCIOUSNESS.

*Selflessness*, "When you do something that triggers the dopaminergic system in the brain, you want to do it again."

So, what makes us disposed to care about others in the first place? The answer is in our prefrontal cortex, involved in empathizing with others, and in something called "mirror neurons."

About 20 years ago, Giacome Rizzolatti and researchers at the University of Parma in Italy were trying to understand motor command neurons, the nerve cells that send signals to muscles to make them move. They put electrodes in the brains of monkeys to record signals as the animals carried out tasks such as cracking and eating a peanut. By chance, the researchers discovered that a subset of those motor neurons fired not only when the monkey ate a peanut or cracked a peanut but also when the monkey watched an experimenter perform those actions. Those special cells fired even when the monkey merely heard someone crack a peanut. They called the cells mirror neurons.

Babies are born with mirror neurons that allow them to imitate the expressions they see on the faces around them. Mirroring is an essential part of social bonding, and takes place in the presence of oxytocin.

The theory behind mirror neurons is they allow you to feel what someone else is feeling. They give you a view into someone else's body and emotional system, which in turn lends power to feelings of empathy generated in the prefrontal cortex. You can truly say, "I feel your pain."

Helping someone is often a matter of joining in their pain. When we do this, we get a big emotional payoff. It often comes with a smile. In the currency of the emotions, a smile is a special kind of payoff. Faces are the most powerful conveyors of the information we need for our survival: the emotional state of others in our group. The face is the only place on the body where skin attaches directly to muscle, which gives it the ability to convey extremely subtle gradations of emotion, and even secret microexpressions that we cannot knowingly see because they happen too fast. When we help someone out, we are rewarded with microexpressions that enter our emotional system below the horizon of consciousness. We know it feels good, but because we can't bring it to consciousness, we can't say why.

The parts of the brain that allow us to feel the pain of someone in need also allow us to assess our efficacy in helping, and then to feel satisfaction when our help works. We feel the happiness that the needy person experiences, along with that person's gratitude. It is a circular path. We perceive and feel a need, plan a response that addresses that need, take action, and then feel the satisfaction of completing the loop and achieving our goal. All of those feelings provide a strong emotional incentive to keep giving.

Bill Benter had not been building schools in the countryside for long when he began to understand that he had somehow become addicted to helping. "People talk about getting a warm feeling from helping others," he says. "It's a visceral reward. Rotary helps to encourage and facilitate that kind of philanthropy." ■

# The Gambler Who Cracked the Horse-Racing Code

Bill Benter did the impossible: He wrote an algorithm that couldn't lose at the track.
Close to a billion dollars later, he tells his story for the first time.

By Kit Chellel 《Bloomberg Businessweek》3 May 2018

Horse racing is something like a religion in Hong Kong, whose citizens bet more than anyone else on Earth. Their cathedral is Happy Valley Racecourse, whose grassy oval track and floodlit stands are ringed at night by one of the sport's grandest views: neon skyscrapers and neat stacks of high-rises, a constellation of illuminated windows, and beyond them, lush hills silhouetted in darkness.

On the evening of Nov. 6, 2001, all of Hong Kong was talking about the biggest jackpot the city had ever seen: at least HK$100 million (then about $13 million) for the winner of a single bet called the Triple Trio. The wager is a little like a trifecta of trifectas; it requires players to predict the top three horses, in any order, in three different heats. More than 10 million combinations are possible. When no one picks correctly, the prize money rolls over to the next set of races. That balmy November night, the pot had gone unclaimed six times over. About a million people placed a bet—equivalent to 1 in 7 city residents.

At Happy Valley's ground level, young women in beer tents passed foamy pitchers to laughing expats, while the local Chinese, for whom gambling is a more serious affair, clutched racing newspapers and leaned over the handrails. At the crack of the starter's pistol, the announcer's voice rang out over loudspeakers: "Last leg of the Triple Trio," he shouted in Australian-accented English, "and away they go!"

As the pack thundered around the final bend, two horses muscled ahead. "It's Mascot Treasure a length in front, but Bobo Duck is gunning him down," said the announcer, voice rising. "Bobo Duck in front. Mascot fighting back!" The crowd roared as the riders raced across the finish line. Bobo Duck edged Mascot Treasure, and Frat Rat came in third.

Across the road from Happy Valley, 27 floors up, two Americans sat in a plush office, ignoring a live feed of the action that played mutely on a TV screen. The only sound was the hum of a dozen computers. Bill Benter and an associate named Paul Coladonato had their eyes fixed on a bank of three monitors, which displayed a matrix of bets their algorithm had made on the race—51,381 in all.

Benter and Coladonato watched as a software script filtered out the losing bets, one at a time, until there were 36 lines left on the screens. Thirty-five of their bets had correctly called the finishers in two of the races, qualifying for a consolation prize. And one wager had correctly predicted all nine horses.

"F---," Benter said. "We hit it."

It wasn't immediately clear how much they'd made, so the two Americans attempted some back-of-the-envelope math until the official dividend flashed on TV eight minutes later. Benter and Coladonato had won a jackpot of $16 million. Benter counted the zeros to make sure, then turned to his colleague.

"We can't collect this—can we?" he asked. "It would be unsporting. We'd feel bad about ourselves." Coladonato agreed they couldn't. On a nearby table, pink betting slips were arranged in a tidy pile. The two men picked through them, isolating three slips that contained all 36 winning lines. They stared at the pieces of paper for a long time.

Then they posed, laughing, for a photo—two professional gamblers with the biggest prize of their careers, one they would never claim—and locked the tickets in a safe. No big deal, Benter figured. They could make it back, and more, over the rest of the racing season.

Veteran gamblers know you can't beat the horses. There are too many variables and too many possible outcomes. Front-runners break a leg. Jockeys fall. Champion thoroughbreds decide, for no apparent reason, that they're simply not in the mood. The American sportswriter Roger Kahn once called the sport "animated roulette." Play for long enough, and failure isn't just likely but inevitable—so the wisdom goes. "If you bet on horses, you will lose," says Warwick Bartlett, who runs Global Betting & Gaming Consultants and has spent years studying the industry.

What if that wasn't true? What if there was one person who masterminded a system that guaranteed a profit? One person who'd made almost a billion dollars, and who'd never told his story—until now?

In September, after a long campaign to reach him through friends and colleagues, I received an email from Benter. "I have been avoiding you, as you might have surmised," he wrote. "The reason is mainly that I am uncomfortable in the spotlight by nature." He added, "None of us want to encourage more people to get into the game!" But in October he agreed to a series of interviews in his office in downtown Pittsburgh. The tasteful space—the top two floors of a Carnegie Steel-era building—is furnished with 4-foot-tall Chinese vases and a marble fireplace, with sweeping views of the Monongahela River and freight trains rumbling past.

Benter, 61, walks with a slight stoop. He looks like a university professor, his wavy hair and beard streaked with gray, and speaks in a soft, slightly Kermit-y voice. He told me he'd been driven only partly by money—and I believed him. With his intelligence, he could have gotten richer faster working in finance. Benter wanted to conquer horse betting not because it was hard, but because it was said to be impossible. When he cracked it, he actively avoided acclaim, outside the secretive band of geeks and outcasts who occupy his chosen field. Some of what follows relies on his recollections, but in every case where it's been possible to corroborate events and figures, they've checked out in interviews with dozens of individuals, as well as in books, court records, and other documents. Only one thing Benter ever told me turned out to be untrue. It was at the outset of our conversations, when he said he didn't think I'd find anything interesting to write about in his career.

Benter grew up in a Pittsburgh idyll called Pleasant Hills. He was a diligent student and an Eagle Scout, and he began to study physics in college. His parents had always given him freedom—on vacations, he'd hitchhiked across Europe to Egypt and driven through Russia—and in 1979, at age 22, he put their faith to the test. He left school, boarded a Greyhound bus, and went to play cards in Las Vegas.

Benter had been enraptured by《Beat the Dealer》, a 1962 book by math professor Edward Thorp that describes how to overcome the house's advantage in blackjack. Thorp is credited with inventing the system known as card counting: Keep track of the number of high cards dealt, then bet big when it's likely that high cards are about to fall. It takes concentration, and lots of hands, to turn a tiny advantage into a profit, but it works.

Thorp's book was a beacon for shy young men with a gift for mathematics and a yearning for a more interesting life. When Benter got to Las Vegas, he worked at a 7-Eleven for $3 an hour and took his wages to budget casinos. The Western—with its dollar cocktails and shabby patrons getting drunk at 10 a.m.—and the faded El Cortez were his turf. He didn't mind the scruff. It thrilled him to see scientific principles play out in real life, and he liked the hedonistic city's eccentric characters. It was the era of peak disco, with Donna Summer and Chic's Le Freak all over the radio. On a good day, Benter might win only about $40, but he'd found his métier—and some new friends. Fellow Thorp acolytes were easy to spot on casino floors, tending to be conspicuously focused and sober. Like them, Benter was a complete nerd. He had a small beard, wore tweedy jackets, and talked a lot about probability theory.

In 1980 he'd just applied for a job as a night cleaner at McDonald's when his buddies introduced him to the man who would change his life. Alan Woods was the leader of an Australian card-counting team that had recently arrived in Las Vegas. Woods was then in his mid-30s, with a swoop of gray hair and cold blue eyes. Once an insurance actuary with a wife and two kids, he'd decided one day that family life wasn't for him and began traveling the world as an itinerant gambler.

Woods impressed Benter with his tales of fearlessness, recounting how he'd sneaked past airport security in Manila with $10,000 stuffed into his underwear. Most appealing, he pursued the card counter's craft with discipline. His team pooled its cash and divided winnings equitably. Having more players reduced the risk of a run of bad luck wiping out one's bankroll, and the camaraderie offset the solitary nature of the work. Benter joined the squad.

Within six weeks, he found himself playing blackjack in Monte Carlo, served by waiters in dinner jackets. He felt like James Bond, and his earnings grew to a rate of about $80,000 a year. Benter abandoned any idea of returning to college. When his mother's friends in Pittsburgh asked how his studies were going, she told them, "Bill's traveling right now."

Benter and his teammates got a house in the Vegas suburbs, living like geeky college fraternity brothers. Woods strictly forbade drinking on the job, so the men would wait until after their shifts to knock back beers and trade stories of scrapes with casino security, who were constantly on the lookout for card counting. Bull-necked pit bosses patrolled the floors. A suspicious player would be told to leave or, worse, backroomed: interrogated in a dingy office. There were rumors of counters being beaten and drugged. Benter thought the treatment was unjustified. He wasn't a cheat. He just played smart.

After a couple of years, Benter was playing quietly at the Maxim one day when a meaty hand descended on his shoulder. "Come with me," said a burly guy in a suit. In the back, Benter was shoved into a chair and told to produce some identification. He refused. The guard walked out, and an even more menacing guy walked in: "Show me your f---ing ID!" Benter got out his wallet.

Afterward—it was probably 1984—Benter, Woods, and some of their partners earned a place in the Griffin Book, a blacklist that a detective agency circulated to casinos. On top of the indignity of having their mug shots next to hustlers and pickpockets, the notoriety made it almost impossible for them to keep playing in Vegas. They needed to find another game.

Woods knew there were giant horse-betting pools to tap in Asia—and that the biggest of all was run by the Hong Kong Jockey Club. Begun in 1884 as a refuge for upper-crust Brits who wanted a stretch of England's green and pleasant land in their subtropical colony, the club changed over time into a state gambling monopoly. Its two courses, Happy Valley and Sha Tin, were packed twice a week during a racing season that extended from September to July. Hong Kong's population was then only about 5.5 million, but it bet more on horses than the entire U.S., reaching about $10 billion annually by the 1990s.

Hong Kong racing uses a parimutuel (also known as "totalizer") system. Unlike odds in a Vegas sportsbook, which are set in advance and give a decisive edge to the house, parimutuel odds are updated fluidly, in proportion to how bettors wager. Winners split the pool, and the house skims a commission of about 17 percent. (After costs, the Jockey Club's take goes to charity and the state, providing as much as a tenth of Hong Kong's tax revenue.) To make money, Benter would have to do more than pick winners: He needed to make bets with a profit margin greater than the club's 17 percent cut.

He went to the Gambler's Book Club, a Vegas institution, and bought everything he could find on horses. There were lots of "systems" promising incredible results, but to him they seemed flimsy, written by journalists and amateur handicappers. Few contained real math. Benter wanted something more rigorous, so he went to the library at the University of Nevada at Las Vegas, which kept a special collection on gaming. Buried in stacks of periodicals and manuscripts, he found what he was looking for—an academic paper titled《Searching for Positive Returns at the Track: A Multinomial Logit Model for Handicapping Horse Races.》 Benter sat down to read it, and when he was done he read it again.

The paper argued that a horse's success or failure was the result of factors that could be quantified probabilistically. Take variables—straight-line speed, size, winning record, the skill of the jockey—weight them, and presto! Out comes a prediction of the horse's chances. More variables, better variables, and finer weightings improve the predictions. The authors weren't sure it was possible to make money using the strategy and, being mostly interested in statistical models, didn't try hard to find out. "There appears to be room for some optimism," they concluded.

Benter taught himself advanced statistics and learned to write software on an early PC with a green-and-black screen. Meanwhile, in the fall of 1984, Woods flew to Hong Kong and sent back a stack of yearbooks containing the results of thousands of races. Benter hired two women to key the results into a database by hand so he could spend more time studying regressions and developing code. It took nine months. In September 1985 he flew to Hong Kong with three bulky IBM computers in his checked luggage.

The Hong Kong that greeted Benter was a booming financial center, with some of the most densely populated spaces on the planet. The crowded skyline that had recently inspired Ridley Scott's dystopian megacity in Blade Runner seemed to sprout towers weekly.

Benter and Woods rented a microscopic apartment in a dilapidated high-rise. Warbling Cantonese music drifted through stained walls, and the neighbors spent all night shouting in the hall. Their office was an old desk and a wooden table piled high with racing newspapers. If they went out at all, it was to the McDonald's down the street.

Twice a week, on race days, Benter would sit at the computer and Woods would study the racing form. Early on, the betting program Benter had written spat out bizarre predictions, and Woods, with his yearlong head start studying the Hong Kong tracks, would correct them. They used a telephone account at the Jockey Club to call in their bets and watched the races on TV. When they won, there were satisfied smiles only. They were professionals; cheering and hooting were for rubes.

Between races, Benter struggled to make his algorithms stay ahead of a statistical phenomenon called gambler's ruin. It holds that if a player with limited funds keeps betting against an opponent with unlimited funds (that is, a casino, or the betting population of Hong Kong), he will eventually go broke, even if the game is fair. All lucky streaks come to an end, and losing runs are fatal.

One approach—familiar to Benter from his blackjack days—was to adapt the work of a gunslinging Texas physicist named John Kelly Jr., who'd studied the problem in the 1950s. Kelly imagined a scenario in which a horse-racing gambler has an edge: a "private wire" of fairly reliable tips. How should he bet? Wager too little, and the advantage is squandered. Too much, and ruin beckons. (Remember, the tips are good but not perfect.) Kelly's solution was to wager an amount in line with the gambler's confidence in the tip.

Benter was struck by the similarities between Kelly's hypothetical tip wire and his own prediction-generating software. They amounted to the same thing: a private system of odds that was slightly more accurate than the public odds. To simplify, imagine that the gambling public can bet on a given horse at a payout of 4 to 1. Benter's model might show that the horse is more likely to win than those odds suggest—say, a chance of one in three. That means Benter can put less at risk and get the same return; a seemingly small edge can turn into a big profit. And the impact of bad luck can be diminished by betting thousands and thousands of times. Kelly's equations, applied to the scale of betting made possible by computer modeling, seemed to guarantee success.

If, that is, the model were accurate. By the end of Benter's first season in Hong Kong, in the summer of 1986, he and Woods had lost $120,000 of their $150,000 stake. Benter flew back to Vegas to beg for investment, unsuccessfully, and Woods went to South Korea to gamble. They met back in Hong Kong in September. Woods had more money than Benter and was willing to recapitalize their partnership—if it was renegotiated.

"I want a larger share," Woods said, in Benter's recollection.

"How much larger?" Benter asked.

"Ninety percent," Woods said.

"That's unacceptable," Benter said.

Woods was used to being the senior partner in gambling teams and getting his way. He never lost his temper, but his mind, once set, was like granite. Benter was also unwilling to budge. Their alliance was over. In a fit of pique, Benter wrote a line of code into the software that would stop it from functioning after a given date—a digital time bomb—even though he knew it would be trivial for Woods to find and fix it later. Woods would keep betting algorithmically on horses, Benter was sure of that. He resolved that he would, too.

Benter's Las Vegas friends wouldn't stake him at horse racing, but they would at blackjack. He took their money to Atlantic City and spent two years managing a team of card counters, brooding, and working on the racing model in his spare time. In September 1988, having amassed a few hundred thousand dollars, he returned to Hong Kong. Sure enough, Woods was still there. The Australian had hired programmers and mathematicians to develop Benter's code and was making money. He'd moved into a penthouse flat with a spectacular view. Benter refused to speak to him.

Benter's model required his undivided attention. It monitored only about 20 inputs—just a fraction of the infinite factors that influence a horse's performance, from wind speed to what it ate for breakfast. In pursuit of mathematical perfection, he became convinced that horses raced differently according to temperature, and when he learned that British meteorologists kept an archive of Hong Kong weather data in southwest England, he traveled there by plane and rail. A bemused archivist led him to a dusty library basement, where Benter copied years of figures into his notebook. When he got back to Hong Kong, he entered the data into his computers—and found it had no effect whatsoever on race outcomes. Such was the scientific process.

Other additions, such as the number of rest days since a horse's last race, were more successful, and in his first year after returning to Hong Kong, Benter won (as he recalls) $600,000. The next racing season, ending in the summer of 1990, he lost a little but was still up overall. He hired an employee, Coladonato, who would stay with him for years, and a rotating cast of consultants: independent gamblers, journalists, analysts, coders, mathematicians. When the volume of bets rose, he recruited English-speaking Filipinos from the ranks of the city's housekeepers to relay his bets to the Jockey Club's Telebet phone lines, reading wagers at the rate of eight a minute.

A breakthrough came when Benter hit on the idea of incorporating a data set hiding in plain sight: the Jockey Club's publicly available betting odds. Building his own set of odds from scratch had been profitable, but he found that using the public odds as a starting point and refining them with his proprietary algorithm was dramatically more profitable. He considered the move his single most important innovation, and in the 1990-91 season, he said, he won about $3 million.

The following year the Hong Kong Jockey Club phoned Benter at an office he'd established in Happy Valley. He winced, remembering the meaty hand of the Las Vegas pit boss on his shoulder. But instead of threatening him, a Jockey Club salesperson said, "You are one of our best customers. What can we do to help you?" The club wasn't a casino trying to root out gamblers who regularly beat the house; its incentive was to maximize betting activity so more revenue was available for Hong Kong charities and the government. Benter asked if it was possible to place his bets electronically instead of over the phone. The Jockey Club agreed to install what he called the "Big CIT"—a customer input terminal. He ran a cable from his computers directly into the machine and increased his betting.

Benter had achieved something without known precedent: a kind of horse-racing hedge fund, and a quantitative one at that, using probabilistic modeling to beat the market and deliver returns to investors. Probably the only other one of its kind was Woods's operation, and Benter had written its code base. Their returns kept growing. Woods made $10 million in the 1994-95 season and bought a Rolls-Royce that he never drove. Benter purchased a stake in a French vineyard. It was impossible to keep their success secret, and they both attracted employees and hangers-on, some of whom switched back and forth between the Benter and Woods teams. One was Bob Moore, a manic New Zealander whose passions were cocaine and video analysis. He'd watch footage of past races to identify horses that should have won but were bumped or blocked and prevented from doing so. It worked as a kind of bad-luck adjuster and made the algorithms more effective.

The computer-model crowd spent nights in a neighborhood called Wan Chai—a honey pot of gaudy bars and topless dancers that's been described as "a wildly liberated Las Vegas." Moore favored Ridgeway's pool bar, where he'd start fights and boast about his gambling exploits. Woods didn't drink much, but he enjoyed ecstasy, and he could be found most nights in Neptune II, a neon dungeon full of drunk businessmen and much younger women.

Benter was a more reserved presence. He could often be seen sitting at the end of a bar, engaged in quiet conversation. Over time an aura built up. To the small group of insiders who knew that software had conquered Happy Valley—perhaps a dozen people—Benter was the acknowledged master. Even Woods (in an interview he later gave to an Australian journalist) admitted that his rival's model was the best. But the two men couldn't resolve their differences. When Benter saw his old partner in Wan Chai, he would smile politely and walk away. They'd gone 10 years without speaking.

Throughout 1997 a shadow loomed over Hong Kong. After 156 years of colonial rule, the British were set to hand the territory back to China on July 1. There were news reports of Chinese troops massed at the border, and many islanders feared it would be the end of Hong Kong's freewheeling capitalism. China tried to reassure residents that their most treasured customs would be protected. “Horse racing will continue, and the dancing parties will go on,” said Deng Xiaoping, the former Communist Party leader.

Benter faced an additional and more peculiar anxiety. A month before the handover, his team won a huge Triple Trio jackpot. They were in the middle of an epic winning season, up more than $50 million. The Jockey Club normally put Triple Trio winners in front of the TV cameras to show how, for example, a night watchman had changed his life with a single bet. This time, nobody wanted to tout that the winner was an American algorithm.

The club had come to see the syndicates’ success as a headache. There was no law against what they were doing, but in a parimutuel gambling system, every dollar they won was a dollar lost by someone else. If the everyday punters at Happy Valley and Sha Tin ever found out that foreign computer nerds were siphoning millions from the pools, they might stop playing entirely.

Benter had his Big CIT privileges revoked. On June 14 one of his phone operators called the Telebet line and was told, “Your account has been suspended.” Woods was also blocked. Club officials issued a statement saying they had acted to “protect the interests of the general betting public.” Benter flew back to Vegas, as he did every summer, to think about his next move. He reread the club’s statement. Phone betting was out—but nowhere did it say he was prohibited from betting altogether. He got an idea. As in his blackjack days, it would require a low profile.

One Friday evening that autumn, after the handover of the territory to China, Benter paid for a hotel room in Hong Kong’s bayside North Point district. He made sure to get a space on the ground floor for easy access. He had helpers haul in laptops, a 50-pound printer, and stacks of blank betting slips. On Saturday morning—race day—they checked the internet connection and put a “Do Not Disturb” sign on the door.

At 1:45 p.m., 15 minutes before the first race, the laptops received lines of bets from Benter’s Happy Valley office. The printer began to suck in blank tickets and churn them out with black marks in the relevant betting boxes.

Eight minutes to starting pistol. Benter grabbed a pile of 80-odd printed tickets and a club-issued credit voucher worth HK$1 million and bolted for the door. Across from the hotel was an off-track betting shop. It was loud and smoky inside, and he found an automated betting terminal free at one side of the room. Two minutes to go. He started feeding in tickets, one after another after another, until the screen flashed a message: “Betting closed.”

Benter hurried back to the hotel room to see which wagers had hit. At 2:15 p.m. the laptops downloaded the next package of bets from the office. Time to go again. Simultaneously, other teams hired by Benter were doing the same in different parts of Hong Kong.

Benter’s solution to the phone ban was time-consuming and required him to manage teams of runners, who risked being robbed. But it was almost as profitable as his old arrangement. The club continued to exchange his cash vouchers for checks, and no one came to shut him down. Woods kept betting in a slightly different manner, sending members of an extended roster of Philippine girlfriends directly to the racetrack with bags full of cash.

Publicity is a hex for professional gamblers. That fall an increasingly erratic Moore drew more attention to algorithmic betting, first by bragging to the local press—who nicknamed him the "God of Horses"—and then by fatally overdosing on sleeping pills.

Afterward, Hong Kong's tax authority began to investigate the Woods syndicate. By law, gambling winnings were exempt from taxation, but company profits weren't. The question was whether the syndicates had moved beyond conventional betting and started behaving like corporations. The implications would be dire if the Inland Revenue Department decided to tax profits retroactively. When agents asked Woods for a list of his investors, he fled to the Philippines.

Benter continued to operate his in-person betting scheme through the turn of the millennium, with his model expanding to track more than 120 factors per horse, but the logistics were proving a grind. He felt disconnected from his gambler friends in Wan Chai—a nocturnal clique of geeks and rogues. He had started mixing with a more professional crowd, adopting their dress code of smart suits and ties, and he'd taken a more active role in the local Rotary Club chapter. Benter embraced its motto of "Service Above Self," giving millions of dollars anonymously and visiting impoverished schools in China and refugee camps in Pakistan. For the first time, he thought seriously about quitting and moving back to the U.S. If it all has to end, he thought, I've had an incredible run.

It was then, in November 2001, that he decided to have a final punt on the Triple Trio. Benter had avoided major prizes since 1997 for fear of angering the Jockey Club's management, but this jackpot was too big to resist. Wagering on it was something of a lark, albeit an expensive one: He spent HK$1.6 million on the 51,000 combinations. If he won, he decided, he would leave the tickets unclaimed. Club policy in such cases directed the money to a charitable trust.

After Bobo Duck, Mascot Treasure, and Frat Rat romped across the finish line—and then days turned into weeks, with no one collecting the prize—Benter was unprepared for the level of mounting public interest. "The ghost of the unclaimed $118 million Triple Trio," wrote the racing columnist for the《South China Morning Post》, "is still banging around like an unwanted poltergeist." Outlandish theories spread across Hong Kong. One held that the winner had watched the final leg and died of shock.

Finally, Benter sent an anonymous letter to the Jockey Club's directors explaining his intentions. But the organization never shared it with the public. (Club spokeswoman Samantha Sui told《Bloomberg Businessweek》, "We are not in a position to disclose or comment on matters related to specific customers due to privacy and confidentiality concerns.") At the time, head of betting Henry Chan told the Morning Post that there was no way of knowing who the ticket holder was. "Although this is bad luck for one winner," he said, "it means there will be a lot of winners through the charities."

Later in 2001, without any warning, Jockey Club officials lifted the telephone betting ban. It was as if Benter's gift had appeased the gambling gods. The club also bowed to public pressure and allowed customers to wager over the internet from their homes. Benter opted to move back to Pittsburgh, where he continued to bet. He didn't want to spend his whole life in Hong Kong.

In Manila, Woods lived like a hermit, bingeing on drugs for days at a time, waited on by young women he hired to keep him company. He employed gamblers remotely in Australia and Hong Kong, but he was a difficult boss; he accused staff of stealing, and once he made everyone take IQ tests before telling them all how much smarter he was. Woods started calling himself Momu—short for "master of my universe."

In December 2007 he sent a letter to 《Business Review Weekly》, an Australian magazine, asking to be considered for its rich list. "I had planned to delay my hope for inclusion until I could make it into the top 10," he wrote. "However, as of today, it does not appear I will live long enough." Woods had been diagnosed with cancer. He came back to Happy Valley for treatment; the Hong Kong Sanatorium & Hospital was within sight of the racetrack. He spent his final days beating his friends at a Chinese card game known as *chor dai di* and died on Jan. 26, 2008, at 62.

Interviews with Woods's friends, employees, and other sources indicate he had amassed a fortune of A$900 million (then about $800 million). Mike Smith, a former Hong Kong policeman who knew Woods, wrote about him in his book《In the Shadow of the Noonday Gun》: "He left a very simple will that pretty much summed up his lifestyle. Assets: A$939,172,372.51. Liabilities: A$15.93."

Woods left the bulk of his estate to his two children in Australia and gave token sums to various ex-girlfriends, including a Filipina who said he'd fathered her child. A wake was held in a bar at the Happy Valley racetrack and attended by an eclectic crowd of gamblers and hustlers. To the last, Woods never believed that Benter had won the 2001 Triple Trio and given up the jackpot.

"Gambling," Benter told me in his Pittsburgh office, "has always been the domain of wise guys from the wrong side of the track." Perhaps more than anyone else, Benter has changed that perception—within the tiny population of people who gamble for a living, that is.

By the time he moved back to Pittsburgh, he'd inspired others in Hong Kong to form syndicates of their own. In response, the Jockey Club began publishing reams of technical data and analysis on its website to level the playing field. With a little effort, anyone could be a systematic gambler—or mimic one. The odds boards at Happy Valley and Sha Tin were color-coded to show big swings in the volume of wagers on a horse, specifically to reveal whom the syndicates were backing.

The robo-bettors' numbers have continued to proliferate. After Woods's death, his children maintained his Hong Kong operation, but other members of the team went into business for themselves. And Benter spread the secrets of his success in various ways: He gave math talks at universities, shared his theories with employees and consultants, and even published an academic paper laying out his system. The 1995 document—《Computer-Based Horse Race Handicapping and Wagering Systems: A Report》—became a manual for an entire generation of high-tech gamblers.

Today, online betting on sports of all kinds is a $60 billion industry, growing rapidly everywhere outside the U.S., where the practice is mostly banned. The Supreme Court, however, may lift federal restrictions this year, and if it does, American dollars will flood the market, increasing liquidity and the profits of computer teams. Big names from the world of finance have taken notice.

Many of the biggest players in sports betting can trace a lineage directly to the Benter-Woods axis. For example, the Australian press has called Zeljko Ranogajec "the world's biggest punter." Today he runs a global algorithmic gambling empire, but he began his career in Las Vegas counting cards with Benter and Woods, then followed them to Hong Kong. During a rare interview in London, Ranogajec said, "A substantial portion of our success is attributable to the pioneering work done by Benter."

Benter has few regrets. One relates to an attempt in the early 1990s to create a model for betting on baseball. He spent three summers developing the system and only broke even—for him, a stinging professional defeat. America's pastime was just too unpredictable.

That failure, however, led to a second period of his career as lucrative as Hong Kong was. He worked with one of his baseball backers to start betting on U.S. horse racing. Parimutuel tracks are scattered around the country, and by the late 1990s it became easier to amass data on a lot of them. The U.S. business took off just as competition began eroding profits in Hong Kong. "There is a golden age for a particular market," he said, fiddling with a stack of decommissioned casino chips. "When there aren't many computer players, the guy with the best system can have a huge advantage."

In 2010, Benter married Vivian Fung, whom he'd met at the Rotary Club in Hong Kong. The couple have a young son, and Benter seems in every sense a contented man. An active philanthropist, he donated $1 million to a Pittsburgh charter school program and $3 million to a polio immunization effort in Afghanistan, Pakistan, and parts of Africa. In 2007 he started the charitable Benter Foundation, which donates to health, education, and the arts. Many of the people he meets at fundraising galas and nights at the opera have no idea how he made his money.

And how much is that—exactly? During our interviews, it was the one topic that made him visibly uncomfortable. William Ziemba, a finance professor at the University of British Columbia who studied the Hong Kong syndicates, has said that a first-rate team could make $100 million in a good season. Edward Thorp (who's still writing about gambling in his 80s) asserted in a 2017 book that Benter had a "billion-dollar worldwide business betting on horse races." When pushed, Benter conceded that his operations have probably made close to a billion dollars overall, but that some of the money has gone to partners in Hong Kong and the U.S. "Unfortunately," he said, "I'm not a billionaire."

Thirty-two years after he first arrived in Hong Kong, Benter is still betting on horses at venues around the world. He can see the odds change in the seconds before a race as all the computer players place their bets at the same time, and he's amazed he can still win. He continues tinkering with his model. The latest change: How much does moving to a new trainer improve a horse's performance? Benter also runs a medical transcription company, but it's only modestly profitable. "I find the real business world to be a lot more difficult than horse racing," he told me. "I'm kind of a one-trick pony." *—With Jonathan Browning and Giles Turner*

# Computer Based Horse Race Handicapping and Wagering Systems: A Report

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ABSTRACT

This paper examines the elements necessary for a practical and successful computerized horse race handicapping and wagering system. Data requirements, handicapping model development, wagering strategy, and feasibility are addressed. A logit-based technique and a corresponding heuristic measure of improvement are described for combining a fundamental handicapping model with the public's implied probability estimates. The author reports significant positive results in five years of actual implementation of such a system. This result can be interpreted as evidence of inefficiency in pari-mutuel racetrack wagering. This paper aims to emphasize those aspects of computer handicapping which the author has found most important in practical application of such a system.



## INTRODUCTION

The question of whether a fully mechanical system can ever "beat the races" has been widely discussed in both the academic and popular literature. Certain authors have convincingly demonstrated that profitable wagering systems do exist for the races. The most well documented of these have generally been of the *technical* variety, that is, they are concerned mainly with the public odds, and do not attempt to predict horse performance from fundamental factors. Technical systems for place and show betting, (Ziemba and Hausch, 1987) and exotic pool betting, (Ziemba and Hausch, 1986) as well as the 'odds movement' system developed by Asch and Quandt (1986), fall into this category. A benefit of these systems is that they require relatively little preparatory effort, and can be effectively employed by the occasional racegoer. Their downside is that betting opportunities tend to occur infrequently and the maximum expected profit achievable is usually relatively modest. It is debatable whether any racetracks exist where these systems could be profitable enough to sustain a full-time professional effort.

To be truly viable, a system must provide a large number of high advantage betting opportunities in order that a sufficient amount of expected profit can be generated. An approach which does promise to provide a large number of betting opportunities is to *fundamentally* handicap each race, that is, to empirically assess each horse's chance of winning, and utilize that assessment to find profitable wagering opportunities. A natural way to attempt to do this is to develop a computer model to estimate each horse's probability of winning and calculate the appropriate amount to wager.

A complete survey of this subject is beyond the scope of this paper. The general requirements for a computer based fundamental handicapping model have been well presented by Bolton and Chapman (1986) and Brecher (1980). These two references are "required reading" for anyone interested in developing such a system. Much of what is said here has already been explained in those two works, as is much of the theoretical background which has been omitted here. What the author would hope to add, is a discussion of a few points which have not been addressed in the literature, some practical recommendations, and a report that a *fundamental* approach can in fact work in practice.

## FEATURES OF THE COMPUTER HANDICAPPING APPROACH

Several features of the computer approach give it advantages over traditional handicapping. First, because of its empirical nature, one need not possess specific handicapping expertise to undertake this enterprise, as everything one needs to know can be learned from the data. Second is the testability of a computer system. By carefully partitioning data, one can develop a model and test it on *unseen* races. With this procedure one avoids the danger of overfitting past data. Using this 'holdout' technique, one can obtain a reasonable estimate of the system's real-time performance before wagering any actual money. A third positive attribute of a computerized handicapping system is its consistency. Handicapping races manually is an extremely taxing undertaking. A computer will effortlessly handicap races with the same level of care day after day, regardless of the mental state of the operator. This is a non-trivial advantage considering that a professional level betting operation may want to bet several races a day for extended periods.

The downside of the computer approach is the level of preparatory effort necessary to develop a winning system. Large amounts of past data must be collected, verified and computerized. In the past, this has meant considerable manual entry of printed data. This situation may be changing as optical scanners can speed data entry, and as more online horseracing database services become available. Additionally, several man-years of programming and data analysis will probably be necessary to develop a sufficiently profitable system. Given these considerations, it is clear that the computer approach is not suitable for the casual racegoer.

## HANDICAPPING MODEL DEVELOPMENT

The most difficult and time-consuming step in creating a computer based betting system is the development of the fundamental handicapping model. That is, the model whose final output is an estimate of each horse's probability of winning. The type of model used by the author is the multinomial logit model proposed by Bolton and Chapman (1986). This model is well suited to horse racing and has the convenient property that its output is a set of probability estimates which sum to 1 within each race.

The overall goal is to estimate each horse's current performance potential. "Current performance potential" being a single overall summary index of a horse's expected performance in a particular race. To construct a model to estimate current performance potential one must investigate the available data to find those variables or *factors* which have predictive significance. The profitability of the resulting betting system will be largely determined by the predictive power of the factors chosen The odds set by the public betting yield a sophisticated estimate of the horses' win probabilities. In order for a fundamental statistical model to be able to compete effectively, it must rival the public in sophistication and comprehensiveness. Various types of factors can be classified into groups:

Current condition:
- performance in recent races
- time since last race
- recent workout data
- age of horse

Past performance:
- finishing position in past races
- lengths behind winner in past races
- normalized times of past races

Adjustments to past performance:
- strength of competition in past races
- weight carried in past races
- jockey's contribution to past performances
- compensation for bad luck in past races
- compensation for advantageous or disadvantageous post position in past races

Present race situational factors:
- weight to be carried
- today's jockey's ability
- advantages or disadvantages of the assigned post position

Preferences which could influence the horse's performance in today's race:
- distance preference
- surface preference (turf vs dirt)
- condition of surface preference (wet vs dry)
- specific track preference

More detailed discussions of fundamental handicapping can be found in the extensive popular literature on the subject (for the author's suggested references see the list in the appendix). The data needed to calculate these factors must be entered and checked for accuracy. This can involve considerable effort. Often, multiple sources must be used to assemble complete past performance records for each of the horses. This is especially the case when the horses have run past races at many different tracks. The easiest type of racing jurisdiction to collect data and develop a model for is one with a *closed* population of horses, that is, one where horses from a single population race only against each other at a limited number of tracks. When horses have raced at venues not covered in the database, it is difficult to evaluate the elapsed times of races and to estimate the strength of their opponents. Also unknown will be the post position biases, and the relative abilities of the jockeys in those races.

In the author's experience the minimum amount of data needed for adequate model development and testing samples is in the range of 500 to 1000 races. More is helpful, but out-of-sample predictive accuracy does not seem to improve dramatically with development samples greater than 1000 races. Remember that *data for one race* means full past data on all of the runners in that race. This suggests another advantage of a *closed* racing population; by collecting the results of all races run in that jurisdiction one automatically accumulates the full set of past performance data for each horse in the population.

It is important to define factors which extract as much information as possible out of the data in each of the relevant areas. As an example, consider three different specifications of a 'distance preference' factor.

The first is from Bolton and Chapman (1986):

> 'NEWDIST' - this variable equals one if a horse has run three of its four previous races at a distance less than a mile, zero otherwise. (Note: Bolton and Chapman's model was only used to predict races of 1 - 1.25 miles.)

The second is from Brecher (1980):

> 'DOK' - this variable equals one if the horse finished in the upper 50th percentile or within 6.25 lengths of the winner in a prior race within 1/16 of a mile of today's distance, or zero otherwise

The last is from the author's current model:

> 'DP6A' - for each of a horse's past races, a predicted finishing position is calculated via multiple regression based on all factors except those relating to distance. This predicted finishing position in each race is then subtracted from the horse's actual finishing position. The resulting quantity can be considered to be the unexplained residual which may be due to some unknown distance preference that the horse may possess plus a certain amount of random error. To estimate the horse's preference or aversion to today's distance, the residual in each of its past races is used to estimate a linear relationship between performance and similarity to today's distance. Given the statistical uncertainty of estimating this relationship from the usually small sample of past races, the final magnitude of the estimate is standardized by dividing it by its standard error. The result is that horses with a clearly defined distance preference demonstrated over a large number of races will be awarded a relatively larger magnitude value than in cases where the evidence is less clear.

The last factor is the result of a large number of progressive refinements. The subroutines involved in calculating it run to several thousand lines of code. The author's guiding principle in factor improvement has been a combination of educated guessing and trial and error. Fortunately, the historical data makes the final decision as to which particular definition is superior. The best is the one that produces the greatest increase in predictive accuracy when included in the model. The general thrust of model development is to continually experiment with refinements of the various factors. Although time-consuming, the gains are worthwhile. In the author's experience, a model involving only simplistic specifications of factors does not provide sufficiently accurate estimates of winning probabilities. Care must be taken in this process of model development not to overfit past data. Some overfitting will always occur, and for this reason it is important to use data partitioning to maintain sets of *unseen* races for out-of-sample testing.

The complexity of predicting horse performance makes the specification of an elegant handicapping model quite difficult. Ideally, each independent variable would capture a unique aspect of the influences effecting horse performance. In the author's experience, the trial and error method of adding independent variables to increase the model's goodness-of-fit, results in the model tending to become a hodgepodge of highly correlated variables whose individual significances are difficult to determine and often counter-intuitive. Although aesthetically unpleasing, this tendency is of little consequence for the purpose which the model will be used, namely, prediction of future race outcomes. What it does suggest, is that careful and conservative statistical tests and methods should be used on as large a data sample as possible.

For example, "number of past races" is one of the more significant factors in the author's handicapping model, and contributes greatly to the overall accuracy of the predictions. The author knows of no 'common sense' reason why this factor should be important. The only reason it can be confidently included in the model is because the large data sample allows its significance to be established beyond a reasonable doubt.

Additionally, there will always be a significant amount of 'inside information' in horse racing that cannot be readily included in a statistical model. Trainer's and jockey's intentions, secret workouts, whether the horse ate its breakfast, and the like, will be available to certain parties who will no doubt take advantage of it. Their betting will be reflected in the odds. This presents an obstacle to the model developer with access to published information only. For a statistical model to compete in this environment, it must make full use of the advantages of computer modelling, namely, the ability to make complex calculations on large data sets.

## CREATING UNBIASED PROBABILITY ESTIMATES

It can be presumed that valid fundamental information exists which can not be systematically or practically incorporated into a statistical model. Therefore, any statistical model, however well developed, will always be incomplete. An extremely important step in model development, and one that the author believes has been generally overlooked in the literature, is the estimation of the relation of the model's probability estimates to the public's estimates, and the adjustment of the model's estimates to incorporate whatever information can be gleaned from the public's estimates.

The public's implied probability estimates generally correspond well with the actual frequencies of winning. This can be shown with a table of estimated probability versus actual frequency of winning (Table 1).

**Table 1**

PUBLIC ESTIMATE VS. ACTUAL FREQUENCY

| range | n | exp. | act. | Z |
|---|---|---|---|---|
| .000-.010 | 1343 | .007 | .007 | 0.0 |
| .010-.025 | 4356 | .017 | .020 | 1.3 |
| .025-.050 | 6193 | .037 | .042 | 2.1 |
| .050-.100 | 8720 | .073 | .069 | -1.5 |
| .100-.150 | 5395 | .123 | .125 | 0.6 |
| .150-.200 | 3016 | .172 | .173 | 0.1 |
| .200-.250 | 1811 | .222 | .219 | -0.3 |
| .250-.300 | 1015 | .273 | .253 | -1.4 |
| .300-.400 | 716 | .339 | .339 | 0.0 |
| >.400 | 312 | .467 | .484 | 0.6 |

# races = 3198, # horses = 32877

**Table 2**

FUNDAMENTAL MODEL VS. ACTUAL FREQUENCY

| range | n | exp. | act. | Z |
|---|---|---|---|---|
| .000-.010 | 1173 | .006 | .005 | -0.6 |
| .010-.025 | 3641 | .018 | .015 | -1.2 |
| .025-.050 | 6503 | .037 | .037 | -0.3 |
| .050-.100 | 9642 | .073 | .074 | 0.1 |
| .100-.150 | 5405 | .123 | .120 | -0.7 |
| .150-.200 | 2979 | .173 | .183 | 1.6 |
| .200-.250 | 1599 | .223 | .232 | 0.9 |
| .250-.300 | 870 | .272 | .285 | 0.9 |
| .300-.400 | 741 | .341 | .320 | -1.2 |
| >.400 | 324 | .475 | .432 | -1.6 |

# races = 3198, # horses = 32877

range = the range of estimated probabilities
n = the number of horses falling within a range
exp. = the mean expected probability
act. = the actual win frequency observed
Z = the discrepancy (+ or - ) in units of standard errors

In each range of estimated probabilities, the actual frequencies correspond closely. This is not the case at all tracks (Ali, 1977) and if not, suitable corrections should be made when using the public's probability estimates for the purposes which will be discussed later. (Unless otherwise noted, data samples consist of all races run by the Royal Hong Kong Jockey Club from September 1986 through June 1993.)

A multinomial logit model using fundamental factors will also naturally produce an internally consistent set of probability estimates (Table 2). Here again there is generally good correspondence between estimated and actual frequencies. Table 2 however conceals a major, (and from a wagering point of view, disastrous) type of bias inherent in the fundamental model's probabilities. Consider the following two tables which represent roughly equal halves of the sample in Table 2. Table 3 shows the fundamental model's estimate versus actual frequency for those horses where the public's probability estimate was greater the fundamental model's. Table 4 is the same except that it is for those horses whose public estimate was less than the fundamental model's.

**Table 3**

FUNDAMENTAL MODEL VS. ACTUAL FREQUENCY WHEN PUBLIC ESTIMATE IS GREATER THAN MODEL ESTIMATE

| range | n | exp. | act. | Z |
|---|---|---|---|---|
| .000-.010 | 920 | .006 | .005 | -0.3 |
| .010-.025 | 2130 | .017 | .018 | 0.3 |
| .025-.050 | 3454 | .037 | .044 | 2.1 |
| .050-.100 | 4626 | .073 | .091 | 4.7 |
| .100-.150 | 2413 | .122 | .147 | 3.7 |
| .150-.200 | 1187 | .172 | .227 | 5.0 |
| .200-.250 | 540 | .223 | .302 | 4.4 |
| .250-.300 | 252 | .270 | .333 | 2.3 |
| .300-.400 | 165 | .342 | .448 | 2.9 |
| >.400 | 54 | .453 | .519 | 1.0 |

# races = 3198,   # horses = 15741

**Table 4**

FUNDAMENTAL MODEL VS. ACTUAL FREQUENCY WHEN PUBLIC ESTIMATE IS LESS THAN MODEL ESTIMATE

| range | n | exp. | act. | Z |
|---|---|---|---|---|
| .000-.010 | 253 | .007 | .004 | -0.6 |
| .010-.025 | 1511 | .018 | .011 | -2.2 |
| .025-.050 | 3049 | .037 | .029 | -2.6 |
| .050-.100 | 5016 | .074 | .058 | -4.3 |
| .100-.150 | 2992 | .123 | .098 | -4.2 |
| .150-.200 | 1792 | .173 | .154 | -2.1 |
| .200-.250 | 1059 | .223 | .196 | -2.1 |
| .250-.300 | 618 | .273 | .265 | -0.4 |
| .300-.400 | 576 | .341 | .283 | -2.9 |
| >.400 | 270 | .480 | .415 | -2.1 |

# races = 3198,   # horses = 17136

There is an extreme and consistent bias in both tables. In virtually every range the actual frequency is significantly different than the fundamental model's estimate, and always in the direction of being closer to the public's estimate. The fundamental model's estimate of the probability cannot be considered to be an unbiased estimate independent of the public's estimate. Table 4 is particularly important because it is comprised of those horses that the model would have one bet on, that is, horses whose model-estimated probability is greater than their public probability. It is necessary to correct for this bias in order to accurately estimate the advantage of any particular bet.[1]

In a sense, what is needed is a way to combine the judgements of two experts, (i.e. the fundamental model and the public). One practical technique for accomplishing this is as follows: (Asch and Quandt, 1986; pp. 123-125). See also White, Dattero and Flores, (1992).

Estimate a second logit model using the two probability estimates as independent variables. For a race with entrants $(1,2,\ldots,N)$ the win probability of horse $i$ is given by:

$$c_i = \frac{\exp(\alpha f_i + \beta \pi_i)}{\sum \exp(\alpha f_j + \beta \pi_j)} \qquad \text{(for } j = 1 \text{ to } N\text{)} \tag{1}$$

$f_i$ = log of 'out-of-sample' fundamental model probability estimate

$\pi_i$ = log of public's implied probability estimate

$c_i$ = combined probability estimate

(Natural log of probability is used rather than probability as this transformation provides a better fit)

Given a set of past races $(1,2,\ldots,R)$ for which both public probability estimates and fundamental model estimates are available, the parameters $\alpha$ and $\beta$ can be estimated by maximizing the log likelihood function of the given set of races with respect to $\alpha$ and $\beta$:

$$\exp(L) = \prod c_{ji^*} \quad (j = 1 \text{ to } R) \tag{2}$$

where $c_{ji^*}$ denotes the probability as given by equation (1) for the horse $i^*$ observed to win race $j$ (Bolton and Chapman, 1986 p. 1044). Equation (1) should be evaluated using fundamental probability estimates from a model developed on a separate sample of races. Use of 'out-of-sample' estimates prevents overestimation of the fundamental model's significance due to 'custom-fitting' of the model development sample. The estimated values of $\alpha$ and $\beta$ can be interpreted roughly as the relative correctness of the model's and the public's estimates. The greater the value of $\alpha$, the better the model. The probabilities that result from this model also show good correspondence between predicted and actual frequencies of winning (Table 5).

**Table 5**

COMBINED MODEL VS. ACTUAL FREQUENCIES

| range | n | exp. | act. | Z |
|---|---|---|---|---|
| .000-.010 | 1520 | .007 | .005 | -1.0 |
| .010-.025 | 4309 | .017 | .018 | 0.1 |
| .025-.050 | 6362 | .037 | .038 | 0.6 |
| .050-.100 | 8732 | .073 | .071 | -0.5 |
| .100-.150 | 5119 | .123 | .119 | -0.8 |
| .150-.200 | 2974 | .173 | .180 | 1.0 |
| .200-.250 | 1657 | .223 | .223 | 0.0 |
| .250-.300 | 993 | .272 | .281 | 0.6 |
| .300-.400 | 853 | .340 | .328 | 0.7 |
| >.400 | 358 | .479 | .492 | 0.5 |

# races = 3198, # horses = 32877

By comparison with Tables 1 and 2, Table 5 shows that there is more *spread* in the combined model's probabilities than in either the public's or the fundamental model's alone, that is, there are more horses in both the very high and very low probability ranges. This indicates that the combined model is more informative. More important is that the new probability estimates are without the bias shown in Tables 3 and 4, and thus are suitable for the accurate estimation of betting advantage. This is borne out by Tables 6 and 7, which are analogous to Tables 3 and 4 above except that they use the combined model probabilities instead of the raw fundamental model probabilities.

**Table 6**

COMBINED MODEL VS. ACTUAL FREQUENCY WHEN PUBLIC ESTIMATE IS GREATER THAN MODEL ESTIMATE

| range | n | exp. | act. | Z |
|---|---|---|---|---|
| .000-.010 | 778 | .006 | .005 | -0.4 |
| .010-.025 | 1811 | .017 | .015 | -0.6 |
| .025-.050 | 2874 | .037 | .035 | -0.7 |
| .050-.100 | 4221 | .073 | .073 | 0.0 |
| .100-.150 | 2620 | .123 | .116 | -1.0 |
| .150-.200 | 1548 | .173 | .185 | 1.2 |
| .200-.250 | 844 | .223 | .231 | 0.6 |
| .250-.300 | 493 | .272 | .292 | 1.0 |
| .300-.400 | 393 | .337 | .349 | 0.5 |
| >.400 | 159 | .471 | .509 | 1.0 |

# races = 3198, # horses = 15741

**Table 7**

COMBINED MODEL VS. ACTUAL FREQUENCY WHEN PUBLIC ESTIMATE IS LESS THAN MODEL ESTIMATE

| range | n | exp. | act. | Z |
|---|---|---|---|---|
| .000-.010 | 742 | .007 | .004 | -0.9 |
| .010-.025 | 2498 | .018 | .019 | 0.6 |
| .025-.050 | 3488 | .037 | .041 | 1.4 |
| .050-.100 | 4511 | .072 | .069 | -0.7 |
| .100-.150 | 2499 | .123 | .122 | -0.1 |
| .150-.200 | 1426 | .173 | .174 | 0.1 |
| .200-.250 | 813 | .223 | .215 | -0.5 |
| .250-.300 | 500 | .272 | .270 | -0.1 |
| .300-.400 | 460 | .342 | .311 | -1.4 |
| >.400 | 199 | .485 | .477 | -0.2 |

# races = 3198, # horses = 17136

Observe that the above tables show no significant bias one way or the other.

## ASSESSING THE VALUE OF A HANDICAPPING MODEL

The log likelihood function of equation (2) can be used to produce a measure of fit analogous to the $R^2$ of multiple linear regression (Equation 3). This pseudo-$R^2$ ($R^2$) can be used to compare models and to assess the value of a particular model as a betting tool. Each set of probability estimates, either the public's or those of a model, achieve a certain $R^2$, defined as (Bolton and Chapman, 1986)

$$R^2 = 1 - \frac{L(\text{model})}{L(1/N_j)}. \quad (3)$$

The $R^2$ value is a measure of the "explanatory power" of the model. An $R^2$ of 1 indicates perfect predictive ability while an $R^2$ of 0 means that the model is no better than random guessing. An important benchmark is the $R^2$ value achieved by the public probability estimate. A heuristic measure of the potential profitability of a handicapping model, borne out in practice, is the amount by which its inclusion in the combined model of equation (1) along with the public probability estimate causes the $R^2$ to increase over the value achieved by the public estimate alone:

$$\Delta R^2 = R^2_C - R^2_P \quad (4)$$

where the subscript P denotes the public's probability estimate and C stands for the combined (fundamental and public) model of equation (1) above. In a sense, $\Delta R^2$ may be taken as a measure of the amount of information added by the fundamental model. In the case of the models which produced Tables 1,2 and 5 above these values are:

| | |
|---|---|
| $R^2_P = .1218$ | (public) |
| $R^2_F = .1245$ | (fundamental model) |
| $R^2_C = .1396$ | (combined model) |

$$\Delta R^2_{C\text{-}P} = .1396 - .1218 = .0178$$

Though this value may appear small, it actually indicates that significant profits could be made with that model. The $\Delta R^2$ value is a useful measure of the potential profitability of a particular model. It can be used to measure and compare models without the the time consuming step of a full wagering simulation. In the author's experience, greater $\Delta R^2$ values have been invariably associated with greater wagering simulation profitability. To illustrate the point that the important criteria is the gain in $R^2$ in the combined model over the public's $R^2$, and not simply the $R^2$ of the handicapping model alone, consider the following two models.

The first is a logit-derived fundamental handicapping model using 9 significant fundamental factors. It achieves an out-of-sample $R^2$ of .1016. The second is a probability estimate derived from tallying the picks of approximately 48 newspaper tipsters. (Figlewski, 1979) The tipsters each make a selection for 1st, 2nd, and 3rd in each race. The procedure was to count the number of times each horse was picked, awarding 6 points for 1st, 3 points for 2nd, and 1 point for 3rd. The point total for each horse is then divided by the total points awarded in the race (i.e. 48 * 10). This fraction of points is then taken to be the 'tipster' probability estimate. Using the log of this estimate as the sole independent variable in a logit model produces an $R^2$ of .1014. On the basis of their stand-alone $R^2$'s the above two models would appear to be equivalently informative predictors of race outcome. Their vast difference appears when we perform the 'second stage' of combining these estimates with the public's. The following results were derived from logit runs on 2313 races (September 1988 to June 1993).

| | |
|---|---|
| $R^2_P = .1237$ | (public estimate) |
| $R^2_F = .1016$ | (fundamental model) |
| $R^2_T = .1014$ | (tipster model) |
| $R^2_{(F\&P)} = .1327$ | (fundamental and public) |
| $R^2_{(T\&P)} = .1239$ | (tipster and public) |

$$\Delta R^2_{(F\&P)\text{-}P} = .1327 - .1237 = .0090$$
$$\Delta R^2_{(T\&P)\text{-}P} = .1239 - .1237 = .0002$$

As indicated by the $\Delta R^2$ values, the tipster model adds very little to the public's estimate. The insignificant contribution of the tipster estimate to the overall explanatory power of the combined model effectively means that when there is a difference between the public estimate and the tipster estimate, then the public's estimate is superior. The fundamental model on the other hand, does contribute significantly when combined with the public's. For a player considering betting with the 'tipster' model, carrying out this 'second stage' would have saved that player from losing money; the output of the second stage model would always be virtually identical to the public estimate, thus never indicating an advantage bet.

## WAGERING STRATEGY

After computing the combined and therefore unbiased probability estimates as described above, one can make accurate estimations of the advantage of any particular bet. A way of expressing advantage is as the expected return per dollar bet:

$$\text{expected return} = \boldsymbol{er} = c \cdot div$$
$$\text{advantage} = \boldsymbol{er} - 1$$

where $c$ is the estimated probability of **winning the bet** and $div$ is the expected dividend. For win betting the situation is straightforward. The $c$'s **are the probability** estimates produced by equation (1) above, and the $div$'s are the win dividends (as a payoff **for a $1** bet) displayed on the tote board. The situation for an example race is illustrated in Table 8.

**Table 8**

| # | c | p | er | div |
|---|---|---|---|---|
| 1) | .021 | .025 | .68 | 33 |
| 2) | .125 | .088 | 1.17 | 9.3 |
| 3) | .239 | .289 | .69 | 2.8 |
| 4) | .141 | .134 | .87 | 6.1 |
| 5) | .066 | .042 | 1.29 | 19 |
| 6) | .012 | .013 | .75 | 61 |
| 7) | .107 | .136 | .64 | 6.0 |
| 8) | .144 | .089 | 1.33 | 9.2 |
| 9) | .019 | .014 | 1.18 | 60 |
| 10) | .067 | .066 | .86 | 12 |
| 11) | .012 | .012 | .83 | 68u |
| 12) | .028 | .047 | .50 | 17 |
| 13) | .011 | .027 | .32 | 30 |
| 14) | .009 | .019 | .41 | 43 |

c = combined (second stage) probability estimate
p = public's probability estimate (1-take) / div
er = expected return on a $1 win bet
div = win dividend for a $1 bet

The 'u' after the win dividend for horse #11 stands for *unratable* and indicates that this is a horse for which the fundamental model could not produce a probability estimate. Often this is because the horse is running in its first race. A good procedure for handling such horses is to assign them the same probability as that implied by the public win odds, and renormalize the probabilities on the other horses so that the total probability for the race sums to 1. This is equivalent to saying that we have no information which would allow us to dispute the public's estimate so we will take theirs.

From Table 8 we can see that the advantage win bets are those with an $er$ greater than 1. There is a positive expected return from betting on each of these horses. Given that there are several different types of wager available, it is necessary to have a strategy for determining which bets to make and in what amounts.

### *Kelly Betting and pool size limitations*

Given the high cost in time and effort of developing a winning handicapping system, a wagering strategy which produces maximum expected profits is desirable. The stochastic nature of horse race wagering however, guarantees that losing streaks of various durations will occur. Therefore a strategy which balances the tradeoff between risk and returns is necessary. A solution to this problem is provided by the Kelly betting strategy (Kelly, 1956). The Kelly strategy specifies the fraction of total wealth to wager so as to maximize the exponential rate of growth of wealth, in situations where the advantage and payoff odds are known. As a fixed fraction strategy, it also never risks ruin. (This last point is not strictly true, as the mimimum bet limit prevents strict adherence to the strategy.) For a more complete discussion of the properties of the Kelly strategy see MacLean, Ziemba and Blazenko (1992), see also Epstein (1977) and Brecher (1980).

The Kelly strategy defines the optimal bet (or set of bets) as those which maximize the expected log of wealth. In pari-mutuel wagering, where multiple bets are available in each race, and each bet effects the final payoff odds, the exact solution requires maximizing a concave logarithmic function of several variables. For a single bet, assuming no effect on the payoff odds, the formula simplifies to

$$K = \frac{\text{(advantage)}}{\text{(dividend - 1)}} . \tag{5}$$

where $K$ is the fraction of total wealth to wager. When one is simultaneously making wagers in multiple pools, further complications to the exact multiple bet Kelly solution arise due to 'exotic' bets in which one must specify the order of finish in two or more races. The expected returns from these bets must be taken into account when calculating bets for the single race pools in those races.

In the author's experience, betting the full amount recommended by the Kelly formula is unwise for a number of reasons. Firstly, accurate estimation of the advantage of the bets is critical; if one overestimates the advantage by more than a factor of two, Kelly betting will cause a negative rate of capital growth. (As a practical matter, many factors may cause one's real-time advantage to be less than past simulations would suggest, and very few can cause it to be greater. Overestimating the advantage by a factor of two is easily done in practice.) Secondly, if it is known that regular withdrawals from the betting bankroll will be made for paying expenses or taking profits, then one's effective wealth is less than their actual current wealth. Thirdly, full Kelly betting is a 'rough ride', downswings during which more than 50% of total wealth is lost are a common occurrence. For these and other reasons, a *fractional Kelly* betting strategy is advisable, that is, a strategy wherein one bets some fraction of the recommended Kelly bet (e.g. 1/2 or 1/3). For further discussion of fractional Kelly betting, and a quantitative analysis of the risk/reward tradeoffs involved, see MacLean, Ziemba and Blazenko (1992).

Another even more important constraint on betting is the effect that one's bet has on the advantage. In pari-mutuel betting markets each bet decreases the dividend. Even if the bettor possesses infinite wealth, there is a maximum bet producing the greatest expected profit, any amount beyond which lowers the expected profit. The maximum bet can be calculated by writing the equation for expected profit as a function of bet size, and solving for the bet size which maximizes expected profit. This maximum can be surprisingly low as the following example illustrates.

| c | div | *er* |
|---|---|---|
| 06 | 20 | 1.20 |

total pool size = $100,000
maximum *er* bet = $416
expected profit = $39.60

A further consideration concerns the shape of the 'expected profit versus bet size' curve when the bet size is approaching the maximum. In this example, the maximum expected profit is with a bet of $416. If one made a bet of only 2/3 the maximum, i.e. $277, the expected profit would be 35.5 dollars, or 90% of the maximum. There is very little additional gain for risking a much larger sum of money. Solving the fully formulated Kelly model (i.e. taking into account the bets' effects on the dividends) will optimally balance this tradeoff. See Kallberg and Ziemba (1994) for a discussion of the optimization properties of such formulations.

As a practical matter; given the relatively small sizes of most pari-mutuel pools, a successful betting operation will soon find that all of its bets are *pool-size-limited*. As a rule of thumb, as the bettor's wealth approaches the total pool size, the dominant factor limiting bet size becomes the effect of the bet on the dividend, not the bettor's wealth.

*Exotic bets*

In addition to win bets, racetracks offer numerous so-called *exotic* bets. These offer some of the highest advantage wagering opportunities. This results from the multiplicative effect on overall advantage of combining more than one advantage horse. For example, suppose that in a particular race there are two horses for which the model's estimate of the win probability is greater than the public's, though not enough so as to make them positive expectation win bets.

| | *c* | *div* | *p* | *er* |
|---|---|---|---|---|
| 1) | .115 | 8.3 | .100 | .955 |
| 2) | .060 | 16.6 | .050 | .996 |

By the Harville formula (Harville 1973), the estimated probability of a 1,2 or 2,1 finish is

$$C_{12,21} = (.115 * .060)/(1 - .115) + (.060 * .115)/(1 - .060) = .0151 .$$

The public's implied probability estimate is

$$P_{12,21} = (.100 * .050)/(1 - .100) + (.050 * .100)/(1 - .050) = .0108 .$$

Therefore (assuming a 17% track take) the public's rational quinella dividend should be

$$\text{qdiv} \cong (1 - .17)/.0108 = 76.85 .$$

Assuming that the estimated probability is correct the expected return of a bet on this combination is

$$er = .0151 * 76.85 = 1.16 .$$

In the above example two horses which had expected returns of less than 1 as individual win bets, in combination produce a 16% advantage quinella bet. The same principle applies, only more so, for bets in which one must specify the finishing positions of more than two horses. In *ultra-exotic* bets such as the pick-six, even a handicapping model with only modest predictive ability can produce advantage bets. The situation may be roughly summarized by stating that for a bettor in possession of accurate probability estimates which differ from the public estimates; 'the more *exotic* (i.e. specific) the bet, the higher the advantage'. Place and show bets are not considered exotic in this sense as they are less specific than normal bets. The probability differences are 'watered down' in the place and show pools.[2] Some professional players make only exotic wagers to capitalize on this effect.

*First, Second, and Third*

In exotic bets that involve specifying the finishing order of two or more horses in one race, a method is needed to estimate these probabilities. A popular approach is the Harville formula. (Harville, 1973):

For three horses ( i, j, k ) with win probabilities ( $\pi_i, \pi_j, \pi_k$ ) the Harville formula specifies the probability that they will finish in order as

$$\pi_{ijk} = \frac{\pi_i \pi_j \pi_k}{(1 - \pi_i)(1 - \pi_i - \pi_j)} . \qquad (6)$$

This formula is significantly biased, and should not be used for betting purposes, as it will lead to serious errors in probability estimations if not corrected for in some way.[3] (Henery 1981, Stern 1990, Lo and Bacon-Shone 1992). Its principle deficiency is the fact that it does not recognize the increasing randomness of the contests for second and third place. The bias in the Harville formula is demonstrated in Tables 9 and 10 which show the formula's estimated probabilities for horses to finish second and third given that the identity of the horses finishing first (and second) are known. The data set used is the same as that which produced Table 1 above.

**Table 9**

HARVILLE MODEL CONDITIONAL PROBABILITY OF 2ND

| range | n | exp. | act. | Z |
|---|---|---|---|---|
| .000-.010 | 962 | .007 | .010 | 0.9 |
| .010-.025 | 3449 | .018 | .030 | 5.3 |
| .025-.050 | 5253 | .037 | .045 | 2.8 |
| .050-.100 | 7682 | .073 | .080 | 2.3 |
| .100-.150 | 4957 | .123 | .132 | 1.9 |
| .150-.200 | 3023 | .173 | .161 | -1.8 |
| .200-.250 | 1834 | .223 | .195 | -3.0 |
| .250-.300 | 1113 | .272 | .243 | -2.3 |
| .300-.400 | 1011 | .338 | .317 | -1.4 |
| >.400 | 395 | .476 | .372 | -4.3 |

# races = 3198, # horses = 29679

**Table 10**

HARVILLE MODEL CONDITIONAL PROBABILITY OF 3RD

| range | n | exp. | act. | Z |
|---|---|---|---|---|
| .000-.010 | 660 | .007 | .009 | 0.5 |
| .010-.025 | 2680 | .018 | .033 | 4.3 |
| .025-.050 | 4347 | .037 | .062 | 6.8 |
| .050-.100 | 6646 | .073 | .087 | 4.0 |
| .100-.150 | 4325 | .123 | .136 | 2.5 |
| .150-.200 | 2923 | .173 | .178 | 0.7 |
| .200-.250 | 1831 | .223 | .192 | -3.4 |
| .250-.300 | 1249 | .273 | .213 | -4.9 |
| .300-.400 | 1219 | .341 | .273 | -5.3 |
| >.400 | 601 | .492 | .333 | -8.3 |

# races = 3198, # horses = 26481

The large values of the Z-statistics show the significance of the bias in the Harville formula. The tendency is for low probability horses to finish second and third more often than predicted, and for high probability horses to finish second and third less often. The effect is more pronounced for 3rd place than for 2nd. An effective, and computationally economical way to correct for this is as follows:

Given the win probability array, $(\pi_{i\ (i=1,2,...N)})$, create a second array $\sigma$ such that,

$$\sigma_i = \frac{\exp(\gamma \log(\pi_i))}{\sum \exp(\gamma \log(\pi_j))} \qquad (j = 1,2,...N) \tag{7}$$

and a third array $\tau$ such that,

$$\tau_i = \frac{\exp(\delta \log(\pi_i))}{\sum \exp(\delta \log(\pi_j))} \, . \qquad (j = 1,2,...N) \tag{8}$$

The probability of the three horses ( i,j,k ) finishing in order is then

$$\pi_{ijk} = \frac{\pi_i \sigma_j \tau_k}{(1 - \sigma_i)(1 - \tau_i - \tau_j)} \, . \tag{9}$$

The parameters $\gamma$ and $\delta$ can be estimated via maximum likelihood estimation on a sample of past races. For the above data set the maximum likelihood values of the parameters are $\gamma = .81$ and $\delta = .65$. Reproducing Tables 9 and 10 above using equations (7-9) with these parameter values substantially corrects for the Harville formula bias as can be seen in Tables 11 and 12.

**Table 11**

LOGISTIC MODEL CONDITIONAL PROBABILITY OF 2ND ( $\gamma$ = .81 )

| range | n | exp. | act. | Z |
|---|---|---|---|---|
| .000-.010 | 251 | .008 | .012 | 0.6 |
| .010-.025 | 2282 | .018 | .024 | 1.9 |
| .025-.050 | 5195 | .037 | .033 | -1.6 |
| .050-.100 | 8819 | .074 | .073 | -0.4 |
| .100-.150 | 6054 | .123 | .125 | 0.5 |
| .150-.200 | 3388 | .173 | .176 | 0.5 |
| .200-.250 | 1927 | .222 | .216 | -0.6 |
| .250-.300 | 973 | .272 | .275 | 0.2 |
| .300-.400 | 616 | .336 | .349 | 0.7 |
| >.400 | 174 | .456 | .397 | -1.6 |

# races = 3198, # horses = 29679

**Table 12**

LOGISTIC MODEL CONDITIONAL PROBABILITY OF 3RD ( $\delta$ = .65 )

| range | n | exp. | act. | Z |
|---|---|---|---|---|
| .000-.010 | 4 | .009 | .000 | -0.2 |
| .010-.025 | 712 | .020 | .010 | -2.7 |
| .025-.050 | 3525 | .039 | .035 | -1.3 |
| .050-.100 | 8272 | .075 | .073 | -0.7 |
| .100-.150 | 6379 | .123 | .130 | 1.7 |
| .150-.200 | 3860 | .172 | .175 | 0.5 |
| .200-.250 | 2075 | .222 | .228 | 0.7 |
| .250-.300 | 921 | .271 | .268 | -0.2 |
| .300-.400 | 582 | .337 | .299 | -2.0 |
| >.400 | 151 | .480 | .450 | -0.7 |

# races = 3198, # horses = 26481

The better fit provided by this model can be readily seen from the much smaller discrepancies between expected and actual frequencies. The parameter values used here should not be considered to be universal constants, as other authors have derived significantly different values for the parameters $\gamma$ and $\delta$ using data from different racetracks (Lo, Bacon-Shone and Busche, 1994).

## FEASIBILITY

A computer based handicapping and betting system could in princple be developed and implemented at most of the world's racetracks. Today's portable computers have sufficient capacity not only for real-time calculation of the bets, but for model development as well. However, several important factors should be considered in selecting a target venue, as potential profitability varies considerably among racetracks. The following are a few practical recommendations based on the author's experience.

### *Data availability*

A reliable source of historical data must be available for developing the model and test samples. The track must have been in existence long enough, running races under conditions similar to today, in order to develop reliable predictions. Data availability in computer form is of great help, as data entry and checking are extremely time-consuming. The same data used in model development must also be available for real-time computer entry sufficient time before the start of each race. Additionally, final betting odds must be available over the development sample for the 'combined' model estimation of equation (1) as well as for wagering simulations.

### *Ease of operation*

Having an accurate estimate of the final odds is imperative for betting purposes. Profitability will suffer greatly if the final odds are much different than the ones used to calculate the probabilities and bet sizes. The ideal venue is one which allows off-track telephone betting, and disseminates the odds electronically. This enables the handicapper to bet from the convenience of an office, and eliminates the need to take a portable computer to the track and type in the odds from the tote board at the last minute. Even given ideal circumstances, a professional effort will require several participants. Data entry and verification, general systems programming, and ongoing model development all require full-time efforts, as well as the day-to-day tasks of running a small business. Startup capital requirements are large, (mainly for research and development) unless the participants forgo salaries during the development phase.

### *Beatability of the opposition*

Pari-mutuel wagering is a competion amongst participants in a highly negative sum game. Whether a sufficiently effective model can be developed depends on the predictability of the racing, and the level of skill of fellow bettors. If the races are largely dishonest, and the public odds are dominated by inside information then it is unlikely that a fundamental model will perform well. Even if the racing is honest, if the general public skill level is high, or if some well financed minority is skillful, then the relative advantage obtainable will be less. Particularly unfavorable is the presence of other computer handicappers. Even independently developed computer models will probably have a high correlation with each other and thus will be lowering the dividends on the same horses, reducing the profitability for all. Unfortunately, it is difficult to know how great an edge can be achieved at a particular track until one develops a model for that track and tests it, which requires considerable effort. Should that prove successful, there is still no guarantee that the future will be as profitable as past simulations might indicate. The public may become more skillful, or the dishonesty of the races may increase, or another computer handicapper may start playing at the same time.

*Pool size limitations*

Perhaps the most serious and inescapable limitation on profitability is a result of the finite amount of money in the betting pools. The high track take means that only the most extreme public probability mis-estimations will result in profitable betting opportunities, and the maximum bet size imposed by the bets' effects on the dividends limits the amount that can be wagered. Simulations by the author have indicated that a realistic estimate of the maximum expected profit achievable, as a percentage of total per-race turnover, is in the range of 0.25 - 0.5 per cent. This is for the case of a player with an effectively infinite bankroll. It may be true that at tracks with small pool sizes, that this percentage is higher due to the lack of sophistication of the public, but in any case, it is unlikely that this value could exceed 1.5 per cent. A more realistic goal for a start-up operation with a bankroll equal to approximately one half of the per-race turnover might be to win between 0.1 and 0.2 per cent of the total track turnover. The unfortunate implication of this is that at small volume tracks one could probably not make enough money for the operation to be viable.

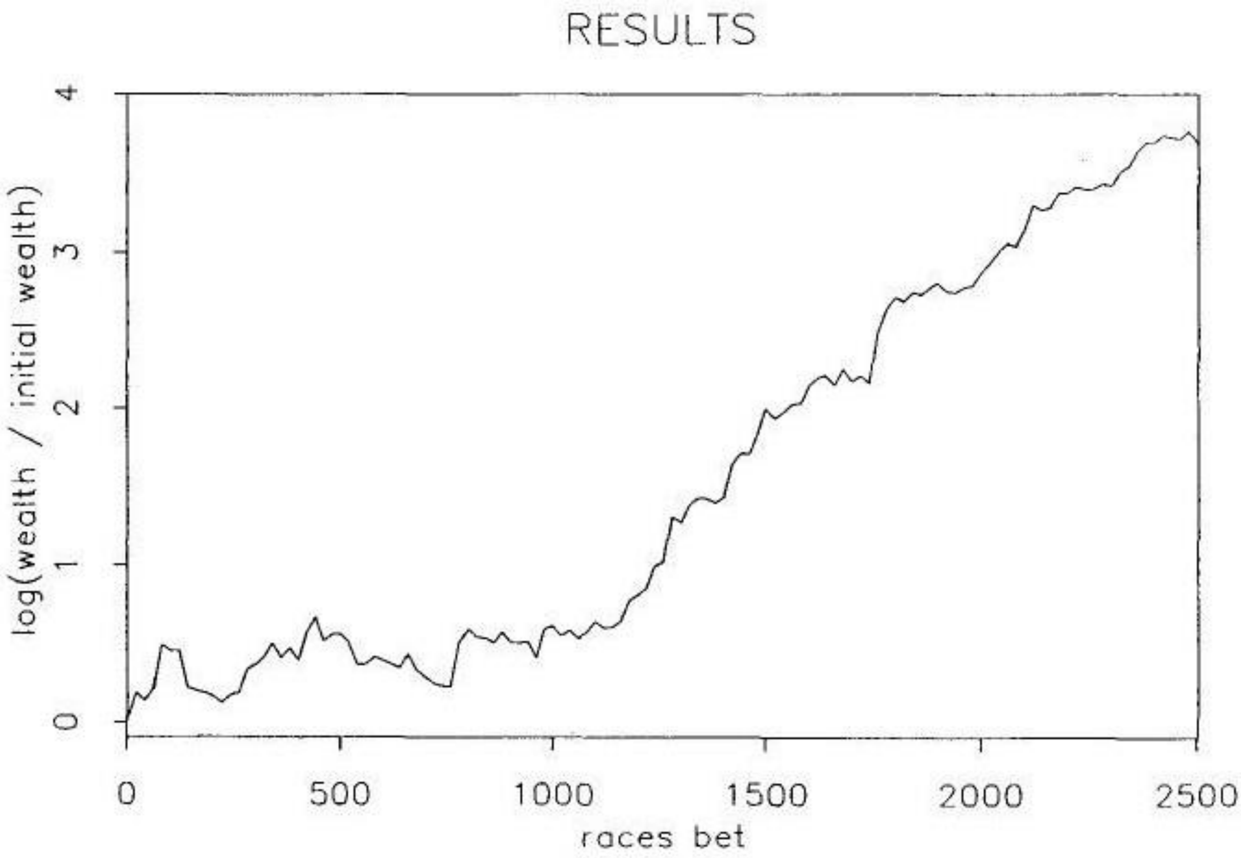
Racetracks with small betting volumes also tend to have highly volatile betting odds. In order to have time to calculate and place one's wagers it is necessary to use the public odds available a few minutes before post time. The inaccuracy involved in using these volatile pre-post-time odds will decrease the effectiveness of the model.

## RESULTS

The author has conducted a betting operation in Hong Kong following the principles outlined above for the past five years. Approximately five man-years of effort were necessary to organize the database and develop a handicapping model which showed a significant advantage. An additional five man-years were necessary to develop the operation to a high level of profitability. Under near-ideal circumstances, ongoing operations still require the full time effort of several persons.

A sample of approximately 2000 races (with complete past performance records for each entrant) was initially used for model development and testing. Improvements to the model were made on a continuing basis, as were regular re-estimations of the model which incorporated the additional data accumulated. A conservative fractional Kelly betting strategy was employed throughout, with wagers being placed on all positive expectation bets available in both normal and exotic pools (except place and show bets).[4] Extremely large pool sizes, ( > USD $10,000,000 per race turnover ) made for low volatility odds, therefore bets could be placed with accurate estimations of the final public odds. Bets were made on all available races except for races containing only *unratable* horses (~5%), resulting in approximately 470 races bet per year. The average track take was ~19% during this period.

Four of the five seasons resulted in net profits, the loss incurred during the losing season being approximately 20% of starting capital. A strong upward trend in rate of return has been observed as improvements were made to the handicapping model. Returns in the various betting pools have correlated well with theory, with the rate-of-return in exotic pools being generally higher than that in simple pools. While a precise calculation has not been made, the statistical significance of this result is evident. Following is a graph of the natural logarithm of [(wealth) / (initial wealth)] versus races bet.




***CONCLUSION***

The question; "Can a system beat the races?" can surely be answered in the affirmative. The author's experience has shown that at least at some times, at some tracks, a statistically derived fundamental handicapping model can achieve a significant positive expectation. It will always remain an empirical question whether the racing at a particular track at a particular time can be beaten with such a system. It is the author's conviction that we are now experiencing the *golden age* for such systems. Advances in computer technology have only recently made portable and affordable the processing power necessary to implement such a model. In the future, computer handicappers may become more numerous, or one of the racing publications may start publishing competent computer ratings of the horses, either of which will likely cause the market to become efficient to such predictions. The profits have gone, and will go, to those who are 'in action' first with sophisticated models*+.

*An earlier version of this paper was presented at the ORSA/TIMS Joint National Meeting in Phoenix, Arizona on November 1, 1993.

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## NOTES

[1]One technique to alleviate the negative consequences of biases which lead to the over-estimation of advantage is to employ a betting rule which specifies a minimum estimated advantage necessary for making a bet. In Ziemba and Hausch (1987) the authors suggest a mimimum advantage of 10% to account for the bias in their place and show betting model. Also, in their model the authors use place and show probabilities so the often present favorite-longshot win bias tends to cancel with the second and third place reverse bias. For simple probability estimations these schemes can work well, but in exotic bets whose probabilities are the products several individual win probabilities, the calculation of the correct minimum advantage becomes exceedingly complex. The author advocates the practice of correcting the probabilities first and then calculating the betting advantage.

[2]A similar calculation to the one carried out in the quinella pool example above shows that a horse with a positive expected return in the win pool will have a lower expected return as a place or show bet, given that the public bets consistently in the different pools. This effect is different than the one which produced advantages in the place and show pools for Ziemba and Hausch (1987). There the advantages arose because of inconsistencies between the public's estimated win probability for a horse, and the amount bet on that horses in the place or show pools.

[3]The bias in this formula is not as serious when used with win probabilities that show a significant favorite-longshot bias. The favorite-longshot bias often observed at racetracks (Ali, 1977) tends to cancel out the Harville formula bias in estimating second and third place probabilities.

[4]Betting off-track, the author did not have access to real-time show pool betting information. (Place betting in the North American sense is not available in Hong Kong.) Without individual horse show pool betting information, one can always achieve higher advantages by betting in 'exotic' pools such as quinella and trifecta. This follows from the above cited principle of 'the more specific the bet, the higher the advantage'. (See Note 2 above)



## APPENDIX

### HANDICAPPING REFERENCES*

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*The following is a partial list of references which the author has found helpful in suggesting ideas for significant *factors*. A useful source for difficult to find books on handicapping is 'The Gambler's Book Club' in Las Vegas, Nevada.

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