Operational Research in Seven Decades

Robert G. Dyson

University of Warwick

Abstract

This paper is an account and reflection on the author's engagement with operational research (OR) starting in the 60s with work in the glass industry coinciding with a PhD at Lancaster and a first encounter with the professional membership debate. The 70s included a brief encounter with stochastic programming, soft OR which recurred throughout the decades, and the start of research into strategy support. The latter continued in the 80s and beyond and work on data envelopment analysis (DEA) began. In the 90s, a strong DEA team was built at Warwick, and the author led the development of the Society's fellowship scheme. In 2000s a group met regularly at Warwick focussing on strategic development and leading to a book on strategy support, and EJOR editing began. In the 2010s editing continued and work began on the contribution of the founders of OR to soft OR and practice. Editing wound down in the 2020s and the founders paper was published in the journal Operations Research.

Keywords

History of OR, practice of OR, OR and strategy, problem structuring, modelling

Introduction

There has been considerable interest in the history of operational research. For example Kirby (2002) has written a history of OR in Britain. Assad and Gass (2017) have made a significant contribution through the profiles of 43 founders of operations research (the US name for OR). There have been articles on the journey of key individuals, Kirby (2003) on Ackoff, and reflections and reminisces by Rosenhead (2009) and Sawyer et al (1989). This paper is the author's reflections and account over seven decades of

engagement with OR as a practitioner, an academic, a president of the OR Society and as a journal editor. The importance of history is that it can remind us of key aspects in the development of the subject that can and should inform the future, including that key innovations can arise in engagement with practice and the process of addressing new problems, the importance of the formal structuring of problems, and of validation, transparency and the key role of stakeholders.

The paper begins with some definitions and then adopts a decade-by-decade approach.

Operational Research (OR) can be defined as:

'**Modelling, experimentation, inductive and deductive reasoning approaches to problem solving and to support decision making**.' The models are usually quantitative, but it has been argued that quantitative models cannot resolve wicked problems or messes (Rosenhead, 1989) and this has led to the development of soft OR (with quantitative approaches sometimes referred to as hard OR). Soft OR can be defined as: **'A complete approach from problem structuring to decision without the development and solution of a quantitative model'.** Associated with soft OR are problem structuring methods (PSMs) which are: '**Specific methods or processes designed to enact soft OR. They are scientific as they involve inductive and deductive reasoning**.'

The Nineteen Sixties

I studied for my first degree in mathematical statistics at Liverpool University in the early sixties, the time of the Merseybeat when the Beatles and others played at the Cavern at lunchtime. A friend who I met at university went to school with Paul McCartney and he pestered me to go to the Cavern with him. 'My mates are playing

today, Paul bought me a drink, they are now top of the Mersey chart…' Big deal said I, I am too busy studying pure mathematics… – and I never went. In my final year I first met OR with a course on OR techniques. I joined Pilkington Brothers in 1964, then the largest private company in the UK. They had recently invented the float glass process which made the previous sheet and polished plate processes obsolete and every flat glass company in the world had to buy a licence. Pilkington still exists as part of the Japanese owned NSG group. My main work at Pilkington was on the efficient cutting of the glass which I will return to later. In 1965 I registered for a PhD at Lancaster University OR department initially located at Skein House in the centre of Lancaster. Pat Rivett had launched the department a couple of years earlier and established a non-residential, full-time PhD programme for people working in industry. This involved being in residence at Lancaster for six weeks for the first two or so years for supervision, but also for joining short courses located at the Midland Hotel in Morecambe or at the Bellfield Hotel in Bowness. The short courses, which were open to the public, were delivered by prominent researchers often from the USA and I went to courses delivered by David Hertz, Anatol Rappaport, Abraham Charnes, Bill Cooper, and others. I had joined the second cohort of students along with John Ranyard and was the first student on the programme to graduate in 1969 (Dyson). (By then Pat Rivett had moved to Sussex leaving the OR department in the capable hands of Mike Simpson and Alan Mercer.) Being based at the Pilkington R&D Laboratories at Lathom allowed me to align my PhD research well with my day job. I joined the OR Society in the mid-sixties when it was embroiled in a discussion about professional membership. The Society had been founded by practitioners in the fifties and there was a desire to professionalise the society. There was a proposal to establish a register of practitioners. The senior members of the Society would join the register and then judge whether other

members were worthy of the honour. There was strong opposition to the proposal led by Jonathan Rosenhead. He was concerned that the proposal could ossify OR and the process seemed to be potentially elitist. After an acrimonious debate the proposal was defeated. As a consequence some members set up a professional group, the Fellowship of OR, and members who met the criteria could be designated as fellows (FOR). I will return to this issue later.

The Cutting Stock Problem in the Glass Industry

Float glass at Pilkington, produced at their Cowley Hill plant in St. Helens, involved floating liquid glass on a bath of tin. The glass would enter the bath molten and leave solid. The process ran 24/7 but the warehousing, including the cutting to order size, only operated during the day so the glass was first cut into stock sizes. A typical two-stage cutting pattern would be as follows (figure 1), where the end pieces are waste and there could be waste at an edge also:

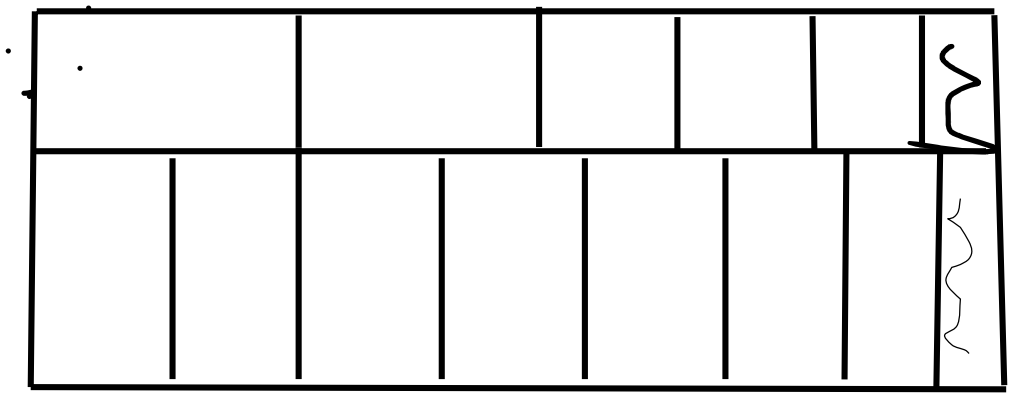

Figure 1 A cutting pattern.

On the main cutting machine the orders were for car windscreens and there would typically be 100 different order sizes to be cut from four or so different stock sizes. Producing the orders with minimum wastage could be found by solving the following

linear program (LP) where the variables are the number of repeats of each cutting pattern, there would be one row/constraint for each order size, each column represented a different cutting pattern, and the right-hand sides are the order quantities. A constraint coefficient would be the number of pieces of the order size from a particular cutting pattern (Dyson and Gregory, 1974). See figure 2.

Minimize the stock used.

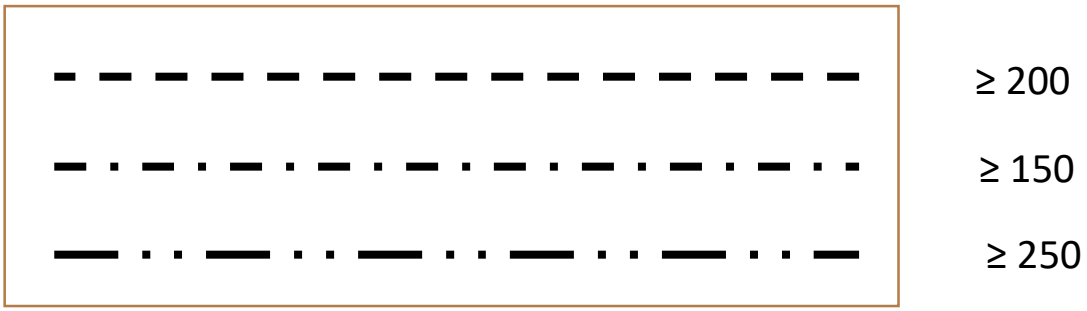

Figure 2 An LP model

With a hundred different order sizes and four stock sizes there would potentially be many thousands of different cutting patterns and therefore columns in the LP, and the computing power available at that time could not solve such a large problem. Gilmore and Gomory (1965) overcame this problem by column generation. They started with any feasible solution and solved a side (knapsack) problem to generate a column (cutting pattern) which would improve the solution. They then carried out a simplex iteration entering the new column into the solution and continued to iterate until the most efficient solution was obtained.

The sequence in which the cutting patterns were produced was important for the smooth operation of the warehouse. An order size might appear in several different cutting patterns which ideally should occur in sequence, as part orders, a result of discontinuities in the sequencing, would need to be in temporary storage causing congestion. The cutting patterns can be sequenced with fewest discontinuities by

applying a travelling salesman algorithm (Little et al, 1963). Unfortunately only 20 or so patterns could be sequenced with the available computing power, so a heuristic algorithm, using a knapsack algorithm, was developed which generated the patterns in an appropriate sequence but did not necessarily achieve minimum wastage.

Another problem was determining the best stock sizes. This had proved to be a difficult task for the schedulers. It was found that a heuristic search of the possible combinations of stock sizes, tested by the LP model, was very effective at finding a good selection of stock sizes (Chambers and Dyson, 1976). (Mike Chambers was my excellent PhD supervisor.) The paper was awarded the President's Medal of the Society in the days when it was awarded to the second-best paper in the Journal of the Operational Research Society (JORS) for that year. I suspect the work would also have had the potential to be a strong submission for the medal under the current practice criteria.

The work led to improved performance in the warehouse and was valuable in strengthening Pilkington's hand in licensing negotiations with an American company, PPG Industries. There were some tensions between the analysts and the managers and schedulers which might have been mitigated if the stakeholders had been more formally engaged as in soft OR.

The Nineteen Seventies

In 1970 I decided to leave Pilkington. I applied for jobs in industry but also following my Lancaster experience I was appointed to a lectureship at the University of Warwick in the School of Industrial and Business Studies. Warwick was not an obvious choice as it had experienced student unrest in the late sixties and was seen as a trailing rather than a leading 'New' university, with perhaps Sussex seen as the leading one at that

time. However, I was attracted to the idea of a broad business school and impressed by the founding Chairman (sic) Brian Houlden, and the Head of the OR Group, Hylton Boothroyd. Brian had been Head of the National Coal Board OR Executive and Hylton his deputy. My PhD thesis had been embargoed for seven years, but Pilkington agreed to my publishing the two previously cited articles, and they appeared Operational Research Quarterly.

I decided to move my research away from cutting problems and with my expertise in mathematical programming and a degree in mathematical statistics I developed an interest in stochastic programming which I will return to later. I also had an introduction to soft OR at an OR Society meeting at Shell. One of the speakers, I think Jonathan Rosenhead, introduced a wicked problem and an integer programming formulation which he demonstrated to be a totally unsuitable approach. I pointed out that the formulation was a very poor one and that MP models could be used in an exploratory way, but my observations were not well received.

Although not engaging with soft OR per se, I became interested in strategic planning. I had a three-month sabbatical at the University of Twente, the Netherlands. I gained access to the Regge en Dinkel Water Authority and Akzo, now AkzoNobel, a leading chemical company. I was able to study and compare their strategic planning processes with a particular focus on the participation of stakeholders. The work was published in Long Range Planning (Dyson, 1978)

Stochastic Programming

One version of stochastic programming is known as the 'wait and see' model. In such a model the values of the decision variables are determined after the realisation of the stochastic parameters. This approach is useful when the model is being used in a

predictive mode to evaluate changes in the system such as capital investments (Dyson, 1978). These can take years to implement, so when the model is run some parameters will be uncertain. These can be replaced by the best forecast, a deterministic model, to evaluate the proposals. However there may also be interest in an evaluation based on a worst-case scenario where the parameters take on their most pessimistic plausible values (Dyson and Swaithes, 1976). (Note that inserting the most pessimistic value for each parameter individually will have a very low likelihood and will be unrealistic or implausible unless the parameters are all highly positively correlated.) This approach can be illustrated with reference to an oil refinery model as follows:

$$\text{Min}(Z)\ \text{Max}(x)\ cx$$

$$Ax = b \text{ (crude oil availability, capacities, product specifications)}$$

$$Bx = Z \text{ (uncertain demands)}$$

The variables are the different types of crude oil used and intermediate and final products. The objective function is the profitability or contribution, and the model can be used to evaluate alternative capital investment proposals. There is a set of deterministic linear constraints and for illustration two demand constraints with uncertain demands. The uncertainty of the demands is represented by a plausible region bounded by an equi-probability contour, capturing a high probability density e.g. 0.99. If the two uncertain demands are normally distributed, the contour will be an ellipse or an ellipsoid in higher dimensions (figure 3). Confining the values of Z to the plausible region will introduce a non-linear constraint to the model.

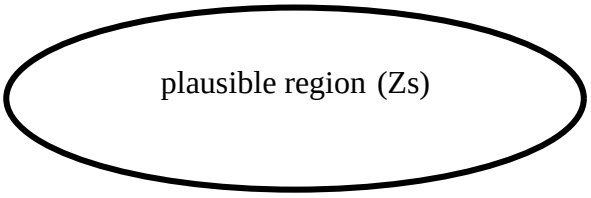

Figure 3 A plausible region

A solution to the model will be a plausible pessimistic evaluation for each proposal. Dyson and Swaithes (1978) also show how to obtain global solutions where the uncertainties are in the objective function and right-hand-side parameters.

In addition to the articles, we presented the work at two conferences. However, there seemed to be little interest in the approach at the time. Also a research student testing the approach at a fruit cannery abandoned his studies and the contract of Gillian Swaithes, a research fellow, expired. I consequently moved on to other things. Our approach had similarities with robust optimization which was developed some years later by Ben-Tal and Nemirovski (1998) although the origins of the approach may be traced back to Soyster (1973). I wonder whether the lack of a real application and more active networking might have led to a greater interest in the work. I am also reminded that in the days of print when publishers sent the author a number of pre-prints, Bill Cooper sent out all his pre-prints to colleagues across the world. Most of mine resided in a box in my office.

The Nineteen Eighties

In the early eighties I was asked to advise on the operations of a peat bog by one of my former students and opted for a socio-technical systems analysis approach. Work on strategic planning/strategy support also developed and I began research on data envelopment analysis.

Socio-Technical Systems Analysis

The peat bog was at Chat Moss on the line of the Manchester to Liverpool railway, one of the earliest passenger railways. The line through Chat Moss had to be built on floats to stop in sinking into the peat. The peat bog manager, Gordon Pearson a graduate from the first intake on the Management Sciences degree at Warwick, asked my advice on how to increase the output of the operation. This was in the days before the use of peat for compost was frowned on. Gordon wanted a quick and easy solution, so although a simulation would have been an appropriate approach, it was thought to be too time-consuming and expensive. I had recently enjoyed a seminar by Tom Lupton on socio-technical systems analysis, a qualitative modelling approach (Warmington et al, 1977) and we agreed to adopt it.

The problem was approached as follows:

- The first stage was to identify the performance measure(s) which in this case was the output of peat.
- Stage two involved identifying relevant variables. It was important to involve relevant stakeholders throughout the process, and this included the manager and operations personnel. Variables included stockholding capacity, internal transport, mode of cutting the peat and so on.
- The next stage was to identify interactions and causal relations between the variables, and the impact on the performance measure.
- The strength of the relationships and the impacts were assessed qualitatively i.e. strong, medium, weak.
- The next key stage was to qualitatively assess the manipulability and controllability of the variables. This included the cost and ease of change.

- Finally an action plan was formulated based on variables that had high manipulability and a strong beneficial impact on the performance measure. The proposals identified were to use rotavating to cut the peat, improve internal transport, increase stockholding capacity and there was a consequential need to increase labour.

The proposals were accepted apart from rotavating as there was a concern that if rotavating turned out to be not a successful method, it would not be easy to return to the traditional block cutting. Hence the reversibility of the variables became an important issue. The results of the analysis were initially presented in tabular form.

I later developed software to display the relationships of the approach in diagrammatic form (further developed by Neil Buxton and MSc student. For the peat bog, the problem can be displayed in figure 4 as follows:

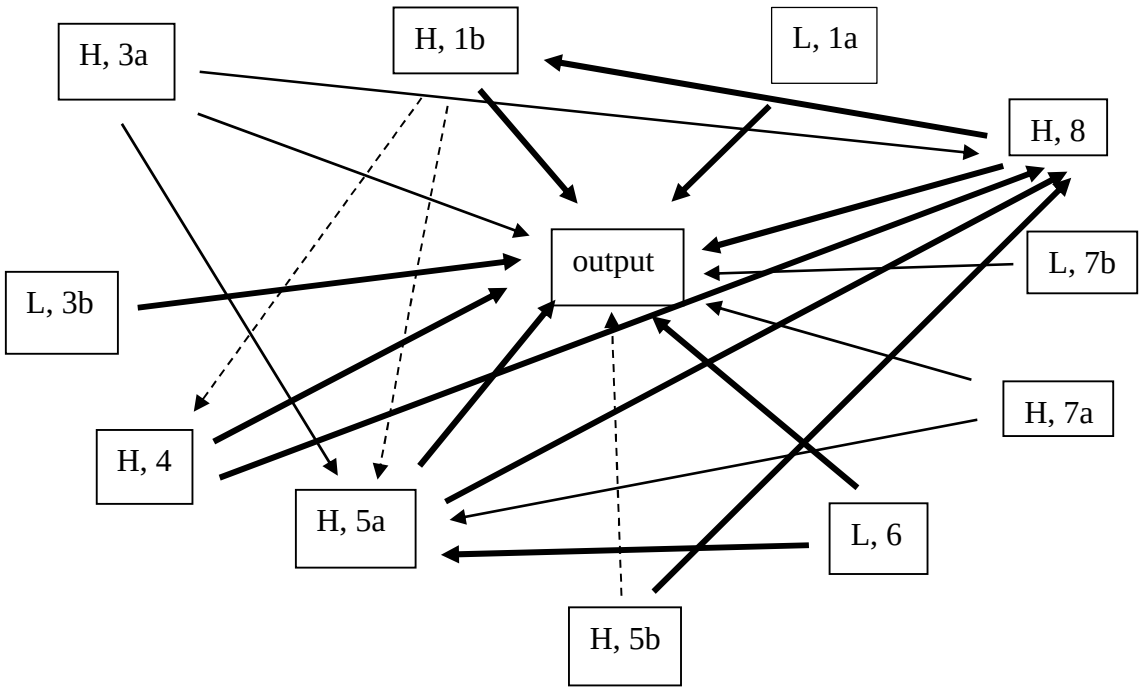

Figure 4 The peat bog relationships

The numbers are the variables, and the capital letters represent their manipulability with H the highest. The thickest lines represent the strongest relationships. The diagram can be developed as a focus for the stakeholders to shape the problem. The variables with the highest manipulability and strongest impact on output are 1b, 4, 5a and 8. They are respectively rotavating, internal transfer, stockpiling and labour, with an increase in labour necessary to increase the other variables. Having lines of variable thickness and indicating the manipulability of the variables, in the diagram, can be a valuable feature in identifying an action plan. The socio-technical systems approach has much in common with soft OR although here it was not deployed to resolve a wicked problem, but to provide a speedy solution. The work was published in JORS (Dyson, 1983) and was awarded the Pergamon prize by the OR Society for a best applied paper. However I did not pursue this line of work at the time, and it made no impact on the academic community with hardly any citations.

Strategic Planning/Strategy Support

I returned to the study of strategic planning systems and with the help of a research grant was able to appoint John Foster as a research fellow.

A particular concern was the concept of an effective strategic planning system. One approach to evaluating effectiveness is by setting goals in the future and seeing to what extent they are achieved. This approach has obvious drawbacks. There may be a tendency to set modest goals which are easily achievable, or there may be unforeseen or unforeseeable change in the environment making the achievement of the goals impossible. This approach was therefore rejected in favour of the concept of an effective process (Dyson and Foster, 1980). The following attributes of an effective planning process were proposed:

(a) Integration of the planning function.

(b) Catalytic action of the planning function.

(c) Richness of formulation (of plans).

(d) Breadth of evaluation.

(e) Treatment of uncertainty in evaluation.

(f) Resources planned.

(g) Data used.

(h) Iteration in the process.

(i) Assumptions.

(j) Quantification of goals.

(k) Control measures (responsiveness to uncertainty).

(1) Feasibility of implementation (testing of shortlisted strategies).

Associated with each attribute was a seven-point scale of effectiveness, with a score of 1 indicating poor effectiveness and 7 the highest. For example in the formulation of plans/strategic options a simple projection from the current state would score 1, whilst a rich search for possible strategic options would score 7. The framework was applied in a study of the planning systems of ten organisations spanning the public and private sectors (Dyson and Foster, 1983) and an investigation was carried out into whether there was any link between effectiveness and the extent of participation by stakeholders in the planning processes (Dyson and Foster, 1982).

I also had a collaboration with Rolfe Tomlinson which resulted in a joint paper on systems aspects of strategic planning (Tomlinson and Dyson, 1983) and we developed a course initially entitled ‘Analytical Aids to Strategic Planning’, which the students referred to as Aids. When the disease came, the title was changed to OR for

Strategic Planning. The course covered hard and soft methods including risk analysis, corporate system modelling, SWOT analysis (strengths, weaknesses, opportunities and threats), scenario planning and models of behaviour.

Data Envelopment Analysis (DEA)

In the mid-eighties Rolfe passed me the seminal article by Charnes, Cooper and Rhodes (1978) to evaluate. (I had spent eight months at the University of Texas at Austin in 1982 at Bill Cooper's invitation, but we never discussed DEA). Ross Tristem, the Deputy Director of the UK Audit Commission and a Warwick PhD graduate approached me at about the same time. The Commission's remit was to identify good practice in local authorities and spread it across the system. There were views in the local authority community as to which were the best performers. Ross wanted to also use an evidence driven approach to identifying best practice and wondered if DEA could provide an answer. I thought that that was certainly worth exploring. My colleague Emanuel Thanassoulis agreed to join me on the project and my ex-colleague John Foster was spending a year at the Audit Commission and was able to contribute and in particular to mine the data.

DEA is a non-parametric approach to identify a best practice, efficient, frontier for a set of homogeneous entities such as bank branches, schools or primary care practices which exhibit multiple inputs and outputs. The DEA model for an individual target unit's efficiency is:

Max efficiency = weighted sum of outputs / weighted sum of inputs

Subject to the efficiency of each unit ≤ 1

The variables are the weights on the inputs and outputs, there is one constraint for each unit in the set with the efficiency of any unit being limited to not exceed 1. The objective function allows the model to seek the weights for the target unit that will maximize its efficiency which will be 1 if the target unit is on the best practice frontier. The model is solved for each unit and provides their most favourable weights. This freedom of flexibility of the weights recognises that units may value inputs or outputs differently. The model is solved for each unit in turn. The model is a fractional linear program which can be easily transformed into an LP. A system with two outputs and a single common input can be illustrated as follows (figure 5):

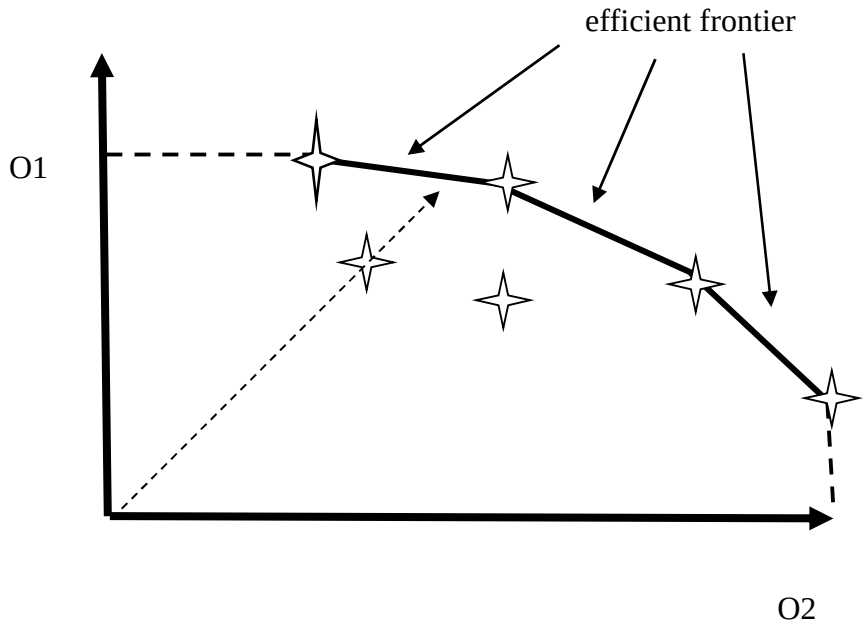

Figure 5 A DEA illustration

O1 represents one output e.g. academic achievement in schools and O2 represents achievement in say performing arts. The stars represent the units (schools) and four are on the best practice frontier and have an efficiency of 1. The top performing school on output 1 sees its mission as placing most of its pupils at the leading universities with little attention paid to non-academic subjects. The school with the highest measure on O2 may be say the Liverpool Institute School of Performing Arts. Both have an efficiency of 1 although they have very different profiles due to their different missions. The efficient frontier envelopes the inefficient units. Their distance from the frontier is a measure of their inefficiency and the projection to the frontier indicates targets to attain efficiency. The approach was applied to data on the rates departments of local authorities (Thanassoulis et al, 1987). There was a concern that Liverpool was shown to be efficient which surprised the Audit Commission. It turned out that Liverpool was efficient because all the weight had been attached to one output – the number of recalcitrant householders with the other outputs consequently being ignored in the evaluation. A similar situation had been noticed in an early article on Texas schools where all the weight had been attached to self-esteem, one of the outputs, and none to academic achievement. As a result of the total weight flexibility, units could ignore some inputs and outputs in their evaluation even though all the inputs and outputs were deemed to be important at the system level. The model was modified by introducing weights restrictions (Dyson and Thanassoulis, 1988) to give more realistic evaluations. The paper had a major impact on the development of DEA, illustrating the power of engagement with practice. Emanuel and I went on to build a strong team researching various aspects of DEA during the 1990s. Aziz Boussofianie joined us on a research contract working on perinatal care (Boussofiane et al,1991).

The Nineteen Nineties

Towards the end of the eighties the OR for Strategic Planning course was rather limping along as Rolfe retired and my primary focus was on Pro Vice-Chancellor duties. However, in the nineties Frances O'Brien and Maureen Meadows joined Warwick, later to be joined by Martin Kunc, and for many years we taught variations of the course to undergraduates, masters and MBA students. The course was supported by a book of papers which I edited (1990) and later in the decade by a second book edited by myself and Frances (1998). The course was enriched by invited speakers including John Friend on strategic choice and John Hough on his Rolls Royce experiences. An account of the evolution of the course is in O'Brien et al (2011).

My research focus in the nineties and into the 2000s was DEA and Emanuel and I built a strong team of researchers. Victor Podinovski, Estelle Shale, Andreas Athanasoppoulos, Mette Asmild and Jim Storbeck joined the staff and Ana Camanho, Claudia Sarrico, Ali Emrouznejad, Rachel Allen, Laura Reid, Carla Amado, Nikolaos Maniadakis and Joe Coughlan were research students. The research involved engagement with many organisations including schools (Sarrico et al, 1997), banks (Camanho and Dyson, 1999, Coughlan et al, 2010), primary care (Amado and Dyson, 2009) and perinatal care (Thanassoulis et al, 1995). Topics explored weight flexibility (Allen et al, 1997), efficiency discrimination (Podinovski and Thanassoulis, 2007), alternative perspectives (Sarrico and Dyson, 2000), and Malmquist indices (Camanho and Dyson, 2006). In a discussion between a group of us we had noticed many instances in the literature where DEA had been applied incorrectly or the models were flawed. We decided to write up our concerns and their resolution. Instead of attributing errors to specific authors we decided to write a paper where we outlined our concerns and their resolution in a paper entitled Pitfalls and Protocols in DEA (Dyson et al, 2001) which became very highly cited. I recall that about this time there was a count of DEA publications and conference presentations carried out which ranked Warwick first or second internationally. Again the success of the programme of research illustrates the importance of engagement with practice.

Professional Membership

In the 1960s there was a failed attempt to introduce a Register of Practitioners and a group of members left the Society to set up the Fellowship of OR. The topic of professional membership remained controversial throughout the following decades. In the 1990s a proposal was brought forward for a scheme of professional membership which the Society members in government thought was necessary for OR to be competitive alongside the other professions, particularly economics. The proposal was again controversial and in the vote it received majority support but it did not pass the higher threshold necessary for it to be adopted. I became President of the Society shortly afterwards and decided that the matter should be revisited as there was considerable interest amongst the society's members. I was conscious of the concerns over defining OR and that a scheme might be elitist. In consultation with colleagues at the Society I outlined a scheme for the category of Fellow of the Operational Research Society (FORS) which all members of the Society could aspire to attaining. (I sent drafts of the scheme to Jonathan Rosenhead and others who had been strongly opposed to the earlier schemes.) There were also Associate Fellow (AFORS) and Associate (AORS) categories and later Valerie Belton introduced a Candidate category which students could join as a first step on the ladder.

The criterion to become a Fellow was: **a significant record of achievement in academia or practice extending over ten years or more in OR.** Additionally academics must have engaged in practice through projects, consultancy or joint work, and practitioners must have placed some of their work in the public domain through for example publication, conference or special interest group presentations. In the early days many of the academics had worked as practitioners and many practitioners had published. Indeed in the early editions of the Society's journal, as there were no academic OR people, all the papers were written by practitioners.

In a vote of the membership, by which time Mike Pidd was President, the proposal gained majority support, exceeded the 75% threshold, and was adopted by the Society. The Fellowship of OR closed down and the members asked to be transferred to the Fellow category. However the criteria of the two schemes were different so an automatic transfer did not occur but I was confident that they would meet the Society's criteria. Perhaps removing the controversy over professional membership from the agenda was at least as important as establishing the scheme. The scheme lost some

momentum as the first version of the online application system adopted was poor and many members abandoned their application in frustration.

The Twenty Zeros

In the 2000s work was continuing on DEA although my interests were focussed more on strategy support/strategic planning. I also wrote a paper for a special issue of JORS linking strategy, performance measurement and OR (Dyson, 2000). In 2006 I was appointed an editor of the European Journal of Operational Research and this was to be a significant activity over the next fourteen years.

Strategic Planning/Strategy Support

From 1999-2005 I was appointed to a second term as a Pro-Vice Chancellor. There were many discussions about the future direction of the University and I agreed to facilitate a strategy workshop with the University Steering Committee whose membership was the Vice-Chancellor, the three Pro Vice-Chancellors, the Chairs of the Faculties, The Registrar, the Deputy Registrar, the Finance Officer, the Secretary and Assistant Secretary to the Committee and the President of the Students' Union. I adopted a SWOT analysis approach followed by a vote on the strategic options generated. In the workshop I was conscious that there were some strong personalities, so to ensure everyone contributed I adopted a system of asking each person in turn to suggest a factor (e.g. strength) and continued the process until the list was exhausted. We then paired internal and external factors to stimulate ideas for strategic options, several of which were subsequently adopted (Dyson, 2004).

Howard Thomas, the Dean of the Business School, also wished to have a series of similar workshops focussing on internationalisation. Alberto Franco was researching into facilitation and we proceeded with Alberto facilitating with a computer-based problem structuring approach combining SWOT analysis with decision explorer (Eden and Ackerman, 2004). The workshops contributed to the development of the Business School and one specific outcome was the establishment of an International Business degree, building on the existing joint degrees with the language departments, which France O'Brien directed for many years.

Maureen Meadows and I supervised two PhD students, one focussing on strategic project management (Asrilhant et al, 2007) and one on strategic development and performance measurement (Tapinos et al, 2005).

A group met regularly at Warwick holding workshops on strategic development. The Warwick staff included Frances, Maureen, Alberto and Giles Hindle, and also Jim Bryant and John Morecroft who had visiting appointments. A focus of the workshops was the development of a model of the strategic development process which was to form the framework for an edited book (O'Brien and Dyson eds.2007). In addition to the group members, authors included Bob Berry, Adrian Caldart, Nigel Howard, Martin Kunc, Abhijit Mandal, Gilberto Montibeller, Martin Murtland, Fernando Oliveira and Stathis Tapinos. The range of hard and soft topics included: visioning, drama theory, problem structuring, resource- based view, SWOT analysis, system dynamics, scenarios, decision and risk analysis and performance measurement. I particularly liked a chapter by myself and Fernando (2007) comparing decision trees, robustness analysis and real options which have interesting common elements, but hardly anyone has read it.

The European Journal of Operational Research (EJOR)

EJOR is sometimes seen as a rival to JORS, the Society's journal, but it is the journal of the Association of European of Operational Research Societies of which the OR Society is a member. EJOR has always operated with the editors making independent decisions and I joined in 2006 as an additional fourth editor. By the time I stood down there were six editors due to the large number of submissions (c3,500 per annum). This large number is due to EJOR covering all OR, Management Science and Decision Analysis topics including soft OR, interfaces with other disciplines and innovative applications and has authors from business schools, economics, engineering, mathematics, and computer science. It is the largest journal in its field with two issues per month and has a developmental approach, but nevertheless scores highly on quality impact factors. One of the editors, myself, followed by Mike Yearworth, covered the softer topics of OR including problem structuring, behavioural OR and community OR (along with other

topics) and with JORS is one of only two journals in the field that regularly accept soft OR topics.

The Twenty Tens

I continued EJOR editing throughout the decade and became interested in the early years of OR due to being introduced by Graham Rand to a book on the founders of OR which was launched at the Informs Annual Conference, Charlotte in 2011 which I attended.

The book, edited by Assad and Gass (2011) profiled the 43 founders of operations research listed below (figure 6). Initially the editors aimed for 50 profiles but obtained only 43. The founders were mainly American, with six Europeans, and they were all male. The founders were mainly hard OR or mathematical modellers but on a first reading of the book I became conscious of many connections between most of the founders and soft OR characteristics although there is a view, particularly in the U.S.A that soft OR is not a legitimate branch of OR due to its lack of mathematical modelling (Mingers 2011). Frances O'Brien and I then undertook a rigorous analysis of the profiles to uncover the links to soft OR (Dyson O'Brien and Shah, 2021).

The characteristics of soft OR were defined as:

Context (wicked problems)

- An ill-defined problem situation
- The existence of multiple actors or stakeholders with different perspectives and conflicting objectives
- A high degree of uncertainty, intangibles, qualitative and limited quantitative data

Process

- Engagement with and interactions between stakeholders to seek agreement on the nature of the problem, learning and on actions. This may involve the use of facilitated workshops (real or virtual)

- Concern for process issues /procedural rationality

Content

- The use of models as a focus for the discussions which are transparent and understandable. These are typically diagrammatic models such as causal maps, cognitive maps, influence diagrams, decision graphs and rich pictures.

The problem structuring methods designed to enact soft OR include (Rosenhead, 1989):

- Strategic Options Development and Analysis (SODA), with its technical content of cognitive mapping

- Soft Systems Methodology (SSM)

- Strategic Choice, including the Analysis of Interconnected Decision Areas (AIDA)

- Robustness Analysis

- Metagame Analysis

- Hypergame Analysis

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Russell L Ackoff	C West Churchman	Ellis A Johnson	Howard Raiffa
E Leonard Arnoff	William W Cooper	Leonid Vital'evicj Kantorovicj	Patrick Rivett
Egon Balas	George Dantzig	George F Kimball	Bernard Roy
Martin Beale	Jay Wright Forrester	George Kozmetsky	Thomas L Saaty
Stafford Beer	D Ray Fulkerson	Harold W Kuhn	Herbert A Simon
Richard E Bellman	Saul I Gass	John DC Little	Jacinto Steinhardt
Patrick Blackett	Murray Aaron Geisler	John F Magee	Albert W Tucker
Alfred Blumenstein	Ralph E Gomory	Harry Markowitz	Stephen Vajda
Seth Bonder	Charles Frederick Goodeve	Hugh Jordan Miser	Andrew Vazsonyi
Abraham Charnes	David Bendel Hertz	Phillip Morse	Philip Starr Wolfe
	Ronald A Howard	John von Neumann	Harvey M Wagner

Figure 6 The 43 Founders

A number of the founders were direct influencers of soft OR. In their early work: Eden (SODA) cites Ackoff, Beer, Saaty, Forrester and Simon; Friend (strategic choice) cites Ackoff; Beer, Howard and Raiffa; Checkland (SSM) cites Ackoff, Beer and Churchman; Bennett/Bryant (metagames) cite von Neumann and Rosenhead cites Ackoff. These founders are at the softer end of OR and indeed Churchman and Ackoff left the OR community because of its dominance by mathematics. It was found that a larger number of founders often seen as mathematical modellers also exhibited soft OR characteristics. For example: Bellman (dynamic programming) was concerned with applications with qualitative features; Gass (LP) recognised the involvement of multiple stakeholders with multiple objectives; Little (queuing) recognised the place for different stakeholders in the decision process; Gomory (integer programming) recognised the multiple stakeholders concerned with international trade and their conflicting objectives and Vazsonyi (mathematics of inventory and production control) used his GOZINTO (input/output) diagrams showing a pictorial representation of materials requirements to communicate with key stakeholders.

It was also observed that the Founders and indeed the soft OR pioneers were all engaged in practice leading to the development of many techniques and to new processes. For example Dantzig's work at the Pentagon, which focused on the allocation of air force resources, led to his interest in linear programming and the development of the simplex method, Forrester's interest in large fluctuations in production, inventories, employment, and profit at GE led to the development of system dynamics modelling and Hertz worked as a consultant in the 1950s and 1960s, and his experience led him to develop the field of risk analysis.

The conclusions from the paper were: Soft OR pioneers were influenced by a subset of the founders; a wider group of founders, often characterised as 'hard' modellers, aligned with many of the soft OR characteristics of context, process and content; thus there is strong evidence from the work of the founders of OR (and from definitions of OR) that soft OR is a legitimate subset of OR; the emergence of mixed soft and hard modelling indicates that hard models can have an important decision support role in resolving wicked problems and the proponents of soft OR and the founders were all heavily engaged in practice leading to key modelling and process developments. Although the Informs journals Management Science and Operations Research were reluctant to publish soft OR papers, the paper was published in Operations Research.

Twenty Twenties

Editing of EJOR continued although wound down. I stopped receiving new articles at the end of 2020 but continued to handle the many papers in the system with the final paper being accepted in the summer of 2023. The Founders paper was published in the journal Operations Research and I gave the Beale lecture to the OR society.

Reflections and Conclusions

Algorithms as in the hard modelling at Pilkington's can be effective problem-solving tools, but aspects of problem structuring including the systematic involvement of stakeholders and the use of diagrammatic models can enhance the process and lead to better formulation and implementation. The work on strategic planning/strategy support emphasised the importance of process as in soft OR. Socio-technical systems analysis advocates qualitatively assessing the strength of relationships and the manipulability of variables. When using model maps with stakeholders, including lines of variable thickness to indicate the strength of relationships, and indicating the degree of

manipulability of the variables can facilitate the development of action plans. The use of qualitative models only can lead to speedy solutions where that is appropriate as on the peat bog. Published articles, like reports as Florence Nightingale observed, are not self-executive. Networking and publicising research is essential in reaching the appropriate community. The Warwick DEA team had been particularly effective and also exemplified the benefits of the mix of academic research and engagement with practice. In the days of electronic searching, perhaps having punchy titles as in the pitfalls DEA paper can be helpful also in publicising research. A study of the founders uncovered strong links between them and soft OR supporting the view that soft OR is a legitimate subset of OR. It also highlighted the importance of engagement with practice for the development of OR. Although it was initially claimed that hard OR could not solve wicked problems, the domain of soft OR, the emergence of mixed hard and soft modelling shows that hard OR does have a role to play there.

Finally, there is a debate about the benefits and dangers of artificial intelligence (AI) i.e. carrying out tasks by a machine that could have required human intelligence. Our methods and algorithms are designed to improve on human performance, either supporting or replacing humans so fall within the definition of AI. In the sixties when I first engaged with computing there was a common and apt slogan 'rubbish in, rubbish out'. That applies equally or perhaps more so to some of the current AI systems. With our principles of validation, transparency and stakeholder engagement the OR community should have much to offer to that debate.

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