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2016

The International Mathematical Modeling Challenge (IM^{2}C)
Summary Sheet

Summary

The first official insurance was signed in the year 1347 in Italy. At that time it didn't bear such meaning, but as time passed, this kind of dealing with risks became very popular, because in the world of finance, it's extremely important to determine the costs as precisely as one can.

Today, various TV shows in which people try to win financial or other prizes due to their knowledge are becoming quite popular. As it's usually very hard to estimate what kind of prizes the participants are going to win, the TV stations view it as a practical move to insure against financial loss. This way, they can precisely calculate a month's profit for the TV show. In a similar way, organizers of sporting events, who offer bonuses for breaking a world (or other) record, also often insure against financial loss.

In our paper, we deal with this issue. We look at it from the perspective of an insurance company, whose aim is to identify such an insurance, which will bring gain them profit, but they also want to assure that the price the offer isn't too high for the organizers to pay. Also, we have looked at the problem from the perspective of the organizers interested in getting insurance, but of course only if the offer is a reasonable one, so that they can precisely calculate how much money they have available.

The first step in our working process was to estimate the probability of breaking a record in a race by studying the data regarding the previous years of the Zevenheuvegenloop race, but also some other endurance competitions. Trying to determine this, we took into account an assumption on our part considering the time until the next record is broken, as well as the prestige of the competition itself. Based on this estimate, we were able to calculate the average cost per competition.

Subsequently, we compiled a model to determine the amount of insurance premium using standard formulas of financial mathematics and estimating the expected gain and the inflation adjustment as well as the earnings derived from the investment of the insurance company.

Finally, we evaluated the situation from the perspective of the competition's organizers, where we were able to determine the maximum acceptable value of the insurance premiums, which would still be more efficient than paying out the bonus to the winner in form of a loan due to missing resources after the adjustment regarding the probability. We also considered the possibility of insuring multiple sports disciplines here.

The final step in our solution was to propose a clear procedure for the organizers of athletic competitions regarding their choice of insurance for the individual organized disciplines in a way that could benefit new but also experienced organizers.

Introduction

Athletics is considered to be the queen of sports, with already 12 athletic disciplines during the time of the first modern Olympic games in 1896 [1]. In 2015, a total number of 1373 athletic events took place in Europe alone [1]. If we compare this number to the number of races that took place in the last century, we can realize that the popularity of these events is rapidly growing. With growing numbers of events athletics gains also publicity, which, understandably, attracts in even more sponsors.

Whereas athletics gets more money over time, athletes are often motivated by a great bonus for breaking a world record. Thus, for example, in the Dubai Marathon can the runner who breaks the world record obtain $ 100,000 [3].

However, not all event organizers have such amounts of money at their disposal in order to offer competitors such large bonuses. Therefore, to keep up with the competition, they insure against financial problems arising from the paying out of the bonuses. This means that the organizers pay premiums to an insurance company before the event takes place. The company commits it will pay out the bonus in the event that an athlete breaks the world record. Whereas the insurance premium is a significantly lower sum than the bonus itself, these organizations are still able to offer a rather high financial incentive for runners.

The process of insurance is stated below:

1. The organizer asks the insurance company for a price offer.
2. The insurance company states the amount of the premium.
3. The organizer decides, whether he wants to pay the premium or take a risk in not insuring the event.
4. In case there are more disciplines in one event, the organizer has to decide, which disciplines he wants to insure and which not.

Terminology

Race
A repetitive, competitive event with a defined place and discipline. A race can bear a specific name, e.g. The Boston Marathon, The Zevenheuvelenloop race etc.

Organizer of a race
An institution, organization or any other form of association that hosts a racing event and handles its financials.

Insurance company / Insurance
A company responsible for the pay out of the bonus in case the world record gets broken.

Premium
The amount of money, which the organizer of the race has to pay to the insurance company for insuring the event.

Event
The organization of a race. It's tied to a place, a discipline and a certain date of realization. One race, if it's organized annually, consists of several events.

Bonus
The amount of money promised to the winner of a particular race. A bonus can be different for different races.

Custom policy
A situation in which the organizer of a race decides not to insure a particular event and in the case of breaking of a world record, he will cover the costs from his own resources.

Assumptions

At the beginning of solving of this issue, we think it's essential to set some assumptions with which we will count into the solution. It's basically just an explanation of factors, so that there won't be any disputes during the process of solving.

There are no two events incorporating the same discipline at one place and on the same day.

We state this assumption to simplify our work with the data, which is connected to the results in the various races and various disciplines. This however, doesn't pose any further restrictions. We simply assume that while organizing an athletic event, the host town gets into a non-standard situation, an extraordinary situation, where e.g. its roads can be closed due to a run.

The organizer of all the events in a single race is the same.

A race doesn't have to have just one organizer - there can be one and more of them and it's possible that the organizers will change in time. We set this assumption only so that the activities such as the organization of a race in the future or the analysis of the financial situation are easier from the point of view where the organizer is a single entity.

The insurance company won't go bankrupt.

In reality, there's of course the possibility that an insurance company will go bankrupt. But we assume that this risk is really negligible, as it doesn't happen too often. When calculating the probability and costs, a much bigger variability can be caused by the different factors of influence.

No catastrophic or emergency situation will take place.

The case of unexpected and unfortunate events and catastrophes, but also positive events or extraordinary and unique situations constitutes a factor that cannot be predicted or involved into the equation. Such situations are:

- A sudden and unexpected financial crisis (such as the organizer of the event receiving a financial penalty).
- Involvement of a big sponsorship which couldn't have been predicted.
- A fire, a flood or any other unexpected natural disaster.
- Any similar emergency.

We can assume that the risk of something of such importance happening is negligible and can be balanced out in regards to the positive as well as negative aspects.

Organizer as well as insurance company has the same information about the history of all races.

Among such information we include e.g. the full results of athletic events, the final times of every runner, information about the runners (dates of birth, countries of origin, etc.), weather and climate, all declared bonuses and bonuss for the placement of runners and similar public information. If all of this information is public and easy to access, there should be no problem to set such an assumption, but it's of great importance, because without it, there could exist a piece of information known only to one subject, and based on this it could set a different estimate that would lead to an agreement which is more advantageous for that subject. This wouldn't happen in an ideal situation.

The organizer is able to pay the full amount of the insurance premium set by the insurance company

If this wasn't the case, then the organizer wouldn't be able to choose and simply had to accept that he's taking the risk to not insure the race. Of course, if he doesn't have enough funds, he can always take on a bank loan. We only exclude such cases in which the organizer is fully unable to pay the insurance premium costs. In these cases, no matter how high the insurance premium cost, the organizer would have to reject the offer.

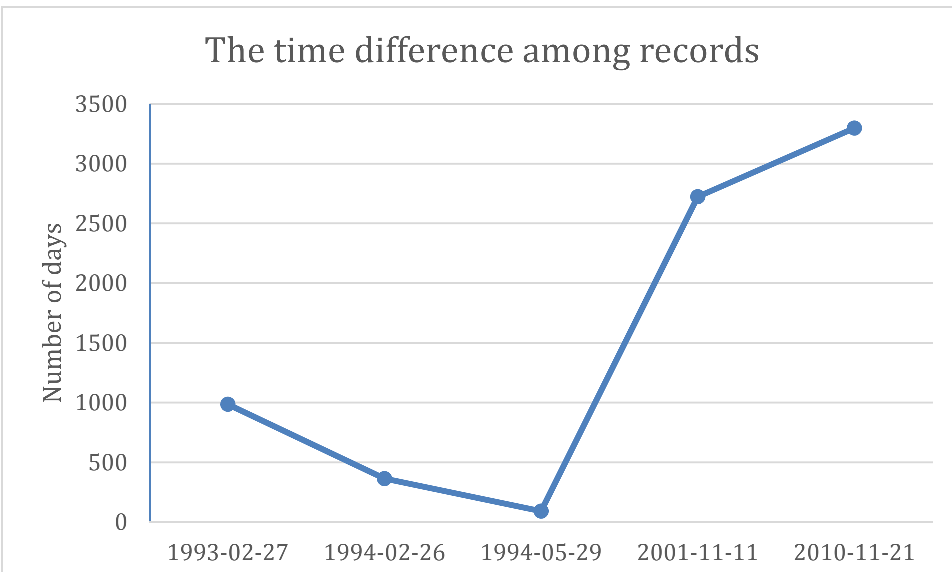
Average cost

In this section we will discuss the methods for determining the average cost. We will outline a model that we will gradually improve.

To calculate the average cost, it's necessary to know the value of the bonus (B is intended for the organizers) and the number of events (N) which are taking place until the another record is created. The ratio of B/N is then the value of the average cost.

Of course, N should not be the number of all events, but only the events tied to the same organizer. We will take a look at a lot of data from all events, we will mathematically describe their behavior and show how to apply the global trends to specific organizers (or particular events).

To approximate and predict the number of events required to break a record is not at all trivial. It is affected by many factors. The first simple solution is to collect data about the discipline and to put a curve of existing dependence (best fit) to the number of events N, which we can express analytically. We get the number of events required to happen to break the record. The graph (Graph 1) shows the number of days required to break every record in the 15 km men run [4].

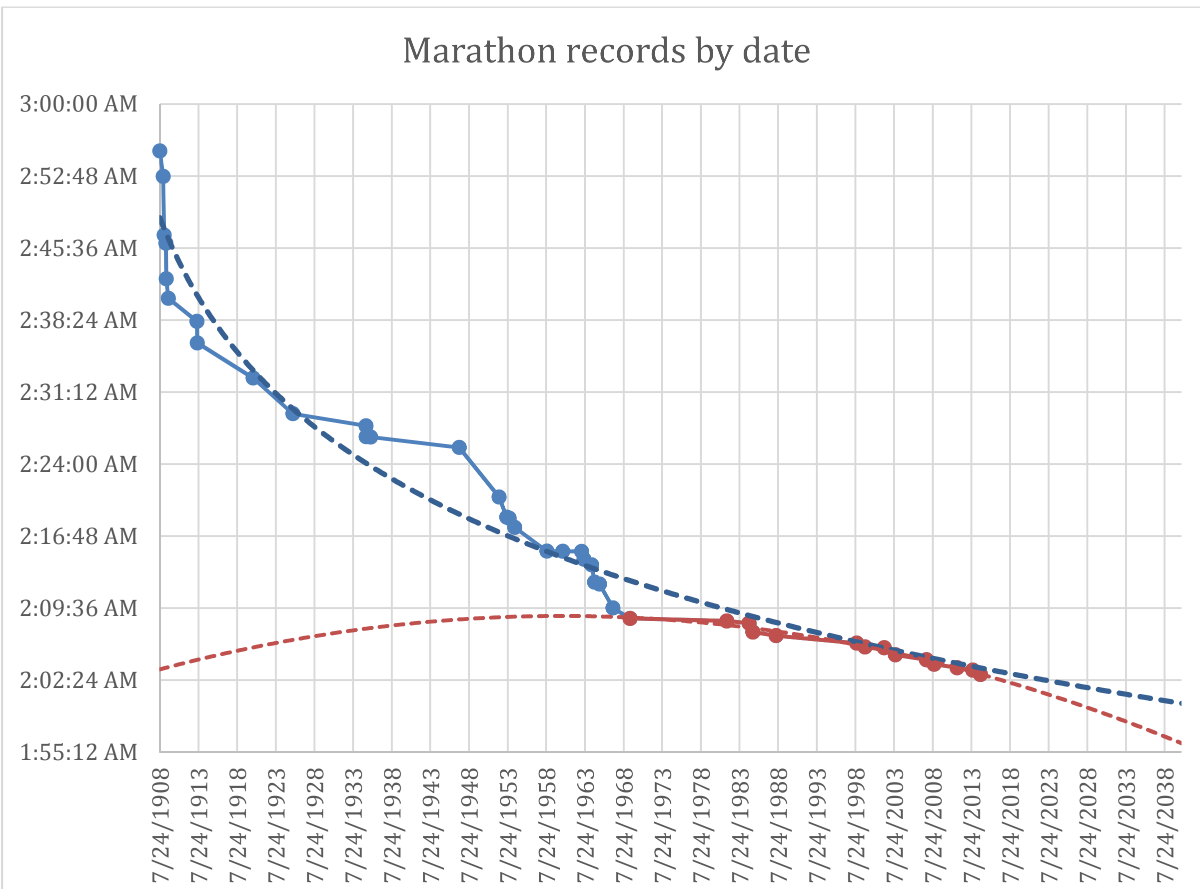


Graph 1

In an ideal situation, if the events were held evenly frequently in a period of time, this number would be directly proportional to the number of organized events. This may not always happen – we think that some races may not take place on a regular basis, or just special one-off races may be held. Therefore, we prefer data collected about the number of days, rather than the number of competitions. In the terms of collecting data, this isn't only easier, but also more accurate – there is no need to have the details about all the events. The number of considered events isn't affected any further.

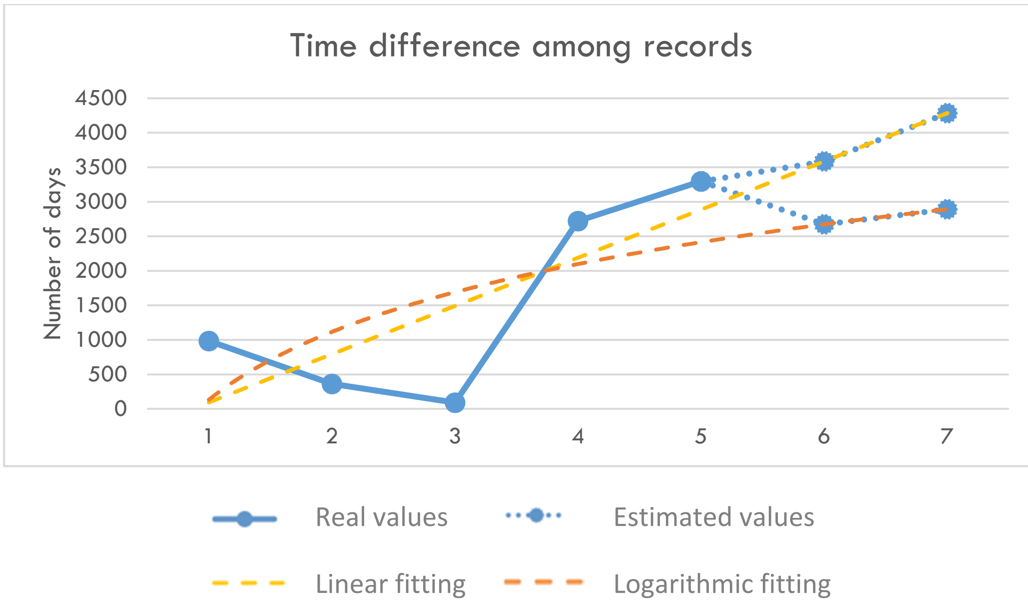
But if the race organizer organizes his event absolutely regularly (e.g. every year on the same date), then the number of days in the history is really exactly proportional to the number of held events. Otherwise, it's also proportional among the records, which happened in a reasonably close period of time, because the number of competitions in time is approximately constant over 3-5 years followed in sequence [4] [5]. We will also show that the records that are in close period of time are enough.

For best results, we have to fit the curve to points which are closer to the present, because it's normal that there (for example) may come to a sudden technological revolution that would substantially alter the development trend of records. Or the record times can come close to the certain human limit, and thus change the trend of its course in time. We can illustrate this in the discipline of the marathon run. The x-axis of the graph (Graph 2) shows the dates of various events of the marathon run and on the y-axis the record times. Thus, this chart shows the intervals between the world records as x distances between the points. The whole development of records is fitted by one curve, i.e. from the early 20th century, and only the last 40 years are fitted by the second curve. We see that the two curves diverge from another and assume other continuation, while to estimate the breaking of the next record we consider only a more precise fit from the data collected from the recent years. We don't need to predict more than a single other record in the future in terms of average costs.



Graph 2

Lets return to the time difference between the records. These can be fitted differently. The graph (Graph 3) shows the logarithmic (orange) and linear (yellow) fit for the 15 km Zevenheuvelenloop race. We calculated the reliability of the equation for every fit, i.e. since it's close to the real data. In all such graphs holding our data, the logarithmic fit was closer. This is most probably due to the fact, that the time difference between records can't constantly – quadratic or otherwise – continuously move up or down. This would otherwise mean that it would never happen, that there would be a record that can't be broken. However, such a record must exist, because all disciplines have a limit that may arise from the rules of the discipline, the possibility of the human race or the basic rules of the universe. This is explained in detail in this article [6]. It implies that the difference of record times of further records should be asymptotically close to zero. Although the logarithm doesn't have its own limit, it doesn't come close to the any value, but is in small intervals very similar and it's easy to work with it. Therefore, we consider this approximation as sufficiently precise and at the same time as better as in the case of a linear line, because the tendency of the number of days required to break a world record would over time become more and more stable.

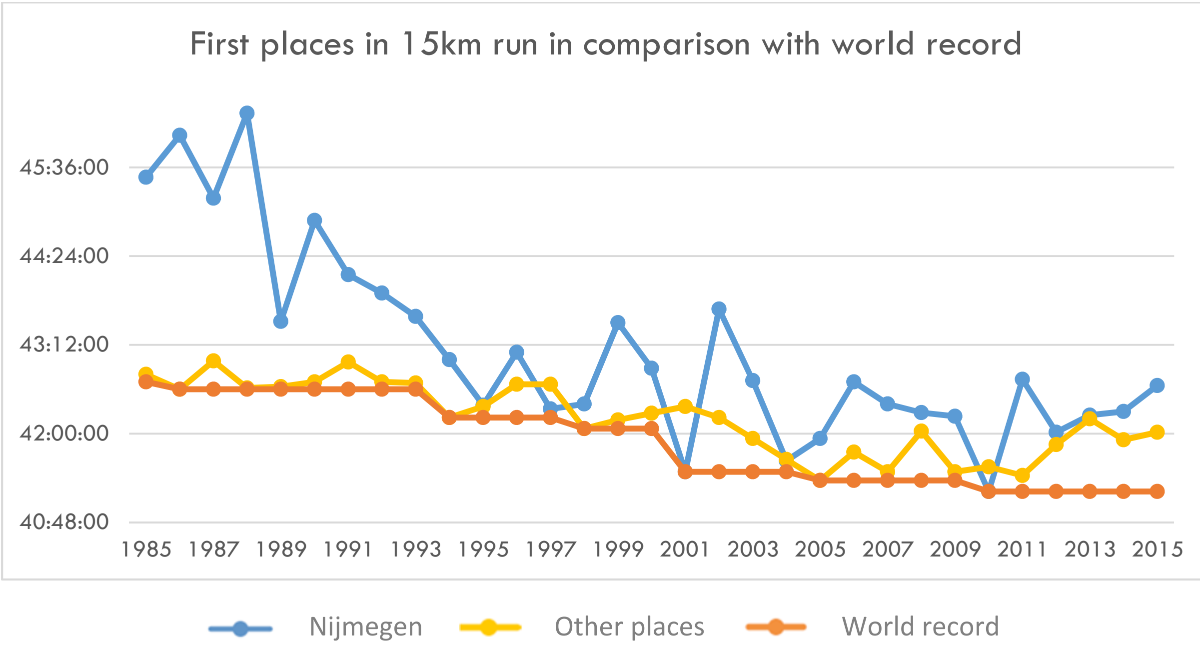


Graph 3

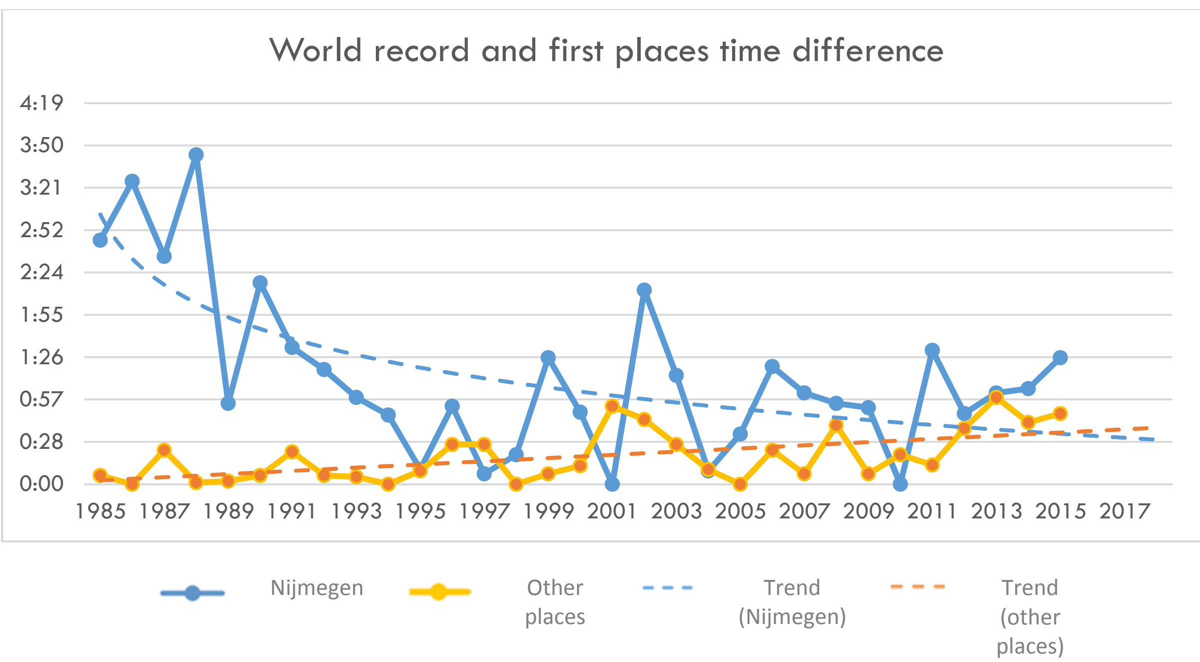
Using this method, we can determine the time in which a new world record will be set. Of course this is not an exact science, it's merely an assumption that will be true in the highest likelihood, compared to the assumptions with a different time. Specifically, according to this model, a new record will most likely occur in about 2,675 days since the last record, so around the spring of 2018.

Next, we need some way to determine the likelihood that another record, which will happen, will happen precisely in the city of Nijmegen (at the Zevenheuvelenloop race). It depends on the nature of the events, provided it's not a one-time characteristic. Such characteristics should include the quality of the contestants, whether they have a chance at creating a new record, the nature of the track (e.g. The Boston Marathon race runs mostly downhill with frequent wind from the back) and many other factors as well as the season (statistically, new records were created mostly in March and November, when it was below 40 °F [7]). The quality of the competition and the likelihood of setting a new record is well reflected by the difference of the best time run in the race and the best world record achieved in the discipline to date. This difference, or lets say a graph, which shows data over time, then reflects not only the trend of the changes in best times at a given place, but also the trend of change in the world record.

The following graphs show the best achieved times each year in comparison with the world record till the given year (Graph 4) and the differences of listed best achieved times and the world record (Graph 5). Both graphs include achieved times shown for achieved times in Nijmegen and for all other cities respectively, allowing us to come even closer to a comparison of likelihoods that a new record will occur in the city od Nijmegen or in any other city. Since all other cities are understood as a single group, we don't need to treat the cities individually, and therefore we don't need to know all the cities in which a 15 km run races are being organized.



Graph 4



Graph 5

We can justify the fitting of the logarithmic curve in case of an event of a discrepancy in best achieved times in Nijmegen and the world record as follows: while the organization of the Zevenheuvelenloop race was in its early stages, its popularity had to be substantially lower than it is presently. Therefore, the best achieved times measured in its early years may have been of a significantly different value than the best achieved times in its following years, when the popularity of the race increased, because of which the race then involved more people with a chance to succeed. After the first few years of organizing the

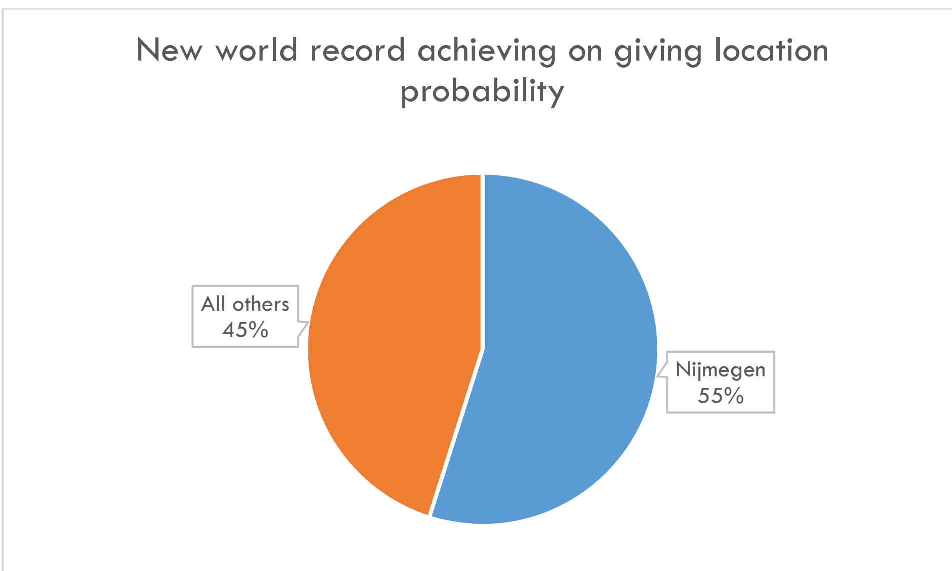
Zevenheuvelenloop race, the popularity of the race grew more stable, which is precisely characterized in the later part of the logarithmic curve with a less steeper slope.

In case of a difference between the best achieved times in other cities towards the world record is a fitted curve a linear one, because we can't observe the popularity of the race in a group of cities that includes all cities except for Nijmegen. This is because we consider this popularity as constant, if we compare it to the popularity of a contest in the individual cities such as Nijmegen.

Based on the acquired features, we can now expect, what will with the highest probability be the difference between the best achieved time and the world record, while we view the best achieved time in Nijmegen and the group of all other cities separately.

City	**The estimated difference between the best achieved time and the world record at the time of breaking of a world record**
Nijmegen	00:32:24
All others	00:39:27

Furthermore, we can say that the closer the estimated difference of achieved times closes on zero, the more likely it is the record will be broken, and vice versa. This relationship is precisely characterized by the function 1 / x, namely the inverse value of the predicted difference. And when we ratio the expressed reciprocals, it will determine the probability of the next world record occurring at the given location.



Graph 6

According to the mentioned model, we estimated the probability q saying, that the next record will occur in the city of Nijmegen with the rate of 55%. If the predicted number of events needed in achieving a new world record in Nijmegen is divided by the probability, that the record will occur exactly in this city, we get an interesting value indicating in what time will the world record be probably broken in Nijmegen.

We can then identify the average cost of the bonus (AC) by mere substitution of the values into the following formula:

$$AC = \frac{B}{N} * q$$
$$B = 25\,000\ €,\ \ N \cong 7.32,\ \ q \cong 55\%$$
$$AC \cong 1878\ €$$

The average cost of the bonus at the Zevenheuvelenloop race is approx. € 1,878.

We can easily express the likelihood that the world record will be broken next year as the inverse value of the number of years between individual records. Furthermore, the probability *P* that the world record will be broken the next year and precisely in Nijmegen will only be a *q* multiplication of the probability, that the record will even occur.

$$p = \frac{1}{N} * q = \frac{q}{N}$$

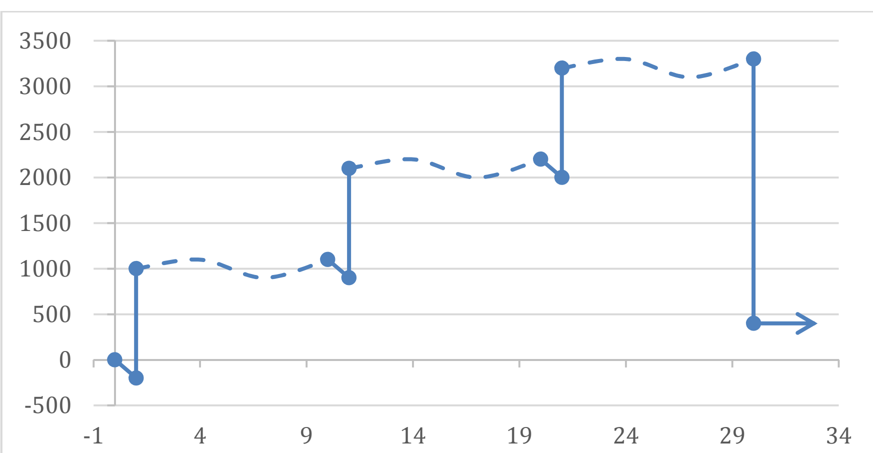
The amount of the insurance premium

This chapter will consider the estimation and calculation of the amount of insurance premium the insurance company should set for the race organizer. The organizer has then the option to accept or decline the offer.

First, let's look at the process of how the insurance policy is concluded between the insurance company and the race organizer, together with the development of finances within the insurance company across time. At the beginning, let's say a year before the organization of a specific event, the organizer asks the insurance company for an offer for an insurance premium for the race. The insurance company uses their employees and invests a certain amount of their time into the research of the situation to analyze the probabilities that will be used to predict the insurance premium. This of course also includes the profit that the insurance company looks to gain from the insurance contract. Subsequently, the contract between the insurance company and the organizers can be finalized and signed. The organizer pays the insurance premium to the insurance company. The whole process will require a certain amount of finances of the insuring company that we will consider to be constant in regards to the amount of insurance premium (provided that we are only concerned with the issue of insuring a race with roughly the same amount of bonus). Likewise, we will not consider the changing value of money over the time from the first analysis of probability to the payout of the insurance itself, as this time tends to be a short one (usually about a week) and the change in the value of money is negligible for such a time.

The time elapsed from the payment of the insurance premium to the insured event can take roughly around a year. This is a timescale at which it becomes necessary to consider the possible change of value of money over time. We are not able to predict possible moments of a financial crisis, however, we can work with a standard value of inflation. During this period, while the insurance company has funds available, the default option is to invest the money into stock and/or bonds [8]. The rate of return for the insurance company is likely significantly higher than the rate of inflation, because it would otherwise be just easier and more beneficial for the insurance company to entrust the funds to a bank that would increase the value through interest more or less at the same rate as is the inflation rate.

The development of the finances within the insurance company could look as follows, in the case of a long-term premium payment:



This cycle, as shown in the graph (e.g. the cost for the insurance company until the end of the period when the money is recovered), is repeated until a record is broken, at which point the insurance company pays the bonus. It is then left with a certain amount of money, which (in an ideal situation, if the estimates of the value of money and the recovery are accurate) is equal to the profit that the insurance company expected at the beginning. In the calculations, we use the following variables:

- p – Probability that a world record occurs during the next event in Nijmegen
- B – Bonus given as a reward to the person who breaks the record in the city (bonus will only be paid to one winner)
- R – Amount of insurance premium
- P – Profit of the insurance company
- i – Inflation rate of Euro for the current year (The Zevenheuvelenloop race is held in Netherlands, where the national currency is Euro)
- j – Refers to the annual rate of recovery for the money by the insurance company
- m – The number of years since now to the next breaking of the record, which also determines the number of times when the organizer pays the premium (i.e. the number of repetitions of the cycle shown in the graph)

With this chart, we are able to create an equation from which we later express R . On the left side of the equation, we place the funds that the insurance company will have just prior to the payout of the bonus, in case sometime in the future (in m years) a world record will be broken. We recalculate what value this sum of money should be if we had it today, thus retrospectively taking the inflation into account. On the right side of the equation, we place the sum of money that the organizer pays in insurance premium to the insurance company over the period of m years, taking into account the possible decline in the value of money over time (due to inflation) and the recovery of money in the insurance company (factor j), and also the fact that inflation impacts the amount of insurance premium as well. However, if we recalculate the insurance premium paid into the value of money today, we remove the need to count in inflation (finances increased by inflation are converted back). We use the annuity-immediate formula for the present value.

$$\frac{B+P}{(1-i)^m} = R * \frac{1-(1+j)^{-m}}{j}$$

Since the current probability p is that a world record occurs during the next event in Nijmegen, we can say that the record occurs on average once in the race. Therefore, let $m = \frac{1}{p}$.

Furthermore, insurance companies tend to set the amount of profit relative to the amount of premium. Let r be the profit share of the insurance premium.

$$P = r * R$$

$$\frac{B+rR}{(1-i)^m} = R * \frac{1-(1+j)^{-m}}{j}$$

$$\frac{B}{(1-i)^m} = R * \left(\frac{1-(1+j)^{-m}}{j} - \frac{r}{(1-i)^m}\right)$$

We express R and get the amount of insurance premium.

$$R = \frac{B}{(1-i)^m\left(\frac{1-(1+j)^{-m}}{j} - \frac{r}{(1-i)^m}\right)}$$

Deal or no deal

In the previous chapter we have set the amount of premium. The next step in the whole insurance process is for the insurance company to submit its proposal to the organizer, who will decide whether to accept the offer or not.

Insurance premiums are obviously higher than the average cost, as they also include the overhead costs of the insurance company and other charges. This means that if the organizers decide to insure their race long-term, they will ultimately pay more than if they would only pay bonuses to competitors. The only case in which it would be beneficial for the organizers to use the services of the insurance company would be if the world record would be broken earlier than expected. If that occurred and the race organizers wouldn't be insured, they would have to borrow money from banks in order to payout the bonuses.

From the organizer's point of view, it's therefore important to consider whether it's more worthwhile to pay insurance premium, or to pay back a loan. We will call the situation in which one pays back a loan as 'self-insurance'. In order to compare these two values, we need to know the amount of insurance premium that we calculated in the previous chapter and also the cost of self-insurance.

The cost of self-insurance can be calculated as the total amount that would have to be paid if a record was broken in the organized event, adjusted through the probability of such an event. This will give us the actual value of the self-insurance.

In this case, we need to find out the current prices of loans which the organizing committee would have to choose if a record would be broken. In such a situation we have no other choice but to take a loan, and it's therefore implied that the organizing committee would pick the most effective among all the offered loan offers. We can compare these deals if we calculate their current value by adding up the values of all payments after adjusting them for the value of money in time.

In this case, we will consider the amortization with constant annuities and annual repayment as well as interest, as it's the most common type of loan repayment. For any other type of amortization we'll just use one of the other widely known equations.

To get started, we will define some variables:

- p – Probability that a world record occurs during the next event in Nijmegen
- B – Bonus given as a reward to the person who breaks the record in the city (bonus will only be paid to one winner)
- k – Presently available capital allocated to the payment of bonuses
- i – Inflation rate of Euro for the year (The Zevenheuvelenloop race is held in Netherlands, where the national currency is Euro)
- g – Interest rate set by the bank for a loan
- n – Number of years over which the loan is paid back
- A – Annuity, which in this case is constant
- S_n – Current price of loans for *n* years
- I – *Self-insurance price*

The loan amount will be the difference between the bonus and the capital currently available. Other conditions are set by the bank. This includes the number of years and the interest rate. From these data, we can calculate the annuity using a generally known equation.

$$A = (B-k)\frac{g}{1-(1+g)^{-n}}$$

Next we must determine the present value of each installment after adjusting it to the inflation, and then add these values together. We use the annuity-immediate formula, but we will use our rate of inflation instead of interest rate. However, since inflation reduces the value of money over time, we need to use this formula with opposite values.

$$S_n = A\frac{1-\left(1+(-i)\right)^{-n}}{-1} = (B-k)\frac{g}{1-(1+g)^{-n}} * \frac{1-\left(1+(-i)\right)^{-n}}{-1}$$

This way, we acquired the present value of the loan, which can be used to compare with different offers. The most efficient choice will be the one with the lowest current value. The organizer can also choose an offer with a higher present value, if – for example – it has a more convenient repayment length or some other benefits.

Once we have decided on the best option, we can use the collected data about the current value in other calculations. In order to calculate the final price for the self-insurance, we have to add the initial capital that we are able to pay from our own money, and the final amount is then multiplied by the probability that the record will be broken.

$$I = P * (S_n + k) = P * \left((B-k)(\frac{g}{1-(1+g)^{-n}} * \frac{1-\left(1+(-i)\right)^{-n}}{-1} + k\right)$$

What we have done just now is that for every possible situation, i.e. whether there will be a record or not, we multiplied the amount the organizer will pay as a bonus by the probability that such a situation occurs. A situation in which a record breaking does not occur is not included in the formula, as the amount paid in this case is zero, and hence does not contribute to the sum.

With this, we obtained an average value the organizer payouts in the next contest in bonuses and we can directly compare this with the offer from the insurance company. If this value is less than the insurance premium we pay for the offered insurance, the self-insurance will be a better deal for us.

Various disciplines

Now that we can assess the offers of insurance companies, our next step will be to consider a greater number of different disciplines organized by the same organizing committee with limited resources, where the organizer could decide whether to insure each event or not.

In this situation, we will look at each discipline in an objective way and our main goal will be to save the greatest amount of money. Therefore, we will not consider options where the organizing committee would decide to insure some disciplines for a different reason than to save money, as this decision does not affect any other part of the event except the finances.

Therefore, the first step in this situation will be to choose for each organized discipline the cheapest offered insurance and calculate the price of the self-insurance. Based on this information, we can right from the start filter out those disciplines not worth insuring. In the next section, we will consider only those disciplines in which we will probably save money through the insurance.

For each of the remaining disciplines we will define the value y_i (where *i* is the index of the discipline) as the amount of insurance premium that we will pay for the particular insurance.

Next, let us have value x_i. This number can be obtained as the difference between the price of a self-insurance and the insurance premium for said discipline. The result will be the amount of money we will save with the insurance of that discipline.

Next, let us for each discipline define the number u_i, which we will get from the relation:

$$u_i = \frac{x_i}{y_i}$$

These figures can then be ordered in the following way:

$$u_a \geq u_b \geq u_c \geq \cdots$$

We can see that there is no practical significance to favor insurance discipline *a* over discipline *b*, if it is true that $u_b \geq u_a$, in case we are able to afford both. The number u_i tells us about how much we will save on average in the given discipline on each monetary unit that will be invested in the insurance.

The most efficient way is therefore to always first insure those disciplines that have the greatest value u_i. When choosing the next discipline to be insured, we consider the discipline with the next greatest u_i value, and if we have enough free capital, we insure it. We then move on to the next discipline, and when we come to the end of the list, we will be positive that we have chosen the most effective combination of insurances.

General scheme

If we want to decide whether we should buy a race insurance premium from an insurance company, we need to use all the knowledge we have acquired so far. The procedure we'll use in deciding is as follows:

1. We calculate the probability that a world record will be broken during the event.
2. We calculate the price of self-insurance.
3. We compare the price of self-insurance with insurance premium.
4. If we have several disciplines, we decide which ones to insure and which not.

1. Calculating the probability of breaking a record

To calculate the probability of breaking a record, we use the estimated time when we expect the record to be broken, and the probability of it happening during said event. The estimated time before breaking a new record can be determined simply by using a chart. For every world record in the discipline, we mark the length of time that has elapsed since the previous record. By fitting the curve in the chart, we will estimate the time needed to achieve another world record.

Next, in order to determine the probability of a record being broken in city A, we simply compare the trends in developments of the differences in the best achieved times with the world record at that point. In the same way as before, we fit the curve and estimate the next value. We do so with the results of the first achieved times in city A and then the results for the first achieved times in all other places. In this way, we can look into the future and predict the difference in the first achieved time of given event and a world record at an exact time, when another world record might occur. We then put into a ratio the inverse value of the predicted difference for city A and for all other cities. We receive the probability that the next record will occur exactly in city A.

The likelihood that a world record will be broken right at the next event of said race is calculated as the inverse value of the number of events that we estimate will occur between the last record and the next record, and that multiplied by the probability, that the next world record will be broken exactly in city A.

2. Calculation of self-insurance

For the determination of the self-insurance, we need the likelihood of a record breaking P, the present value of loans for n years (S_n) and the following data that can be determined without calculation:

- B – Bonus given as a reward to the person who breaks the record in the city
- k – Presently available capital allocated for the payout of the bonuses
- i – Inflation rate of Euro for the year (The Zevenheuvelenloop race is held in Netherlands, where Euro is the national currency)
- g – Interest rate set by the bank for a loan
- n – Number of years over which the loan is paid back

From these data, we can calculate the current cost of a loan for *n* years S_n as follows:

$$S_n = (B-k)\frac{g}{1-(1+g)^{-n}} * \frac{1-\left(1+(-i)\right)^{-n}}{-1}$$

Then, using the formula: $I = P * (S_n + k) = P * \left((B-k)(\frac{g}{1-(1+g)^{-n}} * \frac{1-\left(1+(-i)\right)^{-n}}{-1} + k\right)$

we can calculate the price of self-insurance.

3. Comparing the prices of self-insurance and insurance premium

Insurance premium represents the amount of money that the insurance company requires in order to cover the event. The price of self-insurance indicates the average amount of money that we would have to pay if we wouldn't be insured. For us as the organizers, who plan to support the race long-term, it is important that the costs for one year are on average as low as possible, and the comparison of these two values will tell us if we should cover the event with insurance or not.

4. Choice of disciplines for insurance

For each of the disciplines for which we are considering taking up an insurance, we express the following numbers:

- $y -$ as the price of insurance premium
- $x -$ as the difference between the cost of insurance premium and self-insurance
- $u -$ as the ratio of x/y

If the value of $x -$ will result in a negative number or zero, the insurance for that discipline will not be considered.

We will then rank the remaining disciplines by the size of *u* from largest to smallest. Then we will go over the list and decide for each discipline, if we have enough funds to insure it, and if yes, we will set aside the necessary funds.

When we reach the end of the list, we will have selected the disciplines which we will insure.

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