Pedagogical Strategies the Teaching of OR/MS: Framing as a Meta-Framework

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Abstract

The early development of OR/MS was characterised by the deliberate use of multi-disciplinary project teams, whose composite strengths, creativity and problem-solving abilities were enhanced by the complementarity of the different approaches and perspectives that were brought to bear on a problem.

Throughout the eighties and nineties, the notions of framing, and framing methodology, have gained credence, increasing use and acceptance, particularly in the analysis of organisational structures and organisational effectiveness; and more generally, as an aid to problem identification and problem structuring that values and encourages the development of multiple problem representations and multiple perspectives.

This paper illustrates how framing can be used as a meta-framework, firstly, to guide the design of problem structuring and modelling activities in OR/MS courses that embrace alternative approaches; secondly, to legitimise and integrate the multiple perspectives that arise from the use of multiple problem representations, and, thirdly, to encourage and guide deeper thought about the appropriate role for, and choice of sensitivity analysis.

1 Introduction

1.1 Pedagogy

'Pedagogical advances follow naturally epistemological and methodological advances - and perhaps, premature pedagogical expressions are as natural. We are ever-learning and there is a compulsion to communicate to others that which we learn.' [37]

Simon, Dantzig et al [35] have stated that 'the OR/MS community has, as its common mission, the development of tools and procedures to improve problem solving and decision making'. Indeed, we may reflect that this view has pervaded the academic community since the introduction of OR/MS to management education in the early/mid sixties.

However, we may also reflect that our OR/MS education programmes have provided, in the main, a 'traditional' hard-systems emphasis on technical analytical skill and the generation of optimal solutions, rather than the development of 'softer' problem identification and problem structuring skills. The hard systems approach deals with how to solve the problem; the soft systems approach seeks to ask what the problem is. It was

as if, as Daellenbach [4] contends, our educators assumed that problems had been or could be readily identified, and/or such problems would be amenable to our familiar hard-systems analytical approaches.

Such assumptions do not fit comfortably with Ackoff's view [1] that 'managers do not solve problems in well-ordered mathematical worlds as much as manage messes' which have to be understood. Such assumptions have been similarly critiqued by Grinyer [18],who has stated that whilst effective operational researchers have long recognised the use of models as a means of assisting managers to reframe their understanding of the world, the typical frames-in-use have been mathematical in structure and content, with a prime purpose of specifying a 'best' solution to the problem as 'captured' in its mathematical form, regardless, oftentimes of the ill-match between model and reality, or of the uncertainty surrounding the problem. Fortunately, such assumptions are less likely to be typical of mid-nineties educational practice, given the many initiatives gaining momentum as operational researchers and management scientists review their effective contribution to undergraduate and graduate management courses [3].

Recent focus on aspects of pedagogy, especially as they relate to the teaching of OR/MS / decision making, and especially as they relate to the phenomenom of post-experience management students, have been most evident in recent major conferences. Whole streams have been devoted to aspects of innovative education, teaching and learning, addressing amongst other things, experiential and collaborative learning, making learning fun through role-play, and the use of information and allied interactive computing techologies. See, for example, the work of Savage [34], McKenna [26], Elder [12], Powell [31], Sniedovich [36] at IFORS, DSI, EUOR-InfOR/MS etc

Elsewhere, Horner [20], reporting a discussion with Bell, has specifically referred to the need for teaching via case studies, whilst Bell [4], has asserted that the way a business school positions itself helps determine not only the content and pedagogy for its programmes, but also for its courses. The implications for OR/MS courses and pedagogy, he suggests, are that they must evolve away from being theoretical, content oriented and analysis driven, towards being practical, skills oriented and decision driven, or be considered irrelevant, a view previously expressed by Olaffson and Hannibalsson [28], and more recently by Goldratt [17]. In a similar fashion, Gass [16], whilst commenting on the educational requirements of MBA students, has suggested that their need is to be given the opportunity to build an appreciation of OR/MS, not to be trained as analysts - for the analysts will be working for them.

Many pedagogical developments that have taken place seem to manifest themselves first in the development of teaching aids. Examples range from the use of spreadsheets ([21], [34], [31], [32], [12], [8]) to facilitate learning and understanding in specific situations, to the development of comprehensive teaching and learning packages, for example, Mentor [5]. Several authors have commented directly or indirectly on the pedagogical / computational trade-offs arising from the use of spreadsheets. Plane [29] has confronted the question of how we should use spreadsheets in the teaching and learning of OR/MS - whether we should teach OR/MS by providing spreadsheet models to address common situations, in typical black box fashion, or whether we teach students how to construct, or be constructive with spreadsheet models. Powell has answered the question indirectly, by complementing the pedagogical style of Savage who as a teacher conveys the power of spreadsheets as being a platform for intellectual exploration, not restricted to analyical problem solving. Clauss [9] has similarly suggested that the

essence of good OR/MS teaching relates to students exploring and understanding ‘what to do with solutions after obtaining them’, and understanding whether to change conditions for which ‘a bad solution is optimal’! Of course, these issues are even more relevant for the increasing numbers of MBA/management students who are exposed to OR/MS in our courses, and exposed to spreadsheets in their work.

The suggestion is that OR/MS educators should recognise that whilst they have a role to play in helping future users learn the appropriate applications of spreadsheet tools, that they should also recognise the ‘languaging’ role that spreadsheets implicitly play amongst managers, even to the extent that a manager may often develop a model within a spreadsheet without even acknowledging it [29]. It may not, then, be surprising that the intuitive use of spreadsheet models can tend to be more for evaluative and discussive purposes rather than for the prescriptive purpose of say, optimisation. In other words, managers need to know more about how to evaluate and use ‘solutions’ than how to obtain them, and about how to capture an appropriate representation of the problem if the intent is for any resulting ‘optimal solutions’ to be meaningful.

Given the need to manage Ackoff’s messes which have to be understood, the authors agree with Grinyer [18] and Bryant [7] that the 'quality of discourse' engendered by 'model-building' may often be more important than any direct application or specific solution proposed. Indeed, if we accept the notion of a 'model-as-convention', rather than as a description of reality, then we can accept models as providing the context 'which directs discourses in particular paths' or 'as providing a way of talking about something in a manner that is understandable and useful' [13], that is, as communication vehicles.

In particular, the authors espouse the view of Thomas [38] that we can/should help managers 'less in the form of the provision of technical, algorithmic knowledge which will enable managers to read off solutions to their problems, as … more … in the form of sensitising frameworks - ways of seeing and thinking which alert the manager to alternative ways of understanding and hence managing'.

If we believe that 'how people construct their world and account for what they do in it necessarily influences how they behave {39], then providing a framework (indeed multiple frames) that encourage the construction of multiple perspectives should, hopefully, provide the insights and understanding that lead to better understanding and more 'enlightened' choice in situations of complexity. Whether or not we can demonstrate that the use of multiple frames and the development of multiple perspectives lead to more effective decision making outcomes is, however, problematic [11].

1.2 Frames, Framing and Metaphors

Much of the work undertaken on the framing of organisational problems and situations has been linked to the use of metaphor. The work of Pondy [30], Morgan [27] et alia, has given much impetus to the use of metaphor in examining organisations, organisational activity and management. Morgan claims that our understanding of organisation(s) is based on the 'unwitting' use of metaphor that pervades our life, impacting on our ways of seeing and thinking, on how we 'see' and 'think'. The use of metaphor is based on the premise that insight into organisations, the unfamiliar and complex, can accrue by thinking about them as though they were something else, ie the familiar and simple [6].

However, the authors take the view whilst it is not necessary to seek metaphorical matches to organisational or problem situations, nor necessary to find appropriate analogies, there is considerable value in exposing student managers/analysts

to a variety of frames or metaphors in a directed way [14] as a means of drawing out creativity and creatively exploring problem situations.

Flood and Jackson's three phase Total Systems Intervention methodology [15] provides an another example of an attempt to facilitate creative thinking about a problem situation, and about problem structuring, through the use of metaphors; and through the identification and recognition of dominant and dependent metaphors to determine an appropriate intervention methodology or methodologies.

The purpose of using framing, therefore, is to free the analyst/manager from the implicit or hidden assumptions that s/he may be constrained by, and to surface new insights about the problem situation, and how to tackle it.

1.3 Relevance to OR/MS Practice

As OR/MS practitioners, we are well trained in framing problems as mathematical models, capturing the essence of problems in mathematical form to enable investigation of, analysis of, and to ultimately improve the understanding of the system under investigation. The modelling process underpinning such framing is a reflection of problem solving and decision making as a rational process. The process involves activities ranging across different 'logical' levels, for example, identifying appropriate objectives and criteria at the higher levels, generating and evaluating action options, and choosing and implementing the preferred or best options at lower levels.

Usually, there is, at least implicitly, recognition, even intention, to regard the process as an iterative process; and that once one has identified an initial solution, that the 'problem' will be revisited in each of the process stages.

In practice, there is always the temptation to refine, expand and develop 'models', with a focus on lower logical levels, ie ever increasing detailed structure, addition of modules, detailed evaluation etc. However, such attempts to refine structure are often limited by the context within which the problem has been framed. The process of sensitivity analysis, for example, often focuses on changing some content factors [2], but otherwise, leaving the basic form of the model, the nature of the constraints and the objectives unaltered.

It is much less usual, much harder and more courageous, to revisit the initial assumptions concerning higher level objectives and criteria, as they may ultimately involve abandoning much of the existing model/frame, and starting from scratch. The authors have argued [22] that often, more expansive, creative options may be generated by re-examining these higher levels components of the problem solving process. It is our contention that effective OR/MS practitioners already do this; but that much practice, which is regarded as failure, could be attributed to the restricted framing of such higher level issues.

1.4 Framing as a Problem Structuring Aid

The authors' use of framing and reframing can be seen as an attempt to demonstrate the extent to which context and the nature of the frame can play a part in the surfacing and identification of problem features, as well as the generation of action options.

The authors propose a process which recognises and makes explicit the frame-in-use; which promotes acceptance of the use of multiple frames and the deliberate change of frame - perhaps to provoke the decision maker to consider other possible interpretations of the problem, its objectives, prevailing criteria, existing value judgements etc, and to widen the possibilities from which the decision maker can ultimately choose. The major aim of modelling and models is insight not numbers. The

process of multiple framing and reframing provides another means for improving insight.

This paper provides a case example to illustrate the deliberate use of multiple framing and reframing in order to encourage the investigation of problem structure. The authors hope that the use of framing outlined here, will provide a motivation and means for OR/MS practitioners to incorporate framing within their teaching.

In a previous paper [23], we showed the power of 'metaphor' framing and reframing as a problem-solving and decision-making tool, and the versatility of the approach. The successful outcomes of the framing exercises confirm findings from elsewhere [19] that suggest that the wide range of experiences that mature graduate students bring to their studies can be better exploited in an experiential learning environment. The frames reported in that paper showed both the creativity of students, and the value of the reframing exercise to them and their organisations. Consequently, the authors have been encouraged to extend the use of framing as a pedagogical device.

2 Illustrative Example

The Goulds Fine Food Case Study [24]

This section will examine a case study, developing multiple perspectives about the case situation through the creation and use of alternative frames. The case study material was gathered in typical ways through conversation, formal interviews, briefings, tours, observation, from documentation and reports, with ongoing interaction between the case-writers and others knowledgeable of the case setting. Some of the material gathered could be verified at source; some was anecdotal, with a reliance on local or intimate experience of the case situation. Some information was incomplete; some was missing - perhaps, a typical business case.

The case study material can be delivered to the student in different ways, but, most often, the material is delivered, presented, re-presented, or framed as - narrative. The student is then expected through 'analysis' to gain insights by re-working and re-presenting (again) the case material in different ways, that is, in different frames. It is as if the reframing is limited to being the outcome of prior analysis within the frame-in-use. The authors contend that this process implicitly creates unnecessary hierarchies of parent/daughter frames, undermining the value and/or potential use of the seemingly dependent frames.

In the following sections, the case study material is presented or framed in several ways - as narrative, as a table, as a flow chart, as a spreadsheet model, as a set of equations, as matrices and as a graph. The case study is one of a kind that typically requires attention be given to resource allocation/product mix issues. It is intended to demonstrate the insights and uses that emerge from the 'filling' of the frame, and the use of the frame.

2.1 The Frame as Narrative

Goulds Fine Foods is a medium-sized, Wellington-based company manufacturing and selling bacon, ham, smallgoods and other convenience food products. It had experienced significant growth in the previous two year period, resulting in the construction of a new plant in Petone (the old one had come to the end of its useful life). The machinery however was relatively old and was being replaced as the

cash position of the firm allowed, with priority being given to areas of the operation experiencing the most growth in volume. The case focuses on the production of manufacturing hams (used in commercial products and sandwiches) and pre-cooked sausages. The following extracts describe the production process and demand environment.

> "The ingredients for the two products (manufacturing hams and pre-cooked sausages) are mixed separately, using their own dedicated mixing facilities, but both use the same filling operation. The products are then cooked after filling, taking some 4 hours for the hams, and around one hour per batch of sausages. Each cooker is 2 cubic metres in volume which can take a maximum of 500 kg of product, so hams are cooked in half batches. It is normal practice to cook 350kg of sausage (1 batch) at a time. There are 4 cookers available. After cooking, the batches need to be chilled, prior to pack and despatch. Hams take 10 hours to chill, while sausages take only 2 hours. The chillers are quite large, and can handle any quantity made. The packing line has 4 people usually, each working a 40 hour week. The main time involved on pack and despatch is for sausages, as they need shrink-packaging in small packs for retail sale, while hams are sold in the plastic packs they have been cooked in. Both products require packing in outer cartons, and despatch documentation. Each packer can repack approximately 50 kgs of sausages per hour, so that it takes 7 person-hours to pack and despatch a 350kg batch of sausages. However packers are happy to do overtime or work Saturdays if needed. The two separate mixing processes are able to mix a 1000kg batch of ham mix in 5 hours, while sausages take 30 minutes to prepare. Filling takes place at a rate of 125 kg per hour for hams, and 1 hour per batch of sausages.
>
> "The current weekly demand for hams is in the vicinity of 8 batches per week, though that varies by up to 35%. Likewise sausage demand equates to roughly 20 batches per week, plus or minus 100%. The profit margin on a batch of hams is roughly 6 times that of a batch of sausages."

For teaching purposes, the case posed the possibility of whether or not Goulds should purchase more filling and cooking capacity. Management had estimated that this equipment might give perhaps 50% more capacity than presently available. Given that the demand is certainly more than they could meet at their levels of production at the time, it appeared the extra equipment would be worthwhile.

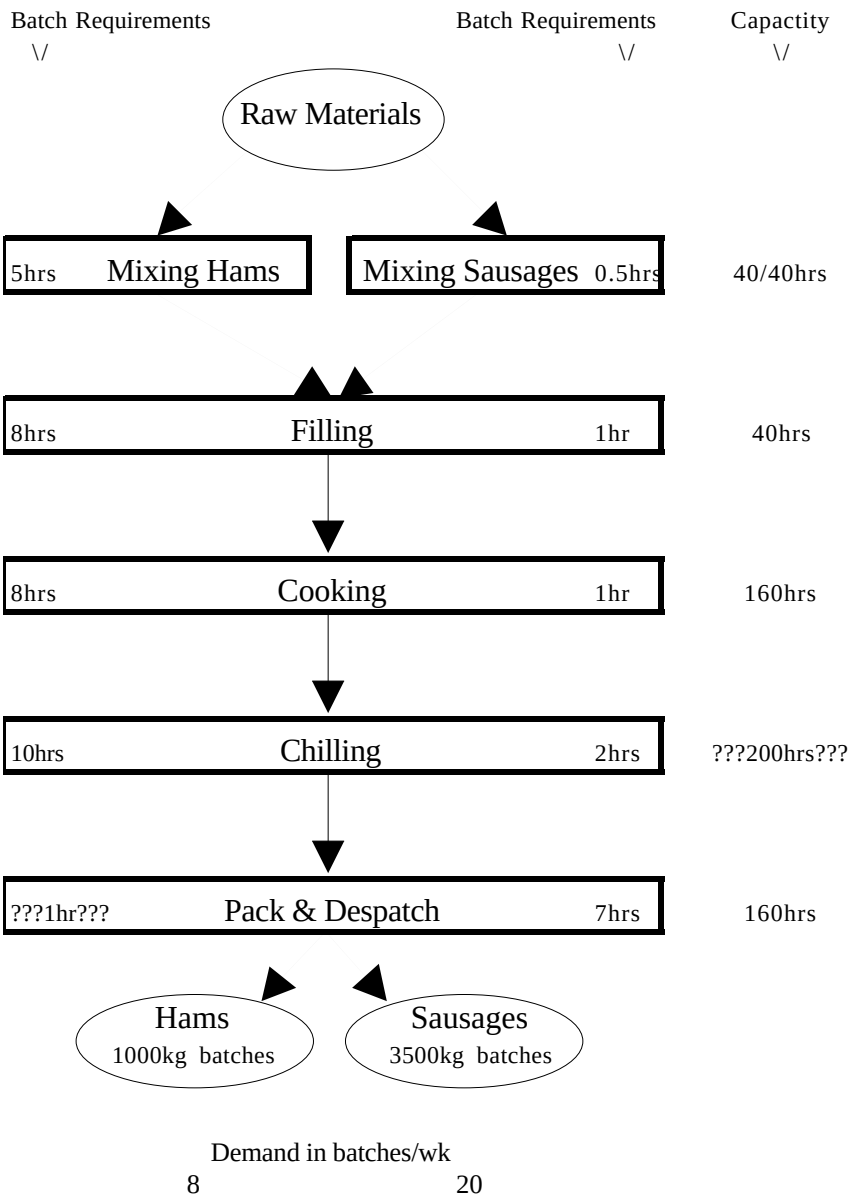
The narrative sometimes poses artificial problems for students, some deliberate, some not so deliberate. In this case, students may not note as readily from the narrative as they would from 'live' data gathering, that the chilling capacity is not stated explicitly - but it would be an issue that they would be expected to confront at some time. For this particular case, de facto chilling capacity is much in excess of potential requirements, and can be set at any arbitrarily large level for the purpose of analysis (here, we set it to 200 hours of available use). Similarly, the narrative is vague about the exact time it takes to pack hams, so the student will be expected to make an educated guess, and then to be vigilant about the effect that her guess might have on analytical outcomes (here, we set the time to pack a batch of ham to be 1hr). For further background to the case, see Mabin(1994).

At this stage, it needs to be stated that as far as most students are concerned, the frames that are displayed in the following sections will have seemed to emerge from the narrative, and will appear to be dependent on the narrative, supported, of course, by some possible subsequent questioning of the case teacher. The authors argue that that such notions of 'frame dependency' are inappropriate, and may lead to students shying

away from the use of frames that could be effectively employed early in the intital problem structuring phase of an investigation.

2.1 The Frame as a Flow Chart

The use of flow charts to describe work flow and process is routine. However, it is easy to lead our students into the trap of thinking that the flow chart is used to summarise the narrative, and represent aspects of the case narrative - when we know that, in practice, the consultant/analyst will seeking to frame immediately as a flow chart, what s/he has observed, what s/he has heard etc about say, a manufacturing process. A flow chart, or some other related schematic representation, is likely to be the first frame used by practitioners.



Frame 3: Process Times, Demands and Capacities

Framing the manufacturing process as a flow chart facilitates understanding of the sequencing logic. The flow chart frame reduces the cognitive load involved by acting as an information filter, highlighting the absence of data, yet allowing for appropriate

annotation. It becomes immediately obvious when the practitioner attempts to fill this frame what information is missing, what extra information needs to be gathered etc.

Filling the frame is part of the problem structuring process. However, this frame is recognised as being incomplete; it may not convey the richness of the picture painted by the narrative, but it does compensate by providing a more structured platform for further analysis - of an intuitive or formal nature. For the more numerate analyst, information is now 'in sight' that leads quickly to a realisation that meeting average demand is not possible, given a lack of capacity on the Ham Mixing and Filling machines.

2.3 The Frame as a Tableau

The building of tables or tableaux are also routine for OR/MS practitioners. For many practitioners, the development of a process flow chart would accompany the placing of data within a table frame, as part of the problem structuring process. However, experience suggests that many students will regard the table frame as just an outcome of 'analysing' the narrative, or as just a stage post in some extended analytical activity. Of course, the table frame, below, does summarise the narrative, but the practitioner working in the field will often use a table to frame her initial investigation, and to provide partial, but deliberate perspectives on the problem. It is important therefore, that educators generate the live case work that provides students with the opportunity (or even requires them) to use, in a deliberate fashion, a variety of frames that are valuable in the process of problem structuring. However, if as Clauss (1997) implies, the advocacy of so called 'simple' tools is often 'beneath the dignity of our profession and text books', and OR/MS educators choose not to convey the value of such framing, then our graduating students will continue to be unaware of what effective practitioners do when confronted with new situations.

	Process times (hrs/batch)		**Total Process Time** (hrs/wk)
	Hams	Sausages	**Available**
Mixing (Ham)	5.0	0.0	40
Mixing (Saus)	0.0	0.5	40
Filling	8.0	1.0	40
Cooking	8.0	1.0	160
Chilling	10.0	2.0	???200???
Pack & Despatch	???1.0???	7.0	160
Average Demand (batches/wk)	8	20	

Frame 3: Process Times, Demands and Capacities

Framing the manufacturing process as a table provides similar insights to the flow chart frame, and reduces the case material to an even more parsimonious form. Missing information is readily spotted, a recognition that the table frame is incomplete. The table frame conveys less information than the flow chart frame presented, but its focus is the capture and representation of the numerical data. It provides another example of a frame structured to generate insights from further analysis. Again, it is

readily seen that meeting average demand is not possible given the capacities of the Ham Mixing and Filling machines.

2.4 The Frame as a Linear Model

The use of a mathematical frame to build an understanding of the problem situation parallels the use of a table frame, but requires the analyst to be more precise in the way in which the logic of relationships, and quantitative information is represented.

Let **number of Hams batches** be **H** Let **number of Sausage batches** be **S**

Then, find the values of H and S

that will maximise profit, calculated as

$$6.0\,H + 1.0\,S \qquad \text{Profit}$$

subject to various production constraints and demand patterns

5.0 H		≤	40	Mixing Machine - Ham
	0.5 S	≤	40	Mixing Machine - Ham
8.0 H +	1.0 S	≤	40	Filling Capacity
8.0 H +	1.0 S	≤	160	Cooking Capacity
10.0 H +	2.0 S	≤	200	Chilling Capacity
1.0 H +	7.0 S	≤	160	Pack & Despatch
1.0 H		≤	8	Ham Demand
	1.0 S	<=	20	Sausage Demand

Frame 4: The Linear Model

In this case, use of the mathematical frame seeks to determine how we assess resources are used, how profits are generated, and what restrictions are placed on resource use. Importantly, it requires us to consider whether production absorbs resources at a uniform rate or not, whether profit accumulate at a uniform rate or not. The mathematical frame, in requiring more precision, also requires the analyst to surface assumptions early in the problem structuring phase. More importantly, filling this frame requires the analyst to determines what the objectives of the problem owner might be. Objectives, too, must be framed.

The mathematical frame, then, requires implicit objectives to be surfaced, and assumptions made explicit and queried. The frame has additional value in that it provides us with a basis for further analysis and experimentation. We can use the mathematical relationships to test ideas and compute the consequences, or we can invoke our traditional analyical processes to identify optimal choices, provided our assumptions, for example about linearity, have been validated.

2.5 The Frame as a Spreadsheet

It would be reasonable to state that most OR/MS practitioners who employ tabling frames as problem structuring devices would likely use the electronic analogue of a spreadsheet to extend the structuring to capture the relationships that exist between variables. It is becoming even more common practice for problem structuring to be attempted and initiated directly within a spreadsheet frame. Although for many analysts, the use of a pencil and paper table frame precedes the development of a spreadsheet

model, the use of a spreadsheet frame mirrors the use of a table frame, rather than being dependent upon it.

In this case, the use of the spreadsheet frame requires one to understand and specify the relationship between action choices on production levels, the use and availability of resources, and profitability. Of course, in filling the frame, we become aware of missing data issues, just as with the previous frames. However, the spreadsheet frame provides a greater capability for analysis and experimentation - providing instant feedback on feasibility and value of alternative decisions. Such decisions are not solely restricted to experiments with the product mix, but can extend to consideration of efficiency improvements in processing, changes to processing capacity, and changes to profit margins. In LP terms, we are capable of going beyond seeking an optimal solution to our current problem, or conducting the standard sensitivity analysis, although of course, we could be informed by them [25].

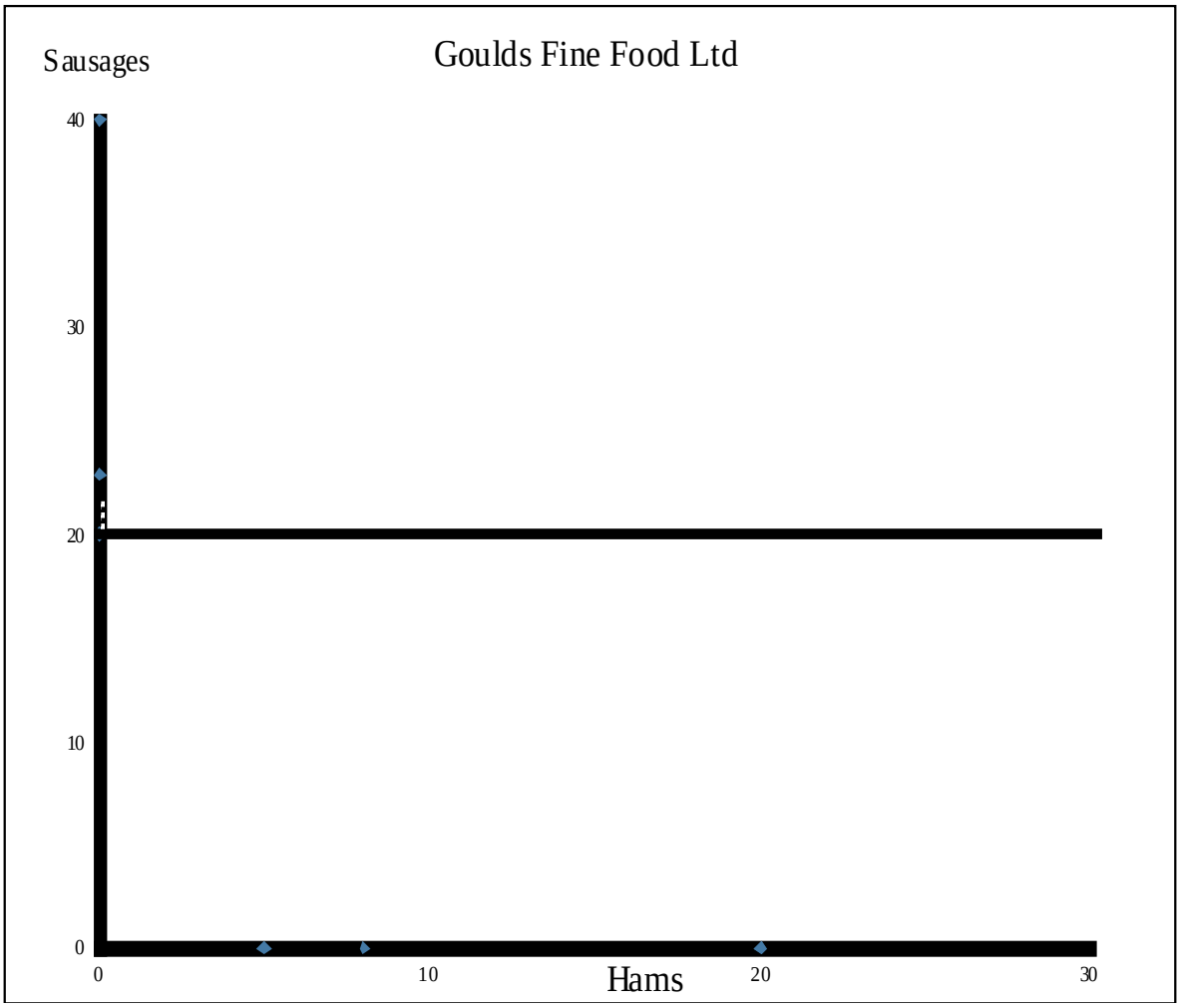
	A	B	C	D	E	F
1	**Spreadsheet Model of Goulds' Production Problem**					
2			**Hams**	**Sausage**		
3	**Decision Variables:**	**No. Produced**	8.0	20.0		
4	**Constraints:**				**Required**	**Available**
5	**Production**	Mixing (Ham)	5.0	0.0	40.0	40.0
6		Mixing (Saus)	0.0	0.5	10.0	40.0
7		Filling	8.0	1.0	84.0	40.0
8		Cooking	8.0	1.0	84.0	160.0
9		Chilling	10.0	2.0	120.0	200.0
10		Pack & Despatch	1.0	7.0	148.0	160.0
11					**Sold**	**Demand**
12	**Demands**	Hams/wk			8.0	8.0
13		Sausage/wk			20.0	20.0
14					**Total**	
15	**Objective function:**	**Profit**	6.0	1.0	68.0	

Frame 5: Spreadsheet Model

2.5 The Frame as a Graph

Many see the graphical model as an alternative representation of, and being based on the linear mathematical model. Indeed, attempting to use a graphical frame to build an understanding of problem structure requires the analyst to confront the same issues of how resources are used, how profits are generated, whether there are economies of scale or whether linearity exits, and whether and what restrictions are placed on resource use. A benefit of the graphical frame is indeed how it captures and portrays the restrictions and constraints.

Major insights, often quickly gained from the graphical frame, relate to the relative influence of various so called constraints and restrictions on choice. The frame above illustrates, quite surprisingly for some student/managers, that only one capacity constraint, that of the Filling machine, is limiting choice; and that there is seemingly excess capacity on other machines, limited only by an inability to raise demand for sausages. Profitability, therefore, is constrained by lack of demand more than it is constrained by lack of capacity in the individual manufacturing processes.


Goulds Fine Food Ltd
Sausages
40
30
20
10
0
0
10
20
30
Hams

how we use them, and how we can extend their use from the analytical to problem identification and problem structuring domain. It would be worthwhile for OR/MS educators to consider the development of an integrative meta-framework that integrates other modelling approaches with framing to provide appropriate guidance students in the development of problem identification and problem structuring skills.

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