

## **Investigating the Development of Operations Research through the Lens of Kuhn's Model of Scientific Development**

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**Abstract:**

**This paper examines the historical development of Operations Research (OR) and represents different OR methods (methodologies) developed during its lifetime. Then, considering Thomas Kuhn's paradigm model of scientific development as a basis for our work, the former and current status of OR are analyzed and the future trend is discussed.**

**Keywords: Operations Research Methodologies, Kuhn's Paradigm Model, Hard OR, Soft OR, Critical OR, Postmodern OR, Philosophical Foundations of OR Approaches.**

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## **Introduction**

This paper is structured as follows: In the first section, the historical development of OR is reviewed. In section 2, different OR approaches, known since their inceptions, are presented. Section 3 deals with the conflict between science and technology in OR literature. Section 4 describes the Scientology schools and their attitudes toward the progress of science. Thomas Kuhn's model of scientific progress and its features are discussed in Section 5. Finally, based on Kuhn's model, OR trend is analyzed and its future is discussed in Section 6.

### **1. The Historical Trend of OR:**

There is no exact time known as OR's birthday (its advent was forecasted before and during the World War I in connection with three technologies introduced during that war: the dreadnought, the aero plane and the submarine (Maccloskey, 1987). However, its fame goes back to the Operations Researches of British military force in the World War II (Williams, 1954: 441-443). Soon after, the United States military began engaging in OR using specialists from various fields such as

chemistry, mathematics, and engineering to create management techniques for allocating scarce resources and to achieve both military and industrial goals (Heyer, 2004: 1).

Although Britain was the OR pioneer, educational provision of it lagged far behind the United States. By the end of the 1950s, there was already a small, but flourishing academic OR community in the United States at a time when OR in Britain was practitioner dominated, with an overwhelming bias in favor of the coal and steel industries. This differing experience can be explained in two ways: First, it is interesting to compare the postwar careers of Patrick Blackett and Philip Morse, the acknowledged British and American pioneers of OR. It is true that, in the later 1940s and early 1950s, Blackett wrote one or two articles on wartime OR for the scientific periodicals of the day (Blackett, 1948:1953). He even contributed the lead article to the introductory issue of the first OR journal, the *Operational Research Quarterly* (Blackett, 1950). However, Blackett soon disappeared from the OR world virtually without trace until the mid-1960s, when he was readmitted to political

life as an adviser on industrial policy. The same can be said about the other great names of British wartime OR men of the calibre of Zuckerman and Bernal; all of them returned after the war to their original academic disciplines in physics, chemistry, anatomy and biology and did not seek to build an academic OR community. The physicist Morse, on the other hand, played a pivotal role, not only in the institutional development of American OR, but also in securing the diffusion of the subject as an academic discipline worthy of university-level study (Morse 1977a, 1997b). By the later 1950s, there were at least six American universities with graduate curricula leading to postgraduate degrees in OR, and it was American operations researchers who produced the first genuine textbook on the subject (Kirby, 2000: 665).

In general, the 1950s and 60s could be seen as the boom of OR, and a pervasive air of optimism about the future of OR was dominated. One of the papers presented by Sir Charles Goodeve (1968), who spoke on "The growth of OR in the civil sector in the UK", produced a graph, illustrating the spectacular growth of membership of the society from below 500 in 1958 to 2300 in 1968. A feature of note at that time was the number of papers

produced by people other than academics (Dando and Bennett, 1981: 92).

In the late 1960s and early 1970s, some criticism of OR practice success was formed little by little by some OR scientists. The first criticism was presented by Mark Cantly (1968: 209-210) in a review of Jantsch's "Technological Forecasting in Perspective", ending as below:

*"Jantsch's book is a major contribution to our understanding of the widest problems of the human situation... Let us hope that by accepting the challenge of these broader problems, we can enlarge the obviously subsidiary place accorded in this study to OR techniques."*

The second was a paper by Rosenhead in 1968 on "Experimental Simulation of a Social System", starting as:

*"Operational research has had only limited success in tackling problems, which involve dynamic social factors.... Rather than abandon the problems or deal with them inadequately by ignoring social factors, there is a third possibility. The situation can be simulated..."* (Dando and Bennett, 1981: 93).

In the early 1970s, criticism got a bit more serious, so that Professor Cook (1973), in a conference named "The State

of Research in OR", criticized the lack of involvement of OR men in human problems and said that the relationships between OR and the social sciences were nowhere near as good as they should be. He also continued: "I am not aware of any practical OR models that incorporated any behavioral elements and daring proposals are needed to create a more enlivened way of thinking ..."  
(Dando and Bennett, 1981: 93).

In the late 1970s, criticism was much more serious. The main criticism was raised from "Russell Ackoff" and influenced the OR society a lot. He made his first wave of criticism in the early 1970s in relation to the interaction between systems thinking and human behavior (Ackoff and Emery, 1972): "If individual systems are 'purposive', it follows that knowledge and understanding of their aims can only be obtained by taking into account the mechanisms of social, cultural and psychological systems". Afterward, Ackoff claimed that the most pressing problems confronting humanity included discrimination and inequality, and since the inefficiency of public services was not considered in the research agenda of OR, Machine Age thinking was seriously compromised, because it could not comprehend the "messes" of unstructured

reality: "Traditional OR models were self limiting, if only because they were rooted in excessively complicated mathematics"  
(Ackoff, 1973: 664).

Ackoff's second "wave of criticism" offered a further condemnation of OR in theory and practice. In two papers published in 1977 (Ackoff 1977a, b), he argued that OR's unrelenting focus on "optimization" and "objectivity" encouraged "opt-out," or a withdrawal from reality. In an increasingly turbulent economic and political environment, "it is silly to look for an optimal solution to a mess". As for "objectivity," Ackoff rejected the view that it could only be achieved by excluding the moral and ethical values held by the researchers involved, because he believed that purposeful behavior could not be value free (Kirby, 2007: 2-3).

Ackoff's final and most controversial "wave of criticism" was described in two papers delivered to the British Operational Research Society's Annual Conference in 1978 (Ackoff 1979 a, b). In the first paper, Ackoff acknowledged that the life of OR, which was born in the late 1930's and gained widespread acceptance in academic, scientific and managerial circles by the mid-60's was over. In Ackoff's view, the

type of model employed in classical OR implied particular assumptions of problem solving, consisting of two parts: *predicting the future and preparing for it*. He believed that “perfect prediction is possible under two sets of conditions: First, when nothing changes. Of course, if nothing could change, choice, hence problems would not exist. At best, we would be restricted to changing our own behavior: only that behavior, which had no effect on anything external to us. The second set of conditions under which perfect prediction would be possible is that the behavior of the phenomenon we predict is in accordance with the deterministic causal laws and that we know perfectly these laws and the structure of the phenomenon we are predicting. However if what we can predict perfectly is necessarily determined, then we can do nothing about it; that is, we cannot change what can be predicted perfectly. But can we not prepare ourselves for it?”. Ackoff himself answers that “the organizations and institutions for which we work, however, are a part of the socioeconomic system that we try to predict; hence, their preparations and those of others affect that system. This is why the behavior of containing systems cannot be

predicted accurately.” ( Ackoff, 1979a:100-101)’.

Ackoff acknowledged that to avoid the dilemma deriving from the predict-and-prepare paradigm, “the operations researcher implicitly assumes that the environment of the system he deals with, i.e. the containing system is deterministic in nature. Hence, it is predictable in principle, if not in practice. However, that the system he is dealing with has choice, and is purposeful. This amounts to assuming that the containing system behaves mechanistically, but the contained system being manipulated is teleological”. In Ackoff’s view, “one of the things we have never been able to conceptualize is a machine that has purposeful parts, and for good reason, it involves a contradiction. Thus there is a critical type of indeterminacy inherent in OR: to the extent that we can predict accurately the behavior of a system of which we are a part, we cannot prepare effectively for it; and to the extent that we can prepare effectively, we cannot predict accurately what we are preparing for”. Ackoff believed that, in such a situation, we required a new OR.

In the second paper, entitled “Restructuring the future of OR” (1979b),

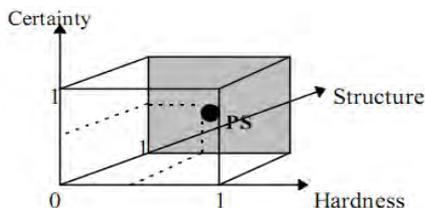
Ackoff explained the features of new OR based on the assumptions such as “*designing a desirable future and inventing ways of bringing it about*”. He introduced the new OR based on the following three principles: participative principle, holistic principle and principle of continuity. He further believed that the new OR must have a systemic approach not a mechanistic (Ackoff, 1979b: 189).

Ackoff’s criticism at that time led to a major crisis in the OR community, such that about one quarter of major papers written and published appeared to contain significant criticism and had a similarly general and critical nature. Critics generally argue that OR practice has been considerably more diverse; some organizational problems could not be solved by pure logic that hard OR employs; problems have continued to become more complex and increasingly difficult to model mathematically; and that standard formulations of OR methodology cannot cope with these less well-behaved situations. They recognize one of the reasons of such a kind of complexity: “people are an integral part of organizations and that these people each bring to the organization their own worldviews,

interests and motivations” (Heyer, 2004: 3-4). This group of scientists defines complexity in terms of three orthogonalities: “softness-hardness”, “well structured-ill structured” and “certainty- uncertainty”:

- Softness that relates to the subjective mentality is attributed to a situation, and this can vary with the degree of subjectivity importance to the world view of an inquirer.
- Structure that relates to perceivable relationships between arbitrarily definable entities within a situation, and this can vary with the richness of its interrelationships that an inquirer sees; it is thus world view dependent.
- Uncertainty (about the nature of a situation that will vary with the knowledge about it), is connected to world view, and relates directly to the future outcomes and predictability.

Yolles (1998: 8) represented this position in a modeling space in as shown Figure 1. The space is a bounded cube with sides, which have been normalized to vary between a measurement of 0 and 1.



**Fig 1.** Example of a Modeling Space for a Problem Situation (PS)

Within the British OR community, one of the most well-known critics of the universal applicability of the classical OR was Peter Checkland, Professor of Systems at the University of Lancaster from 1969 until his retirement in 1997. In developing his critique of “classical OR”, Checkland (1981) noted Patrick Blackett’s wartime view as achievable because of the long-term stability of many of the variables involved in the operations so that the aggregate results were relatively constant. So he believed that the early pioneers of OR developed a methodology based upon model building of the logic of the situation. Checkland criticized the fact that Blackett had identified “the logic of situations”, in that:

“A number of these situations were identified and algorithms developed. Because they were teachable,[they] passed through into university courses. Because it was more attractive to research algorithms than to

conduct action research in organizations, OR research became mathematical in nature. Thus, researchers concentrating on a class of logical situations became separated intellectually from practitioners who had to deal with unique idiosyncratic situations affected by chance events and individual personalities, as noted by Blackett (R. Ormerod to M. W. Kirby, 2005).

From the early 1980s onwards, Checkland, building on the work of earlier British reformers, emerged as a leading exponent of “soft systems methodology” (SSM) as a response to the alleged limitations of the classical paradigm (Checkland, 1981). Checkland’s publications at this time were notable for their acknowledgement of his debt not only to Ackoff but also to Vickers, writing in 1965, and Churchman in 1971; all of these three developed a “system” approach to the resolution of managerial problems, which could be deemed to be “wicked” or “messes” (Kirby, 2007: 3).

In general, we can summarize the above critics as: “OR requires methods that enable decision makers to accommodate multiple perspectives; facilitate negotiating joint agendas; function through interaction and iteration; and generate ownership of problem formulation”.

Thus “Soft OR” with a philosophical and methodological foundation arose in OR community.

In addition, some other Marxism inspired scholars criticized both soft and classic OR approaches. These academics outlined two central criticisms to both hard and soft ORs:

- They are both regulative, i.e. in practice they work to sustain rather than to challenge the status quo. Since they cannot admit external structures and constraints, they cannot recognize nor challenge inequalities of power, resources and knowledge within a particular setting. Changes that may be desirable, generally, have to be subordinated to the feasibility of the existing power structure, and where new ideas are initiated, barriers to change cannot be dealt with.
- Implicit within them are, largely unarticulated, assumptions about power and basic ideology. They share an essentially functionalistic view of power, i.e. that power is a societal or organizational capacity for securing order and consensus – power is equated with authority. In terms of ideology, they are based on liberal ideas of the

free-individual, free-market competition and democracy.

They also believed that hard, cybernetic and soft systems approaches tend to be ideologically conservative. This group of academics attempted to include Marxism in methodological frameworks in terms of an (emancipatory) ethical position and a view of society. They hoped their methods (methodologies) would turn out as a socially conscious and self-reflective approach, distinguished by an openly declared emancipatory interest in an equal distribution of power and chance to satisfy personal needs, and in liberating people from dominance by other people and forces they do not control (Flood and Jackson, 1991: p 244). The emergence of these methodologies has been mainly due to the work of Michael Jackson and Robert Flood at Hull/Humberside in the UK in the early 1980s.

In the early 1990s, an interesting debate in the OR and systems communities in the UK emerged around the issues concerning the use of more than one methodology (combining them or using parts of them); systems academics and systems practitioners have been debating the possibilities of using methodologies from

different paradigms, acknowledging and recognizing their strengths and weaknesses. There are two more or less developed approaches to multi-methodology relatively well known in the UK: (a) critical systems and critical pluralism/complementarism as initiated by Flood and Jackson (1991) and lately developed into “coherent pluralism” by Jackson (1999); and (b) multi-paradigm multi-methodology/critical pluralism developed by Mingers. (Caceres, 2010: 49)

The post-modern OR is another approach which has developed in management science in recent years (since 2000). This approach is based on a narrative that attacks the rationality embedded in the pretensions of modernism in grand narratives. The focus on power/knowledge and the needs of the individual are very much in the agenda of any post-modernist systemic (or anti-systemic) intervention that will resort to a variety of tools and methods available. In the UK, Tacket and White have been pioneering the use of a post-modern approach (Caceres, 2010: 49). They believed that classical and soft ORs are rooted in systemic modernism, and critical/emancipatory OR is rooted in critical modernism.

In criticizing the modernism approach,

they say: “we would like to see the text of OR deconstructed to rise to the surface for debating the tension between rational and irrational”. They believe that by exposing how OR is organized more around the irrational, a space can be opened for a more imaginative OR concerned more with reaction than rational. They believe that the language of OR is constructed in binary opposition in particular, at hard and soft ORs, and the feminization of soft OR, arguing that polarization is entirely misplaced, that it is not helpful to creative OR practice and that it freezes us rather than frees us. The hard and soft ORs are implicated in each other, so we need to work with the creative tension between the two, rather than each attempting to wrest the hegemonic position from the other. They continue that they would not argue for the middle ground, even though there may be a case for a middle ground stance. Instead, what they propose is to be creative and disciplined between the poles to reject dichotomy. They think that modern physicists have gone this route between binary worlds, i.e. they have been creative and yet 'scientific' in the gaps between the world of uncertainty and determinism, and between the universe and the sub-atomic

world (Tacket and White, 1993: 873).

Their other concern is to identify how the language of OR has been flavored by the use of shifting/sliding systems of signifiers and signifieds, in particular involving the “feminization of the soft” as a way of dismissing the validity of soft methods and approaches. One of the dangers of binary thinking is that the reader is enticed through the use of language into lining-up poles of different oppositional couplets and sliding from one binary opposition to another, carrying with them valuation(s) (explicitly or implicitly) from one oppositional couplet to another. From the work of feminists on language, they found the existence of a whole series of oppositional couplets used as equivalent to the masculine-feminine couplet, with the underlying (crude) value loading of good-bad, leading to the use of (sexist) language that implicitly values the 'masculine' pole of the couplet over the 'feminine' (Tacket and White, 1993: 876). Tacket and White deliver their agenda for the future of OR as below:

1. The utilization of text and discourse analyses: Using discourse analysis to examine theoretical writings of OR and

using text analysis as a component of OR practice;

2. To examine the relationship between the OR 'analyst'/'expert' and 'client' to blur the boundaries between their roles and the distinction between high and low ORs; and in doing so, we critically look at the quests for meta-narratives;
3. Deconstruction of the field in which OR engages. (Tacket and White, 1993: 880).

Tacket and White’s strategy for using the post modern approach in OR is “critical pluralism” (Tacket and White, 2000). As Jackson (1999) puts it, the format proposed by Tacket and White is by offering a ‘cookbook’ that sets out some favorite recipes, but then encourages variations and innovations. This framework has been done through their PANDA—participatory appraisal of needs and development of action. There are a few applications in UK OR and systems journals; however none of them are known or applied in the US OR community.

### **Types of Problems in Organizations**

In the OR literature, various categories of organizational issues have been presented by various scientists. For example, we could refer to Rittle and Weber who divide problems

into “Tame Problems” and “Wicked Problems”, or Pidd who provides a spectrum containing three points for problems; “Puzzles”, “Problems” and “Messses”:

- **Puzzles:** situations in which it is clear what needs to be done and, in broad terms, how it should be done. Finding a solution is a process of applying known methods (e.g., a particular mathematical method) to come up with the solution to the puzzle.
- **Problems:** situations in which it is clear what needs to be done, but not at all obvious how to do it. Thus the problem is well defined or well structured, but considerable ingenuity and expertise may be needed to find an acceptable, let alone optimal solution.
- **Messes:** situations in which there is considerable disagreement about what needs to be done and why; therefore, it is impossible to say how it should be done. Thus, the mess is unstructured and must be structured and shaped before any solution (Pidd, 2004: 7)

## 2. OR Schools

According to the historical trend, which was explained above, we can consider a framework consisting of four distinctive

OR/MS schools in which a number of OR/MS methods and methodologies used in the last half-century including “hard OR”, “soft OR”, “critical/emancipatory OR” and “post-modern OR”.

### 2.1. Hard OR

**2.1.1. Definition:** A branch of OR which aids managers to make decisions in organizations using quantitative and mathematical methods, statistical algorithms and systems engineering.

In very crude terms, hard OR can be seen as a series of steps:

**1. Formulation of the Problem:** The operations researcher gathers sufficient information (through research and site visits) to understand the organizational climate, objectives, expectations and alternative causes of action. Only then can a problem be adequately formulated.

**2. Development of the Model:** The operations researcher then expresses the problem as a model that represents the systems, processes and/or environment in terms of equations, relationships or formula.

### **3. Selection and Collection of Data Input:**

The operations researcher must ensure he has sufficient data input to operate and test the model.

**4. Solution to the Model:** The operations researcher finds a solution to the problem, which invariably involves considerable updating and modification.

**1. Validation of the Model:** The operations researcher must ensure that the model is valid, i.e. it can provide a reliable prediction of the systemic performance and be applicable over time, or updated to reflect past, present and future aspects of the problem.

**2. Implementation:** While implementation remains the domain of the implementing authority, the operations researcher should work closely with the management to play a positive role in implementing the solution. (Carter and Price, 2001)

**2.1.2. Philosophical foundation:** There is no consensus among academics about the philosophical foundation of “hard OR”; however, most of them believe that it is rooted in Positivism school of thought.

**2.1.3. Problems:** Hard OR methods are suitable for solving Puzzles.

**2.1.4. Organizational Practice:** Hard OR methods are applicable in operational level problems, which are routine in nature and the logic of their situations could be captured such as: allocation problems; inventory problems; replacement problems; queuing (or waiting line) problems; sequencing and routing problems; search problems (concerned with location); competitive or bidding problems, etc.

**2.1.5. Hard OR Methods (methodologies):** Linear Programming, Simulation, Pert Network Analysis, Forecasting, Decision Trees, Queuing Theory/Waiting Lines, Markov Analysis, Integer Programming, Goal Programming, Statistical Quality Control, Inventory Control Models, Transportation and Assignment Problems, Systems Dynamics, Complexity Theory, and Management Cybernetics (Caceres, 2010: 51).

## **2.2. Soft OR**

**2.2.1. Definition:** Soft OR methods are those that structure a problem, as opposed to hard OR methods that seek to solve it

and use predominantly qualitative, rational, interpretative and structured techniques to interpret, define, and explore various perspectives of an organization and the problems under scrutiny. They generate debate, learning and understanding, and use this understanding to progress through complex problems. For this reason, that the great majority of such soft OR methods are referred to as “problem structuring methods”.

In very crude terms, Soft OR follows the below steps:

1. Seek to help key stakeholders understand the problems they face;
2. Inform each stakeholder the views held by other stakeholders;
3. Negotiate the action to take;
4. Agree to a consensus on a course (or courses) of action to be taken (Heyer, 2004: 4).

**2.2.2. Philosophical Foundation:** There is no consensus among academics about the philosophical foundation of “Soft OR”, but most of them believe that it has a root in the philosophical assumptions of Hermeneutic school of thought, and in social sciences, it is rooted in Interpretativism Sociological School.

**2.2.3. Problems:** Soft OR methods are suitable for structuring “messes” in organizations.

**2.2.4. Organizational Practice:** Soft OR methods are capable of structuring strategic level problems in organizations, which are not repeatable and the logic of their situations could not be captured.

**2.2.5. Hard OR Methods (Methodologies):** Soft Systems Methodology, SSM (Checkland); Interactive Planning, IP (Ackoff); Strategic Assumption Surfacing and Testing, SAST (Mason and Mitroff, 1981); Systems Intervention Strategy, SIS (Mayon-White); Strategic Choice Approach (SCA) (Friend); Social System Design, SSD (Churchman); Cognitive Mapping, SODA, JOURNEY (Eden and Ackerman); Team syntegrity (Beer) (Caceres, 2010: 51).

## 2.3. Emancipatory/Critical OR

**2.3.1. Definition:** A branch of OR inspired from Marxism and critical theory seeking to reveal hidden layers of power in organization and help marginalized groups

to participate in organizational decision making.

The main assault of this school, according to Wood and Kelly (1978) is that traditional management science has accepted the existing structures of inequality of wealth, status, power and authority as given and thereby helped to buttress the status quo. This school aims to consider the origins of values, the historical development of organizations, the relations between organizations and society, and the relationship between OR/MS and developments within capitalism (Jackson, 2003: 295).

**2.3.2. Philosophical Foundation:** This school is rooted in Frankfurt school, especially in the Habermas' theory of "Human Cognitive Interests".

**2.3.3. Problems and Organizational practice:** This approach considers the problem of inequality in decision-making at all levels of the organization and, unlike the previous two approaches, does not seek to achieve organizational goals; rather its main concern is marginalized people in organizations.

### **2.3.4. Emancipatory/Critical OR Methods**

**(Methodologies):** Critical Systems Heuristics; Total Systems Intervention; Critical Systems Thinking; Critical Pluralism; and Multi-methodology (Caceres, 2010: 51).

## **2.4. Post-Modern OR**

**2.4.1. Definition:** This approach attempts to work holistically and pragmatically to address the diversity and heterogeneity found in organizations. It rejects prescription based upon totalizing theories and seeks guidelines, examples, stories and metaphors for use in planning and interaction, in carrying out the interaction, and in reflecting on it during and afterwards. In moving away from prescription, the post modern OR seeks to maintain an open and flexible stance, capable of responding creatively to the characteristics of a particular moment, continually disrupting the comfort of identification with a fixed theory or view, and seeking instead to mix different perspectives (Taket and White, 2000: 69).

Alvesson and Deetz suggest that postmodern thinkers share seven ideas in common:

- The centrality of discourse; The discursive production of the individual;

- The discursive production of natural objects rather than language as a mirror of reality;
- The loss of power of the grand narratives;
- The power/knowledge connection;
- Research aimed at revealing indeterminacy and encouraging resistance rather than maintaining rationality, predictability and order;
- Hyper-reality – simulations replace the “real-world” in the current world order. (Jackson, 2003: 334).

**2.4.2. Philosophical Foundation:** This school is rooted in the postmodernism school of thought.

**2.4.3. Problems and Organizational practice:** This school suggests that using whatever you feel is good enough for dealing any kind of problem in multi-agency settings.

**2.4.4. Emancipatory/Critical OR Methods (methodologies):** Participatory Appraisal of Needs and Development of Action (PANDA) (Caceres, 2010: 51).

### 3. Conflict of Science and Technology in OR:

In its early years, OR was believed to be an applied science drawing on the methods of natural sciences for the purpose of knowledge building and analysis. To be more precise, it was the methods, adopted by the early OR scientists (when they diverted their attention from peacetime scientific research to study the operations of first military and then civil organizations), that were assumed to be scientific. Ackoff (1962), Rivett (1980) and White (1985) each extends the scientific method of observation, generalization, experimentation and validation to produce a method of investigating problematic situations (Key, 1989: 753) An early and influential description of the method of OR was given by Ackoff as follows:

1. Formulating the problem;
2. Constructing a mathematical model to represent the system under study;
3. Deriving a solution from the model;
4. Testing the model and the solution derived from it;
5. Establishing controls over the solution; and
6. Putting the solution to work: implementation.

There is no doubt that the modeling method described is the positivism inductive research approach of scientific enquiry, which constitutes the foundation of traditional OR, and is based on observation and generalization. Although Ackoff himself has led the criticism of this approach, similar definitions of the process of OR remain popular with many practitioners and academics today, and are included in modern textbooks from which students obtain their initial, limited understanding of the scope of OR. For instance, Taha (1992) describes the phases of OR in similar terms to Ackoff, except that he leaves out Step 5.

While the assumption that the scientific world makes progress through the diligent application of an inductive method has been under sustained attack by those interested in the nature of science, including both scientists themselves and philosophers of science, some argue to change the logical underpinnings of the scientific method of OR to the Popper's hypothetico-deductive model or falsificationism. Falsificationism begins by accepting that theory precedes observation and seeks to provide a process, which is logically sound. Theory takes the form of hypotheses about how the situation

being investigated performs, and then attempts to find cases where this is proven false. Observations are, therefore, guided by theory, and the need to argue for objective observation is removed. The logic of the process is also sound, when an observation has been made, which disproves the hypothesis, it must be discarded. Eilon (1957) has interpreted the OR process within this model and shown that such an explanation is possible (Ormerod, 1996: 2).

Dando and Sharp (1977) have identified four characteristics, which should be present in a mature science. First, it should focus on a defined set of phenomena. Second, it should have a working set of paradigms and associated languages. Third, it should have a system for testing theories. Fourth, it should have the aim of producing explanations of how parts of the system work, which in total provide a coherent framework of understanding. They believe that only the fourth characteristic is necessary for a science; the remaining three emerge as a science establishes its unique area of interest and mode of enquiry. In considering OR, it is found that none of these characteristics exist. In particular, OR is not seen to have as a main aim of producing of explanations about behavior- a

view that is shared by those who argue for OR as technology (Key, 1989: 754).

Scientists who question OR as a science, believe that science is concerned with obtaining a body of knowledge about the behavior of the world in which we exist. Different sciences concern themselves with particular parts of that world". There is little disagreement over the view that OR uses scientific methods within its investigations as far as is possible (Key, 1989: 753).

Raitt (1979: 835), who is one of the proponents of "OR as technology", believes that natural sciences, however, as discussed in the standard works in the philosophy of science, and in particular in the Popper-Kuhn-Lakatos' debate, is characterized more specifically in terms of the development of a body of theoretical knowledge. So OR is not a pure science in this sense and has no distinctive subject matter in the way that physics has. Furthermore it does not provide an accumulation of theoretical knowledge about the world. In Raitt's view, the distinctive feature of OR is its use of models and analogies. A model is not a theory; it has no direct substantive implications. No one expects the history of OR to show an accumulation of models of

increasing power, precision or generality. A model is constructed for practical application in a particular situation. It is wholly instrumental. We do not ask if it is true; only if it works, we validate it not verify.

"Key" who is another advocate of "OR as a technology" believes that, there are two models of the science-technology and OR relationship (Key, 1989: 753): The first is the traditional model, which sees technology as applied science. The various calls to see OR as a technology suggest an adherence, in some cases more strongly than in others, to this model. According to the model, Key concluded: "A unified science should be identified to support OR. However, in the case of OR, the historical attachment to several disciplines and the varied approaches adopted in these would prohibit the creation of a unified foundation. Furthermore, this model suggests that technology cannot exist without a science to support it, and that this science triggers technological change. Yet OR appears to have survived and developed for half a century with no science being explicitly present to support it, and has evolved independently to offer some sophisticated tools and techniques" (Key,

1989: 755); the second is the modern understanding of technology which emphasizes science and technology as separate bodies of activity, that support each other in a mutually beneficial way (Both parts of the relationship have their own particular cultures and are concerned to develop and enhance these) (Key, 1989: 756). Key showed that, the first model was an inappropriate model for OR and the modern understanding of technology is then more satisfactory as an explanation of OR activity.

Despite the conflict that still exists between science and technology in the OR community, all academics are in common about one thing: OR/MS is at least related to science. One of the important reasons of investigating OR as a science or being related to a science is that, with recognizing a suitable scientific model for explaining its behavior, we can predict developments and issues facing this area of research.

#### **4. Scientology Schools**

In this section, we present some of the most important Scientology schools and their main features to choose a model that fits best to the characteristics of the OR and, investigate the development of OR/MS

accordingly.

Scientology schools can be divided into two categories: Descriptive schools, which aim to describe the body of knowledge (e.g. Logical Positivism and Popper's Critical Rationalism), and Prescriptive schools (e.g. Kuhn's Sociological school).

Logical Positivism presupposes that the development of science is cumulative and linear. Proponents of this school believe that the conflict among rival theories could objectively be resolved by testing those using objective impartial observations and facts; observations and facts, which are agreed by all parties involved. Though positivists are not in common about the exact quality of the objective impartial observations and facts, but they did not hesitate about the existence of such facts.

Critical rationalism is the philosophy developed by Karl Popper in the mid-20th century. Like the logical positivists, Popper sought to describe the logic embedded in the body of knowledge and its pathology, but unlike logical positivists, his view of science is revolutionary not always linear and cumulative. Popper's approach is based on the naturalistic idea that society has developed through a process of solving problems using trial and error. The natural

and social sciences have been born out of such problem solving and progressed by subjecting potential theories to vigorous testing and criticism. Falsified theories are rejected in CR (Ormerod, 2009: 1). Popper, following a sceptical approach, took 'falsification' as the distinguishing characteristic of science: "Universal theories are never verified or confirmed with any positive probability; they can only be falsified". His approach was to replace induction by falsification. Theories, which cannot be falsified, corroborate. Thus, despite the revolutionary nature of science, in Popper's view, the truth is progressive (Popper, 1959: 251) .

In Thomas Kuhn' belief, instead of rational interpretation of the history of science, we should pay attention to sociological study of science. Kuhn argues that, contrary to the above opinions, progress in the natural sciences has not been "cumulative"- building of advances one on top of another. This impression, conveyed by most scientific textbooks, is in fact caused by the winners of each major argument "rewriting history". (Dando and Bennett, 1981: 95) In his view, in the history of each science, scientific revolutions could be found; old scientific

theories leave aside and new theories come on the work. However this replacement is not based on a firm and objective evidence, it is due to the thrust of scientific community to accept the new theories, and it is that sociological and psychological factors are involved in this process.

Appearance of OR development in the history might fit to Kuhn's model and provide sufficient insight to allow some sensible prediction of what may happen next. So in the following sections, we will analyze OR development using Kuhn's model and try to predict what may happen next.

## **5. Kuhn's Paradigm Model**

### **5.1. The Structure of Scientific Revolutions**

In "Structure of Scientific Revolutions", Kuhn suggests that scientific endeavor could be characterized by periods of "normal science" interspersed infrequently with revolutions. The key element in Kuhn's alternative account is that of a "Paradigm". During the period of normal science, work is carried out under a particular paradigm. Kuhn has used the term "paradigm" in both general and specific senses: Paradigm, in a general term, means a set of assumptions within

which a group of practitioners function during the times of "normal science"; and paradigm, in specific term, determines what theoretical and methodological beliefs are taken for granted, what types of problems are addressed, what types of experiments are conducted and what types of measurements are made; all constitute the content of textbooks.

Every paradigm tends to define the world in limited ways and to deal efficiently with its own particular sort of puzzle. Sooner or later, problems of a quite different order arise. The paradigm-induced expectations about the real world do not work out. Things begin to go wrong. If the lack of success is important and prolonged, the community's life starts to alter. A period of "extraordinary science" or "crisis" sets in, during which the community focuses on the perceived anomaly and is forced to reexamine its own framework of assumptions.

If an unexpected result is obtained, it is treated as an anomaly; perhaps the experimenter did something wrong, perhaps some adjustment to some aspects is required. It is very difficult for scientists to shift paradigms in the middle of their career; as a consequence, they may spend

their whole career in one paradigm.

At some points, a new way of looking at things is suggested and a period of extraordinary, exploratory research is identified thus a new paradigm is developed. Particularly younger scientists and those new to the field, unencumbered with the past commitments, start to adopt the new paradigm because it is thought to be productive in solving some problems of the existing paradigm. Symptoms of a transition from normal to extraordinary research may include the proliferation of competing articulations, the willingness to try anything, the expression of explicit discontent, the recourse to philosophy and debate over fundamentals. Once a transition is underway, the older schools gradually disappear: "To be accepted as a paradigm, a theory must seem better than its competitors, but it needs not to, and, in fact, never does explain all the facts with which it can be confronted" (Kuhn, 1962: 18).

"It is very difficult to compare two paradigms because of their incommensurability: Proponents of competing paradigms fail to make complete contact with each other's viewpoints" (Kuhn, 1962:148). Kuhn is explicit that the new paradigm is not necessarily closer to

the truth than the old: "We may, to be more precise, have to relinquish the notion, explicit or implicit, that changes of paradigm carry scientists and those who learn from them closer and closer to the truth" (Kuhn, 1962: 170). Kuhn had produced an evolutionary view of science, not so much an evolution-towards-what-we-wish-to-know, rather an evolution-from-what-we-do-know (Kuhn, 1962: 171). He rejected any emphasis on falsification rather than verification. When confronted by anomalies, scientists do not renounce the paradigm that led them into the crisis: "No process yet disclosed by the historical study of scientific development at all resembles the methodological stereotype of falsification by direct comparison with nature" (Kuhn, 1962: 77).

## 5.2. OR and Kuhn's Model in Literature

For the first time, "Kuhn Tucker" in his book published in 1977 called to the necessity of a scientific revolution in his terms in the dominant paradigm of OR, not of merely superficial changes to make improvements in this field. In 1978, Radford offered a sketch of a new paradigm for OR. Afterward, as it mentioned earlier, Ackoff in his paper entitled "The future of

OR is past", said that the life of OR had been a short one and the OR, which was based on the "Prediction and Preparation" principal modalities of the Machine Age, was dead (Ackoff, 1979a). In another paper, entitled "Resurrecting the Future of Operational Research", he describes how the new paradigm of OR could be resurrected based on the modalities of the System Age (Ackoff, 1979b).

After Ackoff's two papers and others of a similarly general and critical nature were indeed being written and published, Dando and Bennett (1981) in a paper entitled "A Kuhnian Crisis in Management Science?". They argued in the paper that controversy within OR in late 1970s and early 1980, denoted a Kuhnian Crisis in OR/MS. Then they identified three rival paradigms, labeled "official", "reformist" and "revolutionary", in this field. They believed that the debate in OR differed from that in the natural sciences, because it was not just about the best means of understanding the empirical world. It was also about the type of social world to be constructed through the framework of assumptions adopted. In their view, according to the social and political situations dominated at that time, proponents of the reformist stance would

probably win (Dando and Bennett, 1981:100-102).

Thereafter, the use of the term “paradigm” became prevalent in the OR community, and several papers named different OR/MS approaches as hard, soft and critical and in some of them postmodern paradigms.

Bryer (1977: 47) in his PhD dissertation, entitled “Theoretical Foundations of Operations Research”, examined the relationship between OR and Kuhn’s model in a different way as of Dando and Bennett’s. Bryer, inspired from Beer, knew OR as a revolutionary science, which always questioned the existing structures in organizations. In Bryer’s view, “average managers in organizations are like normal scientists who aim to get on with their conceptual framework and responsibilities, which they exercise within it; OR is not concerned with the “normal science”: “The whole purpose of OR men is questioning the existing frameworks and conventional boundaries, and their task is to institute revolutionary changes in organizations”.

In recent years, some academics, particularly Mingers, agree that Kuhn’s work in the natural sciences presupposes that paradigms generally succeed one

another. However, in the social sciences, Burrell and Morgan construct a set of antithetical paradigms that could exist simultaneously (Mingers, 2003: 559). They further used this idea to combine different methods (methodologies) from different paradigms in an organizational intervention and developed the idea of multi-methodology in OR/MS.

But Pidd (2004: 17-19), accepting Kuhn’s model in the natural sciences, asks “whether hard and soft ORs constitute different paradigms or are they just variations on a theme”? He refers to Ormerod (2001) in that some people do manage to work with both soft and hard approaches. This suggests either that Kuhn is wrong about incommensurability, or that soft and hard ORs do not, in fact, sit within different paradigms. In concluding section, Pidd suggests readers to choose one of the three different ways in which soft and hard OR/MS approaches can relate to one another. Figure 2 shows these ways. In the left part of the figure, the soft and hard approaches are completely distinct and should be regarded, in Kuhn’s terms, as incommensurable. In the middle part of the figure, the two are seen feeding off one another in an eclectic and pragmatic way. In

the right part of Figure 2, soft OR/MS methods are seen as containing the classical hard approaches, in the sense that the understanding of meanings gained in soft OR/MS enables a sensible attempt at hard OR/MS.

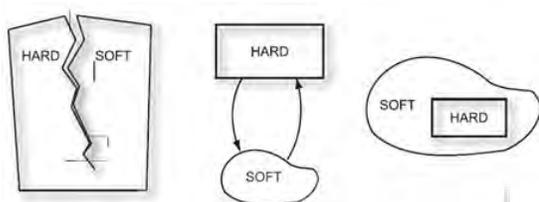


Figure 2. Relationships between hard and soft

## 6. OR and Kuhn's Paradigms: Further Analysis

As mentioned earlier, Kuhn sought to find out how science developed, and in addition to the logic of scientific discovery, paid due attention to the social processes involved in that. He believed that many of the prevailed ideas and theories remain strong, even when there is evidence of them being false. To illustrate this process, Kuhn applied the term “paradigm” as a conceptual framework in which theories of each scientific field are created. Therefore, the power of each theory is maintained for its position in a paradigm not because it explains a phenomenon better than others. However, now the question is that “which is the dominant paradigm in OR?” and “Does the

same paradigm of OR prevails in the entire world?”. Caceres (2010) in a paper, which maps the changes in management science between 1973–2008, argues that although the roots of the paradigm shift in OR, were first proposed by American thinkers such as Chrchman and Ackoff, but development of such ideas has been more serious in the UK. While the number of MS applications adhering to the interpretivist, critical and (to some extent) post-modern paradigms have been fairly regular in British OR community, less attention has been paid to this in the US; and even the few papers published in American journals in this area have been written by the famous British authors. Was Dando and Bennett's prediction of the next OR paradigm correct? Does the prevalence of one paradigm in just a small part of the world means that the paradigm is the dominant one?

To answer the final question, we can refer to the note that Kuhn wrote in the second edition of “The Structure of Scientific Revolutions”. Kuhn, in his analysis, obscured the distinction between the normal and revolutionary sciences; this is while that he previously considered them as completely separated: He acknowledged that a revolution may occur in a small

community of experts without any significant change in the general field of that science. In his view, a paradigm shift in a small community without a crisis at macro-level is allowable.

Accordingly and also considering Kuhn's emphasis on the causes (external) rather than reasons (internal), it can be concluded that Dando and Bennett, who also lived in the UK, were right about the next OR paradigm and, despite the lack of attention of other scholars in other parts of the world, we can name the post-hard paradigm not necessarily "prevailed paradigm" but at least "revolutionary paradigm" in the post 1970s.

But why the proponents of the new paradigms insist on using Morgan's paradigm model instead of the Kuhn's; don't their soft or critical methods work properly that they have to use hard methods as complementarity?

In response to the above questions, it could be said that Kuhn has inspired from the long history of 2500 years of natural science especially that of Physics to develop his model. So it is clear that application of such a model in a short period of 50 years in a scientific field is not properly possible. In the recent 300 years,

no scientific field has experienced a Kuhnian revolution as explained by Kuhn, so presence and competition of more than one paradigm in OR without leaving the rest aside is not unexpected. On the other hand, based on Kuhn's model, different paradigms are incommensurable. So if different OR paradigms are rooted in different philosophical foundations, then they may cope with different types of problems, and applying multi-methodologies in the same problem is impossible. Even Morgan, who accepted the presence of different paradigms at the same time, believes that in different organizational problems different paradigms are dominant. However, the overemphasis of soft and critical system thinkers to use hard approach complementarily means that they cannot leave hard OR, and we believe that the reason can be one of the followings:

1. According to Kuhn's model, the thrust of the normal science community (hard OR) causes to hard OR remain strong, even though there is evidence of it being false. It means that even in the UK, hard OR is the dominant paradigm.
2. The main concern of academics who have developed new OR methodologies

was not to do with OR and it is of the inter-OR community problems. Rather they were influenced by new dominant paradigms in the social sciences and, according to their own philosophical interests, they have imported new ideas in OR and developed new methodologies based on them.

3. Similar to the 1970s, we are in the Kuhnian crisis, which will be continued till a rival paradigm become dominant in the OR community.
4. Soft and critical methodologies have not been able to show properly their advantages to the classical methods in improving problematic situations. So they are not strong rivals for classic OR.

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## بررسی روند توسعه‌ی تحقیق در عملیات با استفاده از مدل پیشرفت علمی توماس کوهن

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در این مقاله روند تاریخی گسترش تحقیق در عملیات در داخل و خارج از کشور را مورد بررسی قرار داده و رویکردهای موجود در OR و روش‌های ذیل هر دسته را در این حوزه معرفی می‌کنیم. سپس مدل پارادایمی توماس کوهن از رشد و پیشرفت علمی را مبنای کار خود قرار داده و بر اساس این مدل روند پیشین و وضعیت موجود در حوزه‌ی تحقیق در عملیات را مورد تحلیل قرار داده و به پیش‌بینی روند آتی آن خواهیم پرداخت.

واژگان کلیدی: روش‌شناسی‌های تحقیق در عملیات، مدل پارادایمی کوهن، OR سخت، OR نرم، OR انتقادی، OR پست مدرن، بنیان‌های فلسفی رویکردهای OR.

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