DESIGN THINKING – CROSSING DISCIPLINARY BORDERS

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Introduction

Design is known to be an interdisciplinary field, and design activities and outcomes are developed in conjunction with (as well as used in) many other disciplines, including management, marketing and entertainment. Moving the concept of design beyond the design discipline itself creates exciting new challenges and opportunities, not only for the various other disciplines involved, but also for design education. The idea for this paper was incubated in a post-graduate classroom environment during an interdisciplinary design elective.[1] Within the current academic environment, it is not strange to have students from diverse disciplines such as management, theology, engineering and publishing studying the same subject matter (and sitting in the same class). This paper therefore finds it fitting to explore conceptually the potential of design thinking in the (seemingly) unrelated discipline of Operations Research/Management Science (OR/MS).[2]

The discipline of OR/MS is first introduced and this is followed by a brief outline of some of the current problems in this well-established discipline. This section highlights these problems as being, amongst others, the increasingly complex management environment that OR/MS has to operate in; as well as the dichotomy between theory and practice in the discipline. This is followed by a description of the characteristics of design thinking, and then by a conceptual exploration of design thinking as a solution to some of the problems that have been identified in OR/MS. The paper concludes with a discussion of the implication for design education.

OR/MS: at the brink of a new era

OR/MS is an applied science that uses quantitative methods and models to analyse and solve real life management problems. It was first used to develop quantitative models to help improve efficiency in military operations during World War II, and was then adopted by an increasing number of public and private organisations. OR/MS became especially popular amongst people who had to manage processes because it usually improved efficiency and because it became accepted as a scientific paradigm. The three decades from 1940 – 1970 are considered the 'golden age' of OR/MS, and during that time the discipline became a legitimate subject for education and academic discourse. The classical OR/MS problem solving approach is illustrated in Figure 1.

In the period between 1970 and 2000, the relevance of OR/MS started to be questioned. What was especially questioned was whether OR/MS could still be a useful tool to solve real life problems. This became known as the 'crisis' in OR/MS.[3] Some practitioners

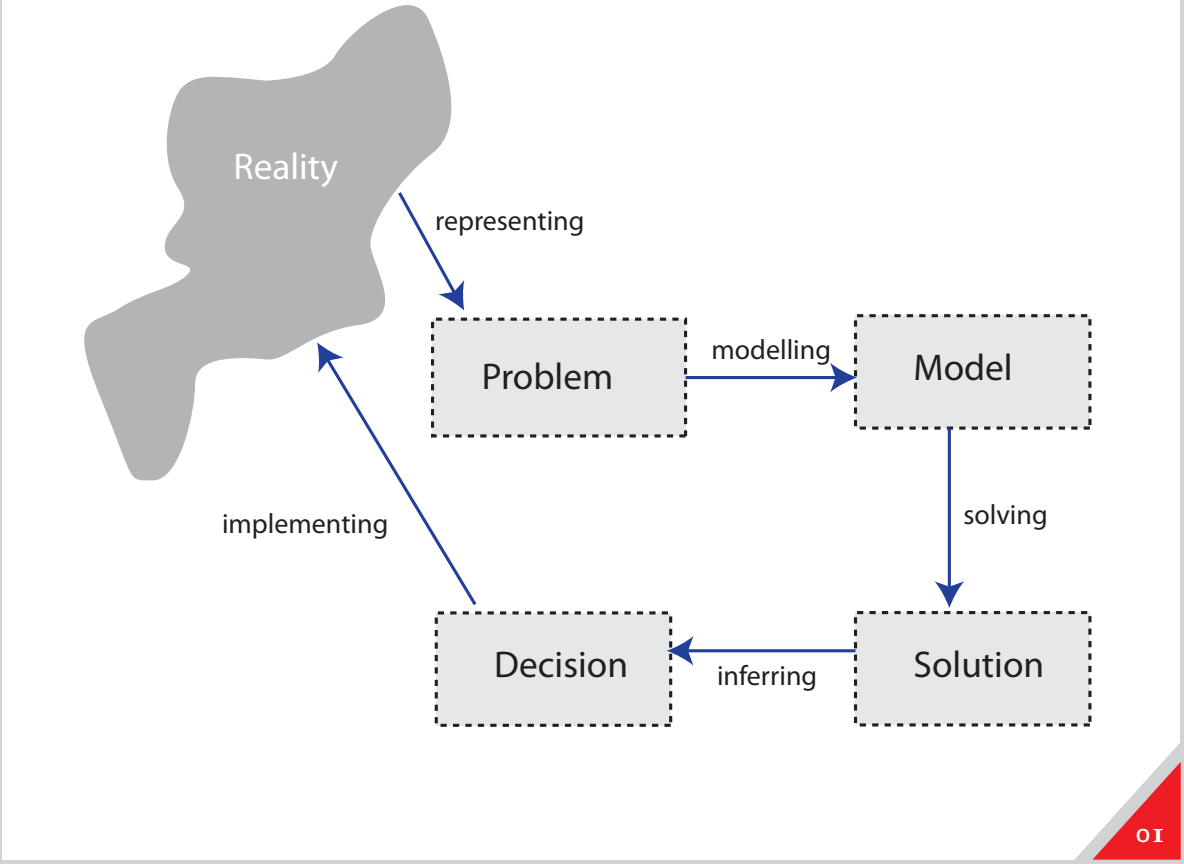

Figure 1: Illustration of the OR/MS problem solving approach [Adapted from Rardin (1998)]

saw the incessant debate surrounding the 'crisis' as counter-productive navel gazing. As the topic's popularity fizzled out in the last decade, the series of publications petered out. It is tempting to conclude that the issues that first sparked the discourse have also faded into irrelevance, however, current discourse in the international OR community (and especially the South African OR community) shows this is not true. Even though OR has evolved, subsequently addressing and remedying some of the issues, niggling remnants exist.[4]

Today, the demand for relevant, effective and timeous solutions to imminent problems is increasing, offering great opportunities for OR to contribute to industry and society. However, to capitalise fully on these opportunities the discipline needs to address what remains of the issues that once threatened to sink a discipline.

A brief context may assist in understanding the so-called 'crisis'. Charles Corbett and Luk Van Wassenhove (1993:627-628) explain that there are three different activities in OR/MS, namely Management Science, Management Engineering and Management Consulting. Management Science is the process of developing new theoretical quantitative tools. Management Consulting, found on the other end of the spectrum, is the process of implementing already well-developed OR/MS tools. Management Engineering is a process

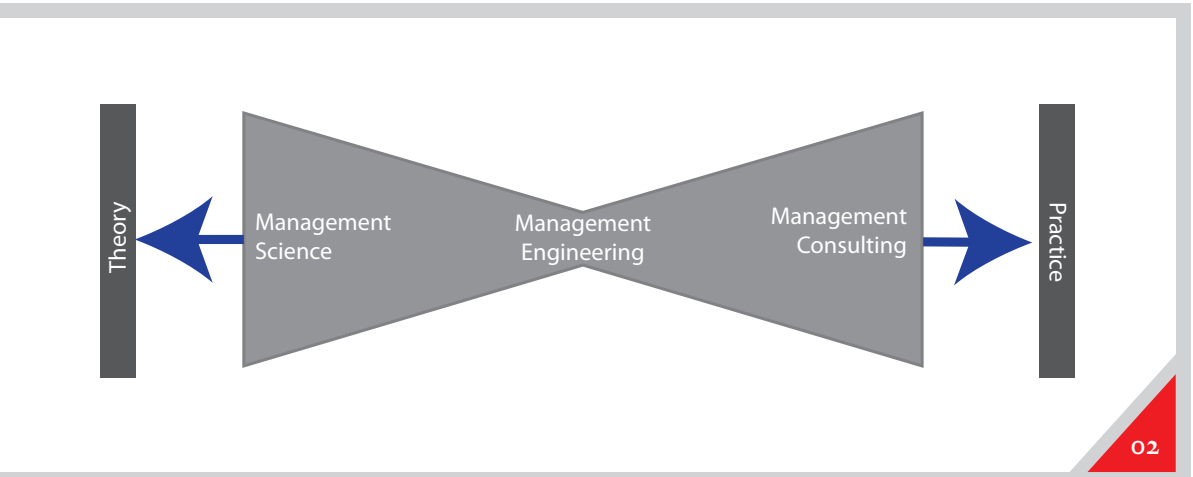

Figure 2: Perceived inconsistency amongst the development of the three domains of OR/MS as described by Corbett and Van Wassenhove (1993:628).

that bridges the gap between the two areas, adapting existing tools or using them in innovative ways to solve real life problems. This is where the problem arose – practical application did not correspond with theory. Russel Ackoff (1979:95) went so far as to call this loss with reality a 'mathematical masturbation'. (This is particularly evident in the history of American OR society and to date American OR is deemed more 'mathematical' while European and British OR are more 'practical'.) This perceived inconsistency amongst the development of the three domains is illustrated in Figure 2.

Corbett and Van Wassenhove (1993) define five problem areas that needed attention if OR/MS was to once more become a valuable and relevant discipline that would be able to provide practical and useful tools with which to solve real life problems. Although efforts were made to redress these issues, current discourse in the OR community confirms that they are still evident – even if to a lesser extent. A sixth problem area defined by Maurice Kirby (2007) will be added to the five points in this paper, and these six points are briefly discussed in the next section.

Tool-orientation vs problem-orientation

OR/MS was initially used to develop tools to optimise the efficiency of operations, and the tools that were developed formed the foundation for the discipline. Later, practitioners were accused of maintaining an overly analytical focus while problems were becoming increasingly complex. Pierre Hansen, an American operations researcher, highlighted the problem when he called it an obsession with tools and ignorance of management needs (in Kirby 2007:2). This problem area is possibly the one area that the OR community has had the most success in redressing – at least within industry, but the tool-orientation still persists in classrooms and academia.

Client relations in OR/MS

Client relations in OR/MS have specific shortcomings, according to Corbett and Van Wassenhoven (1993:631). The first shortcoming is a communication barrier between managers and operations researchers. One of the reasons for this barrier is a lack of common terminology. Management practitioners use the loose terminology of business, and operations researchers use very precise scientific terminology. Secondly, the OR/MS discipline is not visible enough for managers. Lastly,

the value that OR/MS can add to any problem solving (or efficiency improvement) process is not made clear to the client. This last aspect is not as simple as it seems, as the value that OR/MS adds is deeply embedded in the entire problem solving exercise.

The learning effect of an OR/MS study

In practice the purpose of an OR/MS study is to help management understand the complex problems they face by determining the factors that should form the main focus for decision-making. Hans Ittman (2009:sp), an accomplished practitioner and manager of OR teams, comments that the emphasis in OR is structuring complex problems, or 'messes', using a scientific approach. According to him, the emphasis is on addressing (and not necessarily solving) the problem in a way that can bring insight to the decision makers. This is a learning process for management, but this has not received much attention in OR/MS literature. According to Corbett and Van Wassenhove (1993:633), the discipline requires research into how managers can learn from the studies produced by OR/MS.

The relevance of OR/MS at a strategic level

Although OR/MS is more known for its successes in supporting tactical and operational decisions, many authors, (cited by Corbett and Van Wassenhove 1993:634) are of the opinion that OR/MS can be an invaluable strategic decision-making tool if applied correctly. Ittman (2009:sp) supports this view, pointing out that the development of various problem structuring methods such as 'Soft OR' enables practitioners to address complex problems on a more strategic level. He agrees that more should be done to make industry aware of the capabilities in this regard and believes that being more public about one's successes is the most convincing way to do this. Furthermore, the holistic systems approach necessary to develop solutions that address the 'bigger picture' does not come easily to inexperienced practitioners not yet versed in the complexity of application.

The interdisciplinary nature of OR/MS

Operations Research originated from an interdisciplinary platform, uniting scientists from many fields. The dominant paradigm of OR/MS is situated in the mathematical sciences because OR/MS uses actual mathematical models and quantitative logic to perform its task. This limits the field considerably, by excluding input from social and management sciences. William Pierskalla (President of the OR Society of America 1982 – 1983) states in his article *Creating Growth in OR/MS* (1987:155): 'If we are to grow, we must reach out to new areas of knowledge and to new approaches, and integrate them into our field'. The need for this interdisciplinarity is becoming more apparent in the South African OR community as practitioners experience difficulties in approaching problems pertaining to poverty alleviation, policy making and social development.[5]

Complexity of problems in management

Hansen points out that evolving management needs resulted in problems too complex to be solved using existing OR/MS tools (in Kirby 2007:2). New methodologies and techniques have since been developed to address complexity, but scientific thinking is still the point of departure.

OR/MS is in essence a positivist approach that provides quantitative objective realities, prediction and control free of subjective bias. The opposite method is a qualitative, naturalistic approach that allows for multiple realities and different viewpoints. Although there is certainly a place for a quantified approach, frustrations experienced in the OR community suggest that a deliberate inclusion of non-scientific approaches might result in solutions that are considerably more

relevant and accessible. The next section explores concepts and approaches of design thinking as remedies to some of the problems identified in the previous section.

The nature of design thinking

Design is defined by Herbert Simon (1996:112) as the process by which we '[devise] courses of action aimed at changing existing situations into preferred ones'. Design is an iterative human activity, directed at a specific outcome or solution to daily problems that arise (or challenges that need to be overcome). This human activity is based on a thinking process, with 'thinking' and 'doing' working in synthesis towards a solution. Charles Owen, distinguished Professor Emeritus at the Illinois Institute of Technology (IIT) in Chicago, explores the nature of design thinking and its application in several seminal publications (Owen 2006; Owen 2007). Owen views design thinking as complementary, and not antagonistic, to scientific thinking. Design thinking is seen as the invention of 'new patterns and concepts to address facts and possibilities', whereas scientific thinking is illustrated as the sifting of 'facts to discover patterns and insights' (Owen 2007:17).

Some similarities in design and OR exist. Both are concerned with solutions for real life problems, although OR/MS is not always involved in the physical execution of the final solution. Solutions in OR/MS, as in design, have to be strategic and creative, not only tactical or operational. Owen (2007:17) proposes that there are two types of applied creativity – 'finding' and 'making'. 'Finders' work analytically and practise professions that are more scientific, whereas 'makers' demonstrate creativity through invention and gravitate towards fields such as art, engineering and architecture. He illustrates this concept by means of a two-domain model (see Figure 3).

Science is generally regarded as analytic in its use of process, and is symbolic and abstract in nature. Design, on the other hand, is synthetic and real in nature. It must be pointed out that in science some areas overlap into the synthetic domain, and that design also has an analytical part. Owen (2007:17) explains that these two domains can complement each other, although they are the obverse of each other.

Several other authors in design and other literature have written about design thinking. Tim Brown of IDEO describes design thinking in the *Harvard Business Review* (2008:86) as 'a methodology that imbues the full spectrum of innovation activities with a human-centred design ethos'. Brown believes that innovation is powered by a thorough understanding and direct observation of human needs.

Michael Beverland and Francis Farrelly (2007:10) also state the business case for design thinking, and describe this as an embedded corporate culture that is cultivated in companies known for innovation and market leadership. There are a great number of companies successfully implementing design thinking approaches, of which Apple, GE, Proctor & Gamble, Fisher & Paykel, National Australia Bank (NAB) and Maytag are but a few (Beverland &Farrelly 2007:11-16).

Characteristics of design thinkers and design thinking

Various characteristics of design thinkers and design thinking are provided in the growing body of literature on this topic. It is clear from the previous section that design thinking is in the domain of 'makers', and

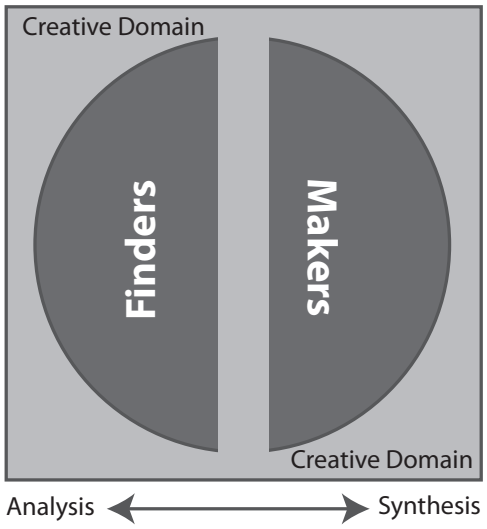

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Figure 3: Two-domain creativity model. [Adapted from Owen (2007)]

is a human process predominantly based on synthesis (and not analysis). A brief overview is provided before applying design thinking concepts to OR/MS.

Human-centred in focus/empathy

Design is client and user directed. Designers imagine the world from multiple viewpoints and imagine appropriate solutions for these viewpoints (Brown 2008: 87). Design solutions are also adaptive to the evolving needs of its users (Owen 2006:4). Beverland and Farrelly (2007:13-14) see designers as constant ethnographers, continuously observing the broader environment.

Ability to visualise and communicate

Visualisation is one of the most important areas of design and design thinking. It is the ability to communicate visually, to reveal, and to make clear that what did not exist before, that makes someone a good designer. In the words of Owen (2006:4), '[v]isual language is used diagrammatically to abstract concepts, to reveal and explain patterns, and simplify complex phenomena to their fundamental essences'.

Optimism

Both Brown (2006:87) and Owen (2006:4) mention optimism as a characteristic of design thinkers. Optimism is seen as the ability to believe that at least one 'potential solution is better than the existing alternatives' (Brown 2008:87).

Integrative thinking and a systemic vision

Design thinking is holistic and is based on integrative thinking. This means that designers see the big picture and develop holistic solutions that are inclusive of people, environments and technology. Designers can also work systematically with qualitative information – also called structured planning (Owen 2006:5). Owen (2006:5) describes this process as a

method of finding information and gaining insights from it, and then organising it optimally for conceptualisation and eventually using the new insights gained to execute the solution.

Generalist in nature

Generalist in nature has the ability to collaborate and an affinity for teamwork. Designers can reach across disciplines to communicate efficiently (Owen 2006:4). Owen (2006:4) also states that a wider reach of knowledge leads to inspiration that is more creative. Designers cannot work in isolation design clients become involved in the design process and therefore good interpersonal skills are an integral part of a designer's tool set.

Experimentalism and conditioned inventiveness

According to Brown (2008:87), design thinkers often develop ideas in entirely new directions, instead of focusing on merely implementing small incremental 'tweaks'; they are more interested in the 'what' questions than the 'why' questions. The 'what' questions direct design activity to a design outcome.

Self-governing practicality

Owen (2006:6) recognises that few other disciplines have the same freedom to dream, but points out that designers have the ability to govern 'flights of fantasy with a latent sense of the practical'. Designers therefore have the potential to match creativity with a realistic understanding of costs and functionality.

Design thinking concepts applied to OR/MS[6]

Several of the problem areas identified in OR/MS by Corbett and Van Wassenhove (1993) and Kirby (2007) can be addressed using design thinking methods and approaches. In the next section, these possibilities are explored conceptually.

Engaging reality from a user/human perspective

The first step in the OR/MS problem-solving approach (Figure 1) takes real life factors and converts them into quantifiable variables. These variables are arranged in such a way that the problem can then be represented as a quantifiable problem. Enough (and relevant) information is required to do this and typical quantitative methods such as interviews, questionnaires, and work, time and motion studies are used to gather the necessary information. Data mining and statistical analysis are used to advance knowledge of the situation when studying business processes and interactions between components of a problem. These techniques should enable the Operations Researcher to understand the reality fully. Nevertheless, in a post-positivistic world many different realities exist with many different viewpoints. Quantitative techniques are limited when it comes to understanding this plural reality, and mathematical equations produced by textbook-trained researchers frequently prove to be inadequate.

The complexity of contemporary problems is one of the factors contributing to the crisis in OR/MS. One way designers deal with complex environments is through constantly observing and interpreting the environment. Designers are natural ethnographers, using ethnographic methods not only for studying a culture but also with the specific aim of developing a solution that will change the culture that is being studied. Using design ethnography as part of the initial problem formulation process could benefit the Operations Researcher by developing a deeper un-

derstanding of the relevant reality/ies. This could also ensure that the *right* problems are understood (Viljoen & Van Zyl 2009:195-196).

Graham Button (2000:328-330), principal scientist at the Xerox Research Center Europe (Cambridge Laboratory), uses an example of a production print shop to highlight what he believes to be the difference between descriptive fieldwork and ethnography that explores the 'how', 'why' and 'what' people do. Fieldwork-based studies reveal that production is enabled by the interactive effort of a number of people. Their efficiency is monitored (the time that they have spent working, for example) using objects such as production lists, scheduling boards and work tickets. Fieldwork would describe how these objects are used, and can be used to formulate a system that could improve the efficiency of the production print shop. Button (2000:329) comments on this approach: '… fieldwork that only describes what relevant persons do may well be missing out on the constitutive practices of how they do what they do, the "interactional what" of their complexes of action'. What one would be missing, is that the primary purpose of the scheduling board is not to manipulate data or calculate start and finish times. Instead, it exists so that personnel can get a picture of what is happening on the production floor with one glance. If a machine were to break, one look at the scheduling board can immediately suggest a number of different possibilities to solve the problem. This small insight could have a monumental effect on the development of a system for the print shop, the solution being much more effective than a mere automation of calculations.

Beverland and Farrely (2007:14) explain that designers are constantly seeking new inspiration from their wider environment and this makes them sensitive to changes in what the client needs, and therefore they are adaptive in their solution approach. Cultivating a culture of ongoing ethnography would ensure that there is a link between the solution being developed, and the reality/ies. Changes often occur during OR/MS projects and these changes result in a product-need mismatch (because of the rigidity of the OR/MS process) that could have been avoided if the researcher were alert to changes and constantly seeking out opportunities for innovation (Viljoen & Van Zyl 2009:195-196).

Maybe the most important design thinking characteristic that the operations researcher should have is the ability to have a human-centred approach to problem solving, as seen in design. Design is not only client directed, but also always has the consumer or user in mind. Human needs should be the driving force for developing solutions, and not the preoccupation with the tool as often identified in OR/MS literature (Kirby 2007:2; Corbett & Van Wassenhove 1993:630).

Figure 4 illustrates the changes in the approach when OR/MS becomes more integrative, with an awareness of the need for a constant solution-orientated focus. The barrier between tool and solution, or OR/MS options and management realities, can be overcome by an integrative and iterative process where multiple realities are constantly considered, while the end goal is always in mind – in other words, a human-centred solution. It must be mentioned that the idea is not to discard well established OR/MS theories and tools, but to complement them with design thinking.

Friendly OR/MS

Another problem area identified in OR/MS is the communication barrier between OR/MS practitioners and management (Figure 4). Corbett and Van Wassenhove

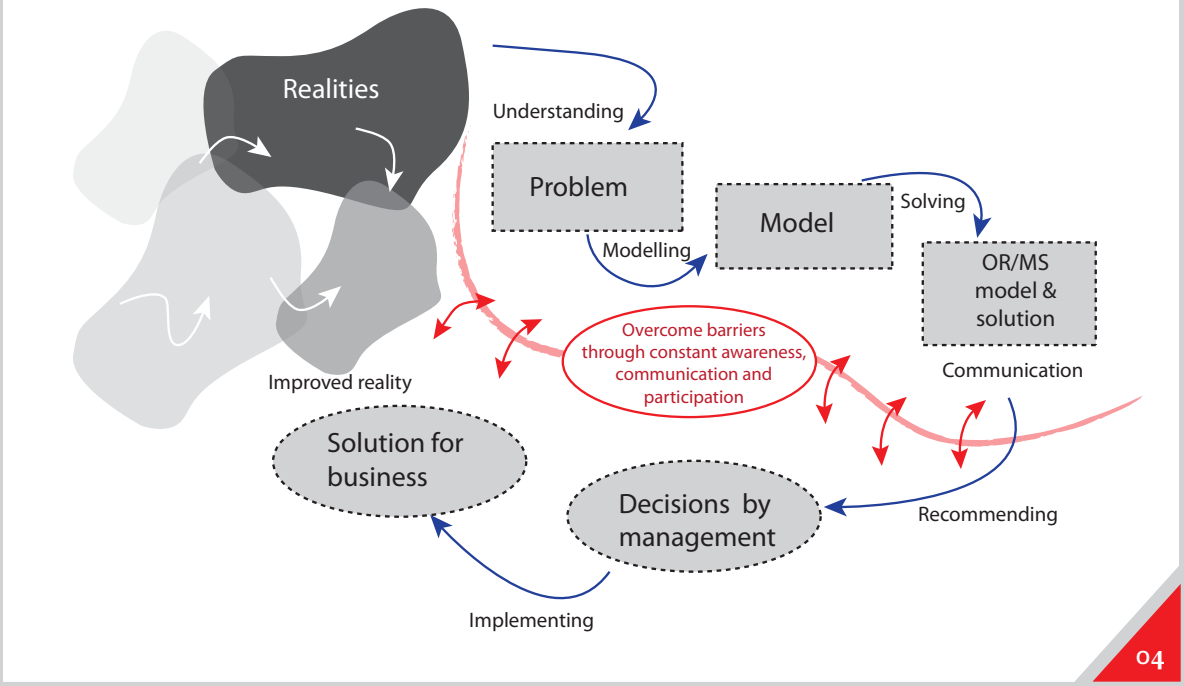

Figure 4: Visualisation of the 'new' OR/MS process [by Van Zyl en Viljoen]

(1993:626) examine this by studying articles related to the subject that have been published in the *Harvard Business Review* over the last six decades. One reason for the barrier between OR/MS practitioners and management, according to Corbett and Van Wassenhove (1993:631-632), arises when the link between the business problem and the mathematical technique becomes vague and specialised jargon or terminology creeps in. This communication barrier results in a negative perception of OR/MS, and consequently very little research is published in business journals about OR/MS. This is especially unfortunate, as Ittman (2009:sp) underlines the importance of compelling OR success stories in creating awareness of the discipline's potential value.

Design, on the other hand, is a personalised heterogeneous process, building strongly on the relationship between designer and client. Margaret Bruce and Catherine Docherty (1993:406) cite Dawes' research of clients' reasons for choosing management consultants. According to them, the three most important criteria for contracting consultants are the reputation of the consultancy, its reputation within its specialist area, and personally knowing the consultant who would work on the project. Personality is also listed as the most common criterion considered when choosing a design consultancy. Designers immerse themselves in a problem so that they do not just understand the problem on an abstracted intellectual level, but also on a deeply intuitive level. This aids designers when challenged with new and varied design problems, which means that in the process they constantly have to cross barriers between clients and other participants. It is designers who immerse themselves in the client's situation, and not the other way around (Viljoen & Van Zyl 2009:sp).

One of the other potentially useful characteristics of

design thinking for OR/MS is empathy; this refers to the ability to observe reality from multiple viewpoints. Empathy can in turn lead to imagined solutions for these multiple viewpoints (Brown 2008:87). It becomes clear when comparing Figures 2 and 4 that the process moves away from being linear, with a logically structured singular viewpoint, but starts with multiple realities that need to be improved. These realities encompass different viewpoints. Management, for example, might have a completely different viewpoint than that of staff.

The perceived bad external reputation of OR/MS is also reflected in internal dialogue. Questions are asked about the value proposition offered by OR/MS and its products. It is the brand or perceptions of OR/MS that has come into question. Beverland and Farrelly (2007:15) quote Michael Smythe who states that '[a]n organization is known by the way it manifests itself through its products and services, its visual communications and its operational environment'. Finding one brand to unify the entire discipline of OR/MS is impossible owing to its varied nature, but the question of brand is critical and must be asked wherever OR/MS is practised, but more importantly wherever OR/MS is taught (Viljoen & VanZyl 2009:sp).

During a panel discussion at the annual ORSSA conference[7] regarding the future direction of OR in South Africa, panellists sought ways to define and communicate the *brand* of OR. Panellists believed effective marketing is essential not only to attract prospective clients but also to source new talent from a national pool of high school graduates that would otherwise be oblivious to the existence of the discipline.

Visual thinking and communication

The third area for discussion is the necessity of an increased focus on visual thinking as part of the OR/MS process. OR/MS presents the client with possible options based on quantified scenarios and models. Very little participation between the client and the operations researcher takes place during the development of these models, with OR/MS practitioners working on a need to know basis. Important variables are therefore often overlooked or not understood from the viewpoints of others. The lack of a common language is one of the fundamental causes for the barrier between the OR/MS practitioner and participants from other disciplines or business clients. For example, when both take part in the development of OR/MS solutions, many of the OR/MS tools are beyond comprehension for the other participants. This is particularly relevant in South Africa, where many new managers still suffer from the disadvantage of a sub-standard educational system caused by apartheid, where maths and science where sidelined (or not taught at a high enough standard). South Africa is also challenged with a multicultural and multilingual society, contributing to a more complex system of communication. Visual thinking and visualisation, both areas associated strongly with design thinking, offer ways to overcome these communication barriers, not only during the presentation of models, but also during the generation of possibilities.

Dziersk (2007:42) discusses the importance of visual thinking when designers try to explain strategic concepts to managers. Unfortunately, very few OR/MS practitioners have ever been exposed to or been taught visual thinking skills. OR/MS might become far more accessible if understood, and this in turn can lead to improved, positive perceptions.

Solving the bigger picture

The most prevalent contemporary world paradigm is that of systemic integration. Kirby (2007:2) cites Ackoff who states that '[a] system is more than the sum of its parts; it is an indivisible whole. It loses its essential properties when it is taken apart. The elements of a system may themselves be systems, and every system may be part of a larger system'. It has become very difficult, if not impossible, to break problems down into unrelated components. OR/MS practitioners are therefore challenged to look at the bigger picture and create strategic solutions for a far more complex environment. This complex environment not only includes quantifiable variables, but also qualitative aspects such as human perceptions, needs and behaviour. Special skills are therefore required to find ways to incorporate the element of human behaviour into OR/MS models. Such an approach can be applied by design thinkers who have an ability to work systematically (and with the goal in mind) with qualitative information.

Big picture thinking also implies that more than one solution exists, and that solutions need to be adaptable for current as well as future use. This fits Owen's (2006:4) idea that one of the characteristics of design thinking is the ability to adapt, or in his words, 'a bias for adaptivity'. The fast pace of change also necessitates adaptive thinking.

Possibilities and implications for design education

This paper has thus far discussed the crisis in OR/MS, a discipline seemingly as far removed from design as one can get; but on closer inspection, many areas of common ground may be found. Both these disciplines start with a problem defined by reality, both work through a process of understanding and generation of models or conceptual solutions, and both share a common goal – an improved situation or reality.

The big difference is in the way solutions are generated. In OR/MS an objective analytical approach is used by developing quantified tools and models to plan courses of action. Designers work alongside the client and end users to develop solutions based on a structured approach that also includes the input of intuition and tacit knowledge. The way designers think and work is defined by Nigel Cross (2007:1-2), a seminal design researcher as 'designerly ways of knowing'.

Designers feel comfortable working in multidisciplinary contexts where better design outcomes are achieved through teamwork and collaboration (Brown 2008:87; Cross 2006:5). The nature of design practice is by default multidisciplinary in nature (multidisciplinary collaboration takes place when people from different disciplines work together). The question that should be asked is whether it is possible to teach non-designers design thinking. One way to generate this culture is to compel non-designers to work in multidisciplinary teams, where team members from disciplines such as OR/MS can learn from designers and design thinkers. It must be pointed out that for this approach to work, designers have to be aware of their own thinking abilities, and they must be mature enough to add value (i.e., to understand both their weaknesses and strengths, and to optimise their work according to this understanding). One other multidisciplinary way forward is research collaboration, where theorists from different disciplines work together to research new opportunities and to develop interdisciplinary hypotheses.

Interdisciplinary activity is different from multi-disciplinarity and takes place when disciplines borrow methods, theories and concepts from other disciplines; and most importantly use these methods, theories and concepts to lead to some form of synthesis. Lisa Lattuca (2001:116) differentiates between different types of interdisciplinarities. Informed interdisciplinarity can be regarded as partial- or crossdisciplinary in nature. This is the intentional borrowing of methods. True conceptual interdisciplinarity strives for systematic integration, obscuring the separate contributions of the individual disciplines (and blurring the line that distinguishes the two disciplines from each other). It is in essence the instrumental borrowing from one discipline to aid in the development of another discipline. Such interdisciplinary development ideally requires knowledge about both disciplines, and poses special challenges for educational approaches since what works for the one discipline would not necessarily work for the other.

Owen (2006:5) explains how design thinking skills are taught to designers. He explains that design thinking is a skill that is acquired almost unconsciously by designers as tacit knowledge when they design projects. But, a completely different set of educational methods need to be developed to teach non-designers suitable and useful design methods. Cross (2007:038-047) views design as a natural form of intelligence that it is to some degree possessed by everyone. The challenge is to harness this natural ability through suitable educational approaches to the advantage of the discipline of OR/MS.

Conclusion

This paper explored two broad areas. Firstly, design thinking was proposed as an operational and conceptual solution to the problems experienced in OR/MS. Secondly, the paper outlined the implications of such interdisciplinary developments for design education. The opportunities that these developments provide for design education and the discipline of design are obvious, but at the same time, they clearly pose a challenge. Relevant research and the development of practical education approaches are paramount to the development of ways to integrate design thinking and OR/MS to position OR/MS so that it can make meaningful contributions to the increasingly complex problems faced by industry and society.

Notes

[1] These interdisciplinary post-graduate design electives were explained at the 2007 DEFSA Conference (Van Zyl 2007).

[2] Operations Research/Management Science (OR/MS) is the discipline of applying advanced analytical methods, such as mathematical modelling, to assist in decision making in business environments.

[3] Maurice Kirby (2007) objectively provides the history of the OR/MS crisis.

[4] This perception is supported by a panel discussion and informal discussions with prominent members of the South African OR community at the annual Operations Research Society of South Africa (ORSSA) conference held in Stellenbosch, South Africa (20-23 September 2009).

[5] As frequently commented during presentations at the annual ORSSA conference held in Stellenbosch, South Africa (20-23 September 2009).

[6] This part was first presented by Viljoen and Van Zyl (2009) at the South Africa Institute for Industrial Engineering (SAIIE) Conference, and has since been developed further for the DEFSA conference.

[7] Held in Stellenbosch, South Africa (20-23 September 2009).

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