

# Twenty-five years of applied Operations Research at ORTEC

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## 1 Introduction

Our roots and the roots of many other ORTECcers are in the Operations Research (OR) department of the Econometric Institute of the Erasmus University Rotterdam. Now we employ 450 people with a quantitative background, who generate a turnover in applied OR of about €40 million. By the definitions of accountants this means that we are now a ‘large’ internationally operating company.

The title of the paper might suggest that the focus of this paper is the past. However, as we learned from historical scientists, understanding the past is especially important to make better, and better founded, decisions in the future. That is also the objective of this paper: Describing a view on 25 years of applied OR, in order to attribute to a strong continuation of further growth.

Worldwide aging and the strong trend of globalization because of the impressive growth of the economies in India and China, strongly forces the western world to increase productivity.<sup>1</sup> From the Nobel prize-winning work of Solow we know that more than 80% of productivity increase comes from creating and better exploiting knowledge. It is our view that exponential growth of successful applied OR, based on models that indeed represent ‘constructive knowledge’, is needed and attainable. Learning from the past, we describe our views and plans to get there.

As a result of aging and the need for higher productivity well-educated OR professionals will remain to have great (probability 1) chances of employment on the labor markets for decades. By elaborating on this, we hope that the paper is also a stimulus for current OR students, and an attracting force for future OR employees who are now working on their future at high school.

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## 2 The Econometric Institute

The roots of many ORTECcers lay in the Econometric Institute. Future-oriented, especially the following historic observations are relevant.

In the 1970s, Rotterdam started the Operations Research program (bedrijfseconometrie) parallel to the by then already world famous Econometrics program (algemene econometrie). For that reason, many ORTECcers of the early years were attracted to the Econometric Institute in Rotterdam. Thus, the Econometric Institute and the Operations Research Department are important factors for the birth of our company.

Important in both OR and Econometrics were (and are) the tutorial classes in which students in groups work on practical cases. Some young ORTECcers (some authors excepted) considered 'werkcollege' as the first really interesting and stimulating class, again an explanatory factor of the birth of ORTEC. Moreover, and more importantly, these classes teach students crucial qualities: how to move from theory to applied models that fit a given situation, working together and the relevance of presentations. The early learning of these qualities is an important explanatory factor of the success of our company.

In hindsight it is curious, if not incomprehensible, that practical applications in the 1970s were considered inferior. For example, simulation was considered an unscientific method, and a student could not graduate on a thesis which saved a production department millions per year by simply modeling this as an LP program, because this was unconvincing evidence of scientific qualities. For us, the challenge to successfully apply OR and econometrics was the primary incentive to start our company. This might be an explanatory factor for the strong development and appreciation, also at the universities, for the applications of OR and econometrics.<sup>2</sup>

Finally, founders of ORTEC combined their first steps in entrepreneurship with a 50% position at Erasmus to work on their PhD. This turns out to be an extremely synergetic combination. We stayed in close contact with new developments in the university community and new colleagues were easily found. If founders immediately fully depend on their startup they more quickly feel the need to pull the plug if times occasionally get rough. Last but not least, the relationship with the university has a magical attraction on new clients. Nowadays, such startups are much more common. Google might be an interesting recent example, but it is our strong opinion that entrepreneurship can be, and should be, strongly encouraged by facilitating much more of these startups than the many that we already see today.

## 3 The development of computation power and algorithms

Like many companies which originated due to the Internet, our company started at the moment that computers and computer-operating software started their exponential progress. In the 1970s, the by then young ORTECcers used the modern IBM 'mainframe' computer of the Econometric Institute. This impressive machine

possessed an internal memory of  $8K = 0,000008$  Gb. This meant that you could load 2000 real numbers in the memory of the computer, and for example, mix them to (sub-) optimal routes of a travelling salesman problem. Moreover, the mainframe could be used only by one person at a time, with an agreed maximum of 30 min of continuous use. Many people who are now at leading positions in science and industry firmly practiced their negotiating capabilities in the 1970s in trying to get the mainframe for 1 h, and we have seen examples where the negotiating qualities even yielded a turn of 2 h. This power of the computer, now seen as medieval and slow, nevertheless enabled us to accomplish results which were unattainable even some years before. But, it meant that one had to be very careful and efficient in designing the models and methods, because otherwise the computer could not load the program, or half an hour was insufficient computer time. The development of these qualities of efficient modeling has been a very important factor of success for the rest of our career.

Just when we started ORTEC (or vice versa) one of the most important innovations emerged: the PC. Our first computer was an Apple II, which performed already much better than a mainframe which had been the top of the bill only a few years before. This innovation has given an enormous boost to the development of practical OR and to our company. Applications, which a few years before either could not be implemented, and/or which were too expensive for the clients, became possible.

The spectacular increase in the capabilities of the computer was not the only factor to enable the use of algorithmic calculations. The algorithms themselves and their implementation improved equally spectacularly. With respect to linear programming, the reduction in the computing time (over the last 25 years) needed for a given instance because of improvements in Cplex even appears to outweigh the improvements due to the increased computer speed.

The correlation between the development and price of computer power and algorithms, and the development of the business of our company is still extremely strong. Many years ago, we foresaw a further strong jump in the growth of applied OR due to the development of ERP software. Simply put, models and software, (e.g. vehicle routing) can only be applied successfully if the system knows where the jam-and-butter is located, and where it has to go. We foresaw this many years ago, but only recently have these systems improved in such a way that the data relevant for OR applications are efficiently available. This will be a strong force for further growth of applied OR.

What about the future? We already run applications in ASP. This means that the clients use the Internet to reach our models and our computers. Again, this creates spectacular efficiency gains. Google-rumours say that in the near future computers might even be gone, and that clients need only communication devices to get in contact with computers with the right data and the right models and software. Of course, this again is an enormous source of growth for applied OR. All relevant data and models will be accessible from one place without the burden that they are scattered over the computers of thousands of clients. Knowledge, being the most

important source for productivity, will become available more and more easily. This further supports our view that there will be renewed strong growth for applied OR.

#### 4 Business development

Progress and specialization go hand-in-hand. In the beginning years of modern science, scientists could cover all available knowledge. Today it is hardly possible to know all models and methods, even of OR. We also see the process of progress through specialization in commercial OR.

We started building dedicated decision support systems including applied OR models for various clients. In these projects, almost everybody did almost everything: acquiring the project, model building, computer programming and implementation. Almost always, we were paid on an hourly basis, and the intellectual property rights of the software belonged to the clients. We were a kind of OR-based competitor of the software companies who detached their employees to work on the software of clients. With some clients, we still have such a much-appreciated relationship.

However, in order to be as efficient as possible in creating value for money for the clients, and in order to win the battle with (international) competitors, through the years we continuously improved our business model, in particular:

- Focus on application areas, such as vehicle routing, human resource planning, and Asset Liability Management, in a way that developed models and software can be re-used efficiently, and the consultants better understand the business processes of the clients.
- Introducing experts for the various phases of OR projects, up to the point that we created specialized software development units, units specialized in the implementation of the products at the client, and even acquired colleagues specialized in marketing and sales in our OR company.
- Continue with, but with clear distinction between, two ways of creating added value for the clients: on the one hand by making our knowledge available by selling licenses of our models and software, and on the other hand by using our models ourselves to advise our clients on possible solutions. This mixture of selling model-based software and model-based consulting frequently confuses investors and bankers. They usually think in a framework of one-product companies (e.g. Microsoft), but we have the strong opinion that selling licenses and consulting is an extremely synergetic mix, and the key success factor of our company.
- Getting abroad: we live in an era of globalization, converging to a situation ‘the winner takes it all’ (Schiller). There is one Microsoft, and dethroning them is getting more and more difficult. In the same trend, there could also remain one vendor of vehicle-routing software, and one independent provider of models for Asset Liability Management. Therefore, the world is the market. Some of our colleagues started an office in the United States, and many initiatives followed, and are going to follow.

In the remainder of this section we will zoom in on business development aspects in two important areas for ORTEC.

## 5 Logistics

Many of the successes of ORTEC have been in the areas of vehicle routing, human resource planning and production planning. Roughly speaking, two-thirds of our activities relate to these areas. The areas are well identified in the OR literature. It is generally believed in the OR society that huge efficiency gains are possible using the models and techniques offered in the literature. We have seen huge efficiency gains to be possible, although we also experienced that just a good algorithm alone does not do the job.

### 5.1 Start

When we started 25 years ago, we encountered a Greenfield situation. No real competition, but also no market. We thought that there should be demand, but in practice it hardly existed. Companies were not aware of the opportunities and therefore did not look for them. Moreover, no databases existed with data related to the business, such that the input for systems to optimize the operations was not available. Luckily, we were able to create interest at some of the leading companies. We were hired on a daily basis to develop tailor-made systems in close cooperation with the departments in need of the system. Every single project was successful, as we could not afford any failures.

### 5.2 Models and methods

Although careful selection of models and methods is important, other aspects are even more crucial for the overall success. Over the years, we encountered that planning processes develop in an evolutionary way. Based on recent (negative) experiences the planning process is adapted over and over. Generally, at the end nobody knows exactly how a planning process works, let alone how it interacts with other processes. Since the people involved hardly know the correct arguments as to why the planning process leads to the desired results, external consultants think that improvements can be realized easily. This is not necessarily true. Many OR consultants have left their clients in despair. The OR consultant focuses on a part of the puzzle, which he may even change a bit, such that he can apply his most beloved optimization technique. In doing so, he may well optimize a non-existing problem, which might moreover have dramatic side effects on other processes, which the consultant was not aware of. Clearly, this should be avoided. From the start, we realized that our background in OR was not enough, and that we should really understand the business processes also. Knowing the complexity of the business adds crucial side constraints when optimizing a subsystem; e.g. there is no use in optimizing routes in such a way that goods

are delivered at a different moment, if it is impossible to reschedule the manpower in this other facility to enable the reception of the goods. Optimization generally means that one becomes able to react with more flexibility to the changing circumstances (fixed routes are not optimal if the orders change every day). However, it does not work if one part of the organization reacts flexibly to changing circumstances and the others do not. As a consequence, the optimization of an organization can often be achieved only in smaller steps. After a subsystem is improved (made more flexible), other subsystems should first adapt (become flexible enough to process the less static input from the first process) before a next step is possible.

This stepwise innovation also has its effect on the optimization techniques to be used. These techniques should be very flexible, since the problem to be solved changes over time. Many mathematical programming methods from the past were less attractive from this perspective. Small changes in the formulation may completely change the nature of the model and a lot of work may be needed to implement the effects of a relatively small change in the problem formulation. Some recent techniques are far more promising in this respect. 'Set Partitioning', for instance, offers a robust way to formulate many planning situations and techniques to solve the set partitioning model have improved considerably.

### 5.3 *Standardization*

In the beginning of the 1990s the many projects we had done in the area of vehicle routing gave us enough understanding of the related business aspects to move towards a next phase. We started the development of SHORTREC, a standardized product which we have by now sold and implemented at hundreds of clients. They use the product for operational route planning and/or use it for strategic studies. The impact is often high. At first, the savings might be only a smaller percentage (since other processes must first adapt), but over the years the savings generally increase up to 20%. Organizations have reported yearly savings of up to €50 million as a result of using our software.

Our efforts in the area of human resource planning evolved in a similar way leading to a standardized product (Harmony) 5 years ago.

Business situations in both areas differ a lot over industries (like transport, health, Oil & Gas, etc.) as well as within industries. Careful implementation by specialists who really know the business therefore remains crucial.

### 5.4 *Internationalization*

The development of standardized products leads to investments that need to be recovered. Here, the opportunities in the Netherlands are clearly only small when compared with the large markets elsewhere. In 1993, we set our first small steps abroad in France. Today we also have offices in large markets like the USA and Germany, which become more and more important for us.

### 5.5 From here

We have reached a situation where we have several standardized products that effectively help to improve the efficiency and commercial power of an organization. The impact of the use of these kinds of products goes beyond the direct cost effects that the optimization might have. Maybe even more important is the way in which the tool structures, clarifies and objectifies the planning processes. In doing so, the tool and its immediate benefits is not the end point, but the starting point. It offers the ability to the user to react more adequately to the opportunities in his market. Moreover, it offers transparency that creates opportunities to improve adjacent processes. This leads to our dream for the next 25 years to be able to support all the planning processes of an organization in an integrated way. Only then will it become possible to effectively react on the changes that occur every day and optimize one's actions.

## 6 Asset Liability Management

In case of Asset Liability Management (ALM), models are used to sustain strategic decision making of 'liability-driven' organizations, especially, pension funds, insurance companies, housing corporations and banks. Today, the Dutch pension assets amount to €600 billion, which approximates the GDP of the Netherlands. Thus, if the investors are able to make 2% more portfolio return per annum on the pension assets, this amounts to 2% of GDP. This fact is already a sufficient argument for ALM to be extremely important. Other countries, such as France and Germany, possess only 5% of our national pension assets per capita, even leading to national strikes. Thus, for different reasons, strategic pension fund management is, or will be, of national importance worldwide.

Asset Liability Management started in the context of one of the previously described first projects of ORTEC. That is, we were hired on a daily basis by the Center of Applied Mathematics of a large Dutch bank, and the center rehired us to the pension fund of the bank. In these days, working for a pension fund seemed to be the end of one's career, but the opposite has proven to be true. Now we employ a group of more than 50 in ALM for pension funds, insurance companies and housing corporations, with an annual turnover of more than €7 million, which is, as far as we know, the largest ALM group worldwide.

How did we get there, and what can we learn from this for the future.

### 6.1 Author rights

An important first step was that at completion of the project at the pension fund, we realized that other pension funds could possibly face similar problems, but the software for analyzing the problems was owned by our client. Thus, we needed the software. We did not follow the Microsoft approach, but simply asked the client if we could buy the software, to which the client agreed for an extremely modest price.

## 6.2 Partners

Then, in order to sell the software to others, and to be able to use it for others, we needed to invest. But investing was not yet a well-developed part of our business, which flourished like software companies by working for our clients on a daily basis. This problem was overcome by two investment managers, whom we could convince to invest in the model in order to be able to serve their pension fund market. This was the first thing that ALM in The Netherlands was 'hot'. Conferences were organized, and we rapidly got new clients, especially large Dutch pension funds. Competitors were not yet awake.

## 6.3 Models and methods

What role was played by models and methods? It is an important observation that in ALM, and in many other applications of model building in finance, both the models and methods of Econometrics and of OR are crucially important. For example, the appropriate modeling of time series of interest rates, inflections and equity returns is important in ALM. That we developed a model which guaranteed that scenarios of time series that are generated by the model have the same statistical moments as the set of historic data which is used to estimate the model is anecdotal. We published this model in *The Journal of the Royal Statistical Society*, and years later found out that the model had already been published in 1928 by Yule-Walker. The pension community now refers to this model as the Johnny Walker scenarios. Until now, the full-fledged ALM-model appears too difficult to obtain optimal dynamic strategies, such that we frequently restrain to simulation techniques, which in the context of ALM are referred to as scenarios. But, as the problems of ALM are of enormous practical importance, we eagerly look forward to further progress in stochastic recourse optimization in order to solve these problems to optimality.

## 6.4 Client driven

People with a background in Econometrics and OR persistently tend to think that the client is faced with a well-defined problem, is interested in an optimal solution for the problem, and is able to understand the modeling approach. In many cases, these are three wrong assumptions in a row, and therefore the model is bounded to fail. In many cases, the most important accomplishment of applied OR and Econometrics is that the client has a better understanding of the problem, and better insight in the impact of possible policy decisions. To illustrate this, we quote some accomplishments about the scenario approach which we follow in ALM:

- Teach managements more about the dynamics of their businesses, and how it might operate in various new circumstances.
- Help to prepare for all different possibilities that can arise, so that one knows what to do in any given situation.

- Because they record explicit assumptions about the future, and provide a common framework for discussion, they also contribute to a better understanding between managers.

## *6.5 Business development*

### *6.5.1 New markets*

An ALM model consists of four parts: (i) a part modeling the uncertainty of the economic environment, (ii) an investment module, (iii) an interface, and (iv) a liability part. This means that when extending the model to, for example, the market of housing corporations, ‘only’ one part of the model has to be rebuilt. Recognizing this, we are now the market leaders in ALM for housing corporations and insurance companies in the Netherlands.

### *6.5.2 New countries*

The next step is of course international growth. In our financial business unit, we have tens of clients outside of the Netherlands, but that must nevertheless be seen as only a small beginning. Here, other aspects of business development such as setting up local partners, and finding more people who are interested in setting up our business in other countries are as well important. For the financial business unit, this is an important new development, where a common business risk can be excluded: we need not worry about lack of potential clients.

### *6.5.3 One-stop-shop and the integral approach*

The last business development could be described as one-stop-shop. That is, if the client has carried out an ALM project, then the strategy should be clear. But the strategy has to be carried out efficiently, and it also needs to be monitored with respect to risk and performance attribution, and in the case of pension funds it also needs to be integrated with the policy making of the sponsoring companies, the so-called enterprise-wide ALM. Our newest development is that we connected our available models to form a complete, consistent integral framework, which sustains the business processes of these clients from the beginning to the end, and back, for possible reviews of the strategy.

Thus, efficient growth in different directions is based on a clear concept. For ALM, the opportunities for further growth along these lines can continue almost endlessly, and many other markets are still waiting.

## **7 Conclusion and future outlook**

About 25 years ago, our supervisor wrote a paper ‘The future of OR is bright’. History proved him right. For the next 25 years, we extend this statement with ‘...and

after 25 years we have only seen the beginning'. We explained that the global trends support our statement. Building and exploiting knowledge is what the world needs, and that is what applied OR efficiently does. Of course, we should make this much more clear to national and international politicians, to industry leaders, and to new students.

In addition, co-operation between the industry and the scientific community should strongly continue because we foresee this as an even more important key success factor than in the past. Industry should identify interesting research areas for the universities, and provide promising career possibilities for the students. The universities should deliver high-quality models and methods, and professionally educated students who are able and eager to apply them successfully. These comprise the most crucial fuel for future growth.

### **Notes**

1. Note that the economies of China and India in 2050 are each expected to be larger than the economies of the US, Europe and Japan together.
2. Where too much focus was given at the universities on science and theory in the 1970s, it is the author's view that the situation might be the opposite today. A firm theoretical background should remain the primary backbone of university education.

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