Operations Research in Post Modern Era: Apple-pie with Ice-cream

[A Personal Perspective]

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Abstract

The field of Operations Research (OR) has passed through ups and downs since its inception in 1940s. The classical OR methods owned and advocated mainly by scientists, mathematicians and technologists were developed, promoted and applied in corporate sectors in manufacturing as well as service industries for modernizing the world economy during the peace and development periods. Because of the hard nature of these mathematical optimization models, classical OR could not rightly capture the complex, uncertain and messy real-world situations and thus their growth of application could not rightly take-off as envisaged by the OR promoters. In the post modern era, many psycho-social and behavioral scientists started criticizing the usefulness of the hard OR methods and initiated the development and applications of soft type of OR by thinking systematically and structuring perceptions of different stakeholders to derive alternative solutions useful for their managerial decision making. These soft OR methods are also found appropriate for development sector including community, voluntary and not-for-profit organizations, which are abundant in developing economy. The field of OR needs to be expanded by embracing the soft OR methods (Ice cream) with hard OR methods (Apple pie) through collaboration of mathematicians, scientists, engineers, psychologists, sociologists and corporate strategists. An I^3 (Industry-Institute Interface) strategy is suggested to develop and apply the hard-soft composite OR methods which may provide decision supports not only to manufacturing and service corporate sectors but also to community development and government activities in developing nations.

Keywords: Hard operations research methods, Soft operations research methods, Composite OR methods, Industry-Institute Interface (I^3) strategy.

1. Evolution of Operations Research (OR)

Challenges always create opportunities for developing new knowledge. As it is wisely said, "necessity is the mother of invention", the new discipline of management 'Operations Research (OR) methods' developed during the period of Great War in the mid of the 20th century. When more than half of the world population was fighting with each other few scientists on both sides of Atlantic (USA and Europe) were working at their respective military research laboratories for devising some scientific methods to win the war in the situation of their depleting scarce resources. Yes! The field of OR was originated immediate prior to and during the Second World War.

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Isn't it surprising that OR is spelled differently in two sides of the Atlantic sea: operations research in USA and operational research in UK. More than this, other many nomenclatures are also used for OR like management science, scientific decision models, optimization techniques, quantitative techniques for management and many other similar terminologies. Some researchers are still ready to discuss on different nomenclature for OR. Whatever may be the names, those who are practicing OR are more or less in agreement that *"OR is finding out optimum or near to optimum solution(s) for fulfilling objective(s) of stakeholder(s) through analyzing interrelated complex real world situation having constrained resources.*" Among modern management academia and corporate world, OR is one of the buzzwords for a complex mathematical model having limited application.

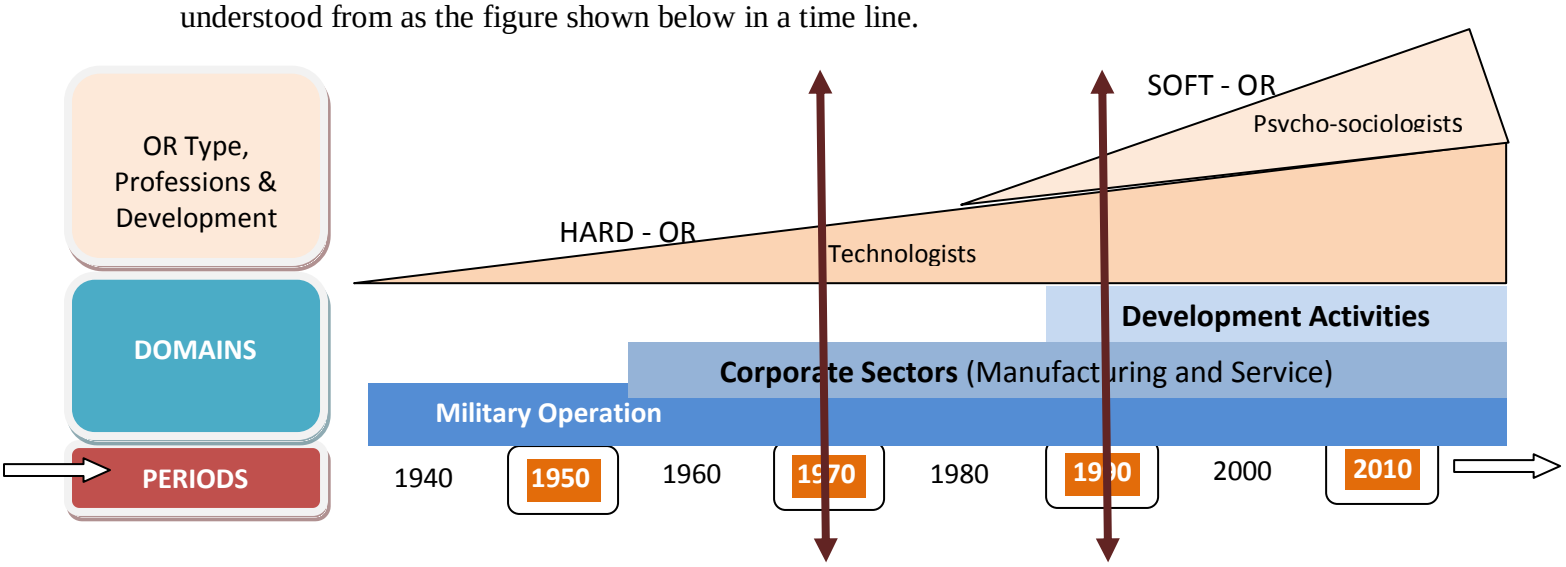
OR, initially was defined, developed and implemented by various scientists and technologists individually or in a team from the field of physics, biology, chemistry, mathematics, statistics, mechanical, electrical and communicating engineering. The term OR seems to be conceived for the first time in 1938, as a descriptive term for the use of scientists to assess, at first hand, military situations and the deployment of devises therein. During the war OR sections were set up in various branches of the British armed forces and then after also in the military services of the USA and Europe. Professor P.M.S. Blackett, Nobel laureate of Physics (1948) from UK, was one of the first scientists to define the essential elements of OR. In 1941 he wrote a Report on OR which is considered by many OR scientists to be the original definition of OR, which in essence says that the scientists apply scientific methods of analysis of operational data and be able to give useful advice to operational staffs. In the USA, Dr. Philip M. Morse, also Physicist and administrator, is considered as the father of OR who organized the Anti-Submarine Warfare Operations Research Group (ASWORG) for the US Navy early in 1942. In 1951, he co-authored *Methods of Operations Research*, the first OR text book in the USA with George Kimball based on the experience of Navy work.

In April 1948, the Operational Research Club was established in London (UK) chaired by Sir Charles Goodeve. It can be said that this club is the first OR association in the world. Five years later the OR Club became the OR Society. The first issue of the Operational Research Quarterly (ORQ) was published in March 1950, published continuously till 1978. Then the quarterly was renamed as the *Journal of the Operational Research Society* which is one of the prestigious journals in the field of OR till now. The Operations Research Society of America (ORSA) was established in 1952, with Dr. Phillip M. Morse as its founding president. And, the same year the first edition of its flagship journal *Operations Research* was published. While ideological confrontation of the 1930's gave birth to Operational Research, IFORS was born some 20 years later out of professional cooperation. The first International Federation of Operational Research Societies (IFORS) conference, held in Oxford in 1957, was in the history making of OR. IFORS officially came into existence in January 1959. Within two years of the formation of IFORS, the three founding members, United States (ORSA), United Kingdom (ORS), and France (SOFRO), had been joined by a further seven national societies. Currently, about 50 active member societies make up the IFORS family. It is never easy as well as wise to enlist the list of OR journals published these days. Each national OR society and university publishes journals on OR discipline. Some of the most widely referred journal published in English language for operations researchers may be listed as European Journal of Operations Research, International Journal of Operations Research, OR/MS Today, OMEGA, Management Science, Journal of the Operational Research Society and Inside OR.

After the war, in peace and development era, the OR professionals thought of creating more of these new scientific (mathematical) approaches of tackling complex operational problems

to provide benefits to the society and promoting these knowledge by including in the field of study and apply it in civil activities.

The phenomena of development and promotion of OR field is still continuing and will continue in future, too. We find the development status of OR in a new paradigm which is different than the period of Great War. The trend of OR development and application can be understood from as the figure shown below in a time line.



OR methods which were developed during the War period were applied in the military domain naturally to achieve the goal of winning the war. Immediately after the war, OR scientists at UK, USA and other European countries started to assemble and organize OR clubs, OR societies and OR groups to create and promote this new but very useful mathematical optimization tools in the corporate sector, especially in manufacturing, mining and service industries. The period from late 30s to 70s is said to be a golden age of OR when many scientists, mathematicians and technologists from many parts of the world continuously worked to develop various OR methods, models, techniques and algorithms to formulate the real world problem and provide solutions to the corporate sectors. Societies started grooming up, academic courses were extensively conducted at many universities, and professional journals were published and circulated in massive way. From this time, OR has been taken as a special discipline of decision science for management.

However, from 1970s, operations researchers worldwide started questioning the basic foundation of the discipline of OR. Critical thoughts on OR started among the operations researchers as well as corporate executives. Professionals started to question the applicability of the mathematical OR methods, calling it as the hard OR. Psychologists, sociologists enter into this debate denying the capability of OR methods for actual formulation of the real world problem and its applicability for accurate decision making. The future of OR seemed critical from 1970s to 1990s and so can be said as a critical age of OR. The article titled "OR/MS: Dead or Dying? Rx for survival" (Hall & Hess, 1978) and "The future of operational research is past" (Ackoff, 1979) posed a big question among researchers on the validity of OR for addressing the messy, unstructured and complex problem of the existing real world situation. However, new approaches of addressing the process of problems solving were initiated through thinking systematically and structuring problems considering perceptions of all stakeholders impacting to and affecting by the problems. The computer capability in terms of memory and speed improved exponentially in 70s to 90s and OR researchers felt very comfortable even to solve the mathematical hard OR models. The field of OR then widened

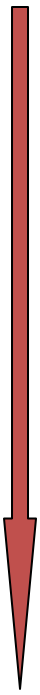
its area of study as well as application by incorporating psychologists and sociologists in OR profession and developing various problem structuring methods which then are termed soft OR. These soft OR then were applied in emerging developing activities, consisting of voluntary activities, government and non-government activities, and social activities.

From 1990s, the field of OR is re-defined to cope the emerging problem of less-applicability of hard OR methods in the messy situation by embracing soft OR methods. In one hand, technologists and scientists are improving the practicality of hard OR methods, in other hand, sociologists, and psychologists are working to improve the soft OR methods to structure the messy problems of the present day situation. Presently, the discipline of OR is widened with hard and soft OR together to cope the problems of military operations, corporate sectors as well as development activities. The article "Recent developments in OR" (Ittman, 2009) rightly explains the evolution of OR may be used for reference.

2. Classical Operations Research Methods: Hard OR

The classical Operations Research (OR) methods is mainly concerned with analyzing complex operational problems and helping decision makers to work out the best means of achieving some objective(s) set by the organization. OR methods generally consist of modeling real world problem, its mathematical formulation and the algorithm to devise the optimum or near to optimum solutions for decision making. OR methods uses tools from a wide variety of disciplines including statistics, mathematics, and engineering and is now applied not only to military problems, but in corporate and development problems, too.

Crudely, one can list out six major steps in application of OR methods. This can be shortened or elaborated as per the need of the situation and the problem to be tackled as well as the wish of the operation researchers.



Step 1 **Formulation of the Problem**	The operations researcher gathers sufficient information to understand the organizational climate, objectives, expectations and resources available.
Step 2 **Develop the Model**	The operations researcher then expresses the problem as a model that represents the systems, processes and environment as equations, relationships or formula.
Step 3 **Select and Collect Data Input**	The operations researcher must then ensure they have sufficient data input to operate and test the model.
Step 4 **Solution to the Model**	The operations researcher then finds a solution to the problem which invariably involves considerable updating and modification.
Step 5 **Validation of the Model**	The operations researcher must ensure that the model is valid for a reliable prediction of the system, performance and be applicable over the time.
Step 6 **Implementation**	The operations researcher then should work closely with management to play a positive role in implementing the solution.

Examples of most widely used classical hard OR methods and their brief explanations are as follows.

- **Linear Programming**
  Linear Programming is a mathematical technique of assigning a fixed amount of resources to satisfy a number of demands in such a way that some objectivity is optimized and other defined conditions are also satisfied. There are many versions of linear programming problem. Transportation and assignment problems are two of them. Linear programming is the one which is most widely used in corporate sector. The simplex algorithm which is used in solving the complex mathematical formula was developed by George B. Dantzig early in 1947 in a military setup. The Linear Programming (LP) model actually revolutionize the OR world.
- **Queuing Theory**
  It is a theory to help calculate the expected number of people in a queue, expected waiting time, expected idle time etc. This theory is applied to situations where measures have to be taken to minimize the extent and duration of a queue with minimum investment cost. Mr. Agner Krarup Erlang is given the credit to formulate the Queuing theory back in 1909 to describe the Copenhagen telephone exchange. The Queuing theory is recognized as one of the important methods of OR by the operation researchers after the OR field is defined in 1950s.
- **Game Theory**
  It is a theory used for decision-making under conflicting situations where there are one or more opponents, with different objectives, that each influences the outcomes of the game. Game theory provides solutions to the games based on the assumption that all players want to maximize their profits and minimize losses. During the World War II, Mr. John Von Neuman invented this Game theory.
- **Simulation**
  It is a technique that involves setting up a model of a real situation and then performing experiments to learn more about a situation. There are various methodologies for developing simulations model.
- **Markov Process**
  It is a technique used in situations where various states are defined and the system moves from one state to another on a probability basis. The technique allows researchers to calculate the probability of being in a particular state.

This is just a limited list of most widely used classical OR methods. There are many other mathematical or quantitative OR methods as well as there are several versions of each OR methods besides these depending on the suitability of problem formulation and solution. Inventory models, dynamic programming, machine scheduling problems, PERT/Critical Path methods and network theories like spanning tree, flow analysis, shortest path problems are some of widely used classical OR methods.

Talking about the applications of OR methods in industrial set up, OR are found used in almost all functions of industry. As for example, location and size of warehouses, factories, retail outlets, distribution policy, loading and unloading facilities for trucks, production scheduling, optimum product mix, project scheduling and allocation of resources are some of the problems that can be solved by applying OR methods in production management function. Credit policy analysis, cash flow analysis, dividend policies, investment portfolios in finance, budgeting and investments functions. Product selection, timing, advertising media, budget allocation, number of salesman required, selection of product mix are some of the problems that can be solved by applying OR in marketing function. Optimal buying and

reordering, replacement policies are some of the problems that can be solved by applying OR methods in purchasing, procurement and exploration functions. Selection of suitable personnel, recruitment of employees, assignment of jobs, skills balancing are some of the problems that can be solved by applying OR methods in personnel management function. Project selection, control of R&D projects, reliability and alternative design are some of the problems that can be solved by applying OR methods in research and development functions. Again, these are not the exhaustive lists of application.

These traditional or classical OR methods described above for solving various decision problems have in recent times termed as hard OR methods. The word "hard" refers to the use of mathematical and quantitative techniques as opposed to softer research that employs predominantly qualitative techniques. More than this, the hard on distinction can be made also in terms of OR's primary and secondary foci. All the above described OR methods are focusing primarily on the problem, the people involved who create the problem or implement the solution are kept in the secondary focus.

3. Critical Scrutiny of Hard OR Methods

If applied properly the hard OR methods in an organization, it will provide better control, better systems, better decisions and better co-ordination.

- Better Control: The management of large organizations recognizes that it is a difficult and costly affair to provide continuous executive supervision to every routine work. An OR approach may provide the executive with an analytical and quantitative basis to identify the problem area. The most frequently adopted applications in this category deal with production scheduling and inventory replenishment.
- Better Systems: Often, an OR approach is initiated to analyze a particular problem of decision making such as best location for factories, whether to open a new warehouse, etc. It also helps in selecting economical means of transportation, jobs sequencing, production scheduling, replacement of old machinery, etc.
- Better Decisions: OR models help in improved decision making and reduce the risk of making erroneous decisions. OR approach gives the executive an improved insight into how he makes his decisions.
- Better Co-ordination: An operations-research-oriented planning model helps in coordinating different divisions of a company.

However, the hard OR methods have some limitations, too. Like dependence on an electronic computer, non-quantifiable factors, distance between manager and operations researcher, money and time costs and implementation.

- Dependence on an Electronic Computer: OR methods try to find out an optimal solution taking into account all the factors. In the modern society, these factors are enormous and expressing them in quantity and establishing relationships among these require voluminous calculations that can only be handled by computers.
- Non-Quantifiable Factors: OR methods provide a solution only when all the elements related to a problem can be quantified. All relevant variables do not lend themselves to quantification. Factors that cannot be quantified find no place in OR models.
- Distance between Manager and Operations Researcher: OR being specialist's job requires a mathematician or a statistician, who might not be aware of the business

problems. Similarly, a manager fails to understand the complex working of OR. Thus, there is a gap between the two.

- Money and Time Costs: When the basic data are subjected to frequent changes, incorporating them into the OR models is a costly affair. Moreover, a fairly good solution at present may be more desirable than a perfect OR solution available after sometime.
- Implementation: Implementation of decisions is a delicate task. It must take into account the complexities of human relations and behaviour.

As written previously, the linear programming (LP) model is one of the most widely used OR method having simple formulation with mathematical equations and effective algorithm to solve them. However, it is difficult to derive the solution manually if there are many variables in objective function and lots of constraints. However, the advancement in the capability of computer in terms of memory and speed and efficient software, now even larger linear programs can be solved dramatically in manageable time. A new solver CPLEX was developed and today it is possibly the most well known code for solving large linear programming problems.

Similarly, the classical and the in-famous OR method like the travelling salesman problem (TSP) has attracted the attention of many mathematicians and computer scientists challenging them to find out algorithms for solving it efficiently. Enumerating all possible routes and finding out the route which cost minimum is really an arduous work to OR professionals. Just think of TSP with 50 cities, total routes one has to enumerate will be (50-2)! that equals 12,413,915,592,536,072,670,862,289,047,373,375,038,521,486,354,677,760,000,000,000 different routes. Solving large TSP would have been impossible if it were not for computing power and sophisticated algorithms used. This advance in algorithms and computer power now allows many other complex, large and data rich problems.

The ultimate purpose and joy of an OR practitioners is to see the implementation and realization of the benefits anticipated of the solution he purposes in a real life context. But, if the problem cannot properly be formulated or modeled with quantifiable data, and even it is conceptualized and modeled properly but cannot be solved, then how can it be implemented?

In 1970s, 80s and 90s the limitations of classical OR became particularly evident. Those limitations actually were not related to the correctness or validity of the methods employed, but rather to the applicability of quantitative methods for many real world problems. It is a fact that mathematics has a much more limited role to play in operations research than many believed that time. Criticisms started coming up from many corporate managers and even OR professionals that threatened the significance of the OR discipline. Many started visualizing the lack of future to OR professionals. After more than three decades of its creation the discipline of OR saw its dark future. Application of OR in corporate sector had expanded into many areas but it had become increasingly mathematical, concentrating still on shop-floor or operational activities.

Here, I like to present my own experience of OR practice in Nepal, during 1980s. I have always a fond of mathematics since my schooling. I loved calculus and statistics, loved working with imaginary numbers and logic. I learned computer programming language in 1970 and worked in IBM 1401 for the National Census 1971.

- **Article Publication:** In 1981, as an initiation to OR discipline in my career, I published one article “Introduction of Operations Research”, a basic introductory article stating various types of OR models and their applications in a local journal of

Nepal Engineering Association (NEA). Thus, my career started as operations researcher.

- **Linear Programming Application:** That time, I was working as a mill manager in jute mill where I tried my first operations research work. Naturally, I tried a simple linear programming problem to identify product mix (jute hessian cloths and sacks of different specifications) subject to constraints (market demand, weavers and jute yarns). A simple OR modeling which I use to solve by hands without any difficulty and started allocating the weekly product mix in the mill. Good enough. I was totally motivated and tried to sell the concept to all my colleagues. I thought I can go ahead with this wonderful mathematical modeling.
- **Dynamic Programming:** Next, I tried a dynamic programming model for purchasing raw jute through forecasting the prices which has a seasonal fluctuation depending on the production and demand of the market. The CEO of the mill, naturally, did not like my idea and calculations. He had his own guts feeling for forecasting and purchasing jute. He used to say that we cannot make our decisions based on mathematics. The market is uncertain. Besides, he said our jute purchase is not only for jute mill production but also for jute trading. I was convinced with my model, but I could not apply it in the real world decision making. But I used my exercise. I published it as an article in the journal of the central department of management in Tribhuwan University.
- **Network analysis:** One of my cousins was working in operations department of Royal Nepal Airline Corporation (Nepal Airlines now). He was just talking once to me about scheduling of flights in various parts of the country is one of the most tedious and blame taking job. Suddenly my interest of OR came forward and I told him that OR has some optimizing methods of scheduling, and if you give me chance, I can help you, voluntarily. I told him, the job is only mathematics, it can be solved with the help of computer (that time there was no computer in RNAC), and people can blame you for the results. He agreed. In 1983, there were 36 airports in the country from east to west, north to south. I used the gravity model to forecast the demands of passengers flying from one city airport to another city airport. I used the Shortest Path Problem (SPP) to determine the minimum time of travelling and fuel cost with the constraints of travelers demand and fleets. The result was interesting- the concept of hub generated, and now we can see that the concept worked with Biratnagar and Nepalgunj as hub centers of flying. To solve the problem I used about one thousand lines of FORTRAN computer programming. There was only one computer centre that time, the National Computer Centre. I used that centre for solving the network problem. The implementation of scheduling programme through optimization model, however did not work sustainably because of the pressures from politicians. However, hub concept developed.
- **Survey on OR application:** In 1983 itself, I thought of doing a national survey on the status of applications of OR in Nepal. With a simple survey questionnaire having questions regarding application level of eleven OR methods, I visited major factories at industrial cities and management schools of Tribhuban University (the only university that time. Not to my surprise, I found no one in business were using OR methods and the simplex and graphical methods of linear programming were popular among many other OR methods in colleges. After knowing the status of OR applications in the country, I dropped the idea of writing a paper, as the data was almost nil. I did not know that in other parts of the developed world, that time people were criticizing on the purpose and applicability of OR. So, sorry!

- **OR Multi-model Software:** However, I tried once again in 1986 to apply OR in a paper mill where I was working in a top management position. I developed a simpler and tailor made software using Basic language to determine the best product mix, best process planning and best purchase requisition. By that time my interest was growing in JIT (Just in Time Production) system. We wanted to purchase only those items which we can consume immediately after arrival and produce only those items which we can dispatch immediately after production. Simple enough. The software was loaded in the IBM personal computer and the decision making were very much successful. We actually launched "No Store Factory" slogan. May be the application of JIT in paper mill was the first experiment in Nepal. The paper industry could reduce the cost of production from Rs. 23 per KG that time to Rs. 16 per KG within a short period of six months. The experiment was nothing but combining the concept of JIT with the development of software with OR methods.

I learned three things from the above experience with OR methods.

1. The mathematical formulation should be so simple that those all involved should understand clearly. Naturally, it will be difficult for non-mathematical people to understand. OR experts sometime forget about this. OR practitioners should make it simple and/or otherwise translate it in a simpler form and make aware to all implementers- not only operational level but also to strategic level.
2. OR practitioners should take confidence of all stakeholders who will be affected by the decisions made through OR methods from the very beginning of OR formulations, data collection to OR application.
3. OR methods are only tool and techniques and not a complete management mantra. Some alternatives should be developed to compromise the external environments of the organization, such as economic, political, technological and social factors and make decisions based on these alternatives.

However, in this critical period of OR- i.e., 1970s to 1990s, through much soul-searching about the limitations and assumptions of OR, a richer and deeper understanding of OR and its process came about. Many realized that the use of OR is not well understood and OR is very difficult to describe. People started discussions on how to efficiently and effectively market the profession of OR to the customers who are not mathematically oriented. The focus was on developing more people oriented OR methods and communicating or marketing the value of OR in much understandable way. People oriented soft OR were developed and practiced. By 1990s, the world started defining new approach of OR, not dismantling the classical mathematical oriented OR, but adding on it with the people and system oriented neo-classical OR methods (Rosenhead,1996), Checkland, 1999, Abdel-Malek et al 1999).

4. Neo-classical Operations Research: Soft OR

The critics of OR methods during the 1970s and 1980s emphasized that OR practice was more than formulating a mathematical and logical model and that optimality was not everything. Many problems could not be solved with the OR tools and techniques available at the time. The question that re-occurred was how to go about solving problems with very little structure or messy problems. Operations researchers mainly in Europe started developing methods that became known as Problem Structuring Methods (PSM) (Rosenhead, 1996). These efforts endeavoured to find approaches which were more appropriate for addressing less structured problems. Many of these methods were conceived in the late 1960s and during the 1970s. However, it was only during the late 1980s and 1990s that they grew in sophistication and became better known as soft OR methods. PSMs are a broad group of

problem handling approaches with the purpose of assisting in the structuring of problems rather than directly solving them. The whole idea with these methods is for them to be participative and interactive in character. These are the methods to address the wicked and messy problems leading to the identification of those factors and issues which should constitute the agenda for further discussion and analysis. An alternative paradigm was therefore established to address problems that were not well suited to optimization approaches (Ittmann, 2009 and Heyer 2004).

Examples of few most widely used neo-classical soft OR methods and their brief explanations are given below:

- **Soft System Methodology**

  This is probably the most widely used soft system thinking approach for problem formulation. SSM works by defining systems of purposeful activity (the root definition), building models of a number of relevant systems, and comparing these models to the real world, in order to structure a debate focusing on the differences. The idea is that this debate should lead the group involved in the process to identify changes to be made, how they will be made, and motivate each other to make the changes. This is a people oriented interactive approach. There are several stages in SSM, not necessary followed in a linear fashion (Checkland, 1999).

Confronting the Problem Situation	Entering the problem situation and identifying within it the people, culture and norms through interviews and discussions, observations, brainstorming and rich pictures to identify relevant themes and ensure a shared understanding of different perspectives.
Developing Root Definitions	Writing root definition which is a sentence that describes the ideal system: its purpose, who will be in it, who is taking part in it, who could be affected by it and who could affect it. Customer, Actors, Transformation process, Worldview, Owner, Environmental factors (CATWOE) technique is employed to formulate the root definition.
Building a Conceptual Model	Drawing a model which is a diagram of activities with links connecting them is developed directly from the root definition using action statements describing the activities which are needed by the root definition.
Comparing Models with the real world	Discussing on the model is done by comparing it with the real world by ordered questions for every activity and link in the model. Group members are asked: does this happen in the real situation?, how?, by what criteria is it judged?, is it a concern in the current situation?
Identifying Changes	Identifying systematically the desirable and culturally feasible changes to the real world system, that appears to those involved in the SSM process as worth trying.
Taking Action	Putting the changes identified in the above Stage into practice, usually through the development and enactment of an action plan.

- **Cognitive Mapping**
  Cognitive mapping, a form of influence diagram, is a technique that has been used by a variety of researchers in a variety of settings. Cognitive maps provide a holistic picture of an individual's overall perspective, without the loss of any detail; enabling researchers to move beyond the assumption of internal consistency to the detailed assessment of specific concepts within the map. For OR, this means gaining a better understanding of the client's perception of a problem which is vital for a successful OR study. In cognitive mapping, self-defined constructs represent the 'causal knowledge' of a decision maker in the form of a map of their own subjective world. Cognitive maps can be seen as a model of action-orientated thinking about a situation where arrows signify influences in a line of argument linking cause and effect.

- **Robustness Analysis**
  Robustness Analysis (RA) provides an approach to the structuring of problem situations in which uncertainty is high, and where decisions can or must be staged sequentially. The specific focus of RA is on how the distinction between decisions and plans can be exploited to maintain flexibility under uncertainty (Rosenhead, 1996). RA does this by identifying early decisions which allow a range of options and therefore add a degree of flexibility to the decision-making process. The result is a list of possible decisions rated in terms of their robustness against a variety of projected futures.

- **Meta-game analysis**
  Meta-game analysis is an interactive method of analyzing cooperation and conflict among multiple actors. Analysts elicit from actors various decision options which are then used to construct possible future scenarios. Threats and promises are then used to explore both the researchers and actors abilities to stabilize the outcome at a more preferred scenario to determine the most credible scenarios.

- **Hyper-game analysis**
  Hyper-game analysis is another interactive approach which focuses on complex problems in conflict situations that are under the partial control of multiple actors. Hyper-gaming explores the pattern and nature of interactions between the actors and the effects of the differences in perception between the actors regarding their preferences between different outcomes and actions. Having established these preferences they can be mapped and analyzed to determine what the best courses of action would be to take in conflict situations.

This is just a limited list of most widely used neo-classical OR methods or soft OR methods. There are many other interactive and qualitative OR methods as well as there are several versions of each of these soft OR methods besides these depending on the suitability of problem formulation and solution. Involvement of Sociologists, psychologists are mostly involved to formulate and come to identify viable better options for decision making. As the problems of real world is becoming more and more complex, and the development sectors are becoming more prominent with world pressure on human values and globalization, soft OR are more preferable than the hard OR.

Soft OR methods considers at the different perspectives of the stakeholders of the problem and is simple enough to convince and define the problem in front of all stakeholders. Soft OR methods are co-constructive method and not an expert only methods. Managing change is easier through soft OR methods than by hard OR methods because all strategic levels and

operational levels are involved in developing models to making plans for changes. Soft methods are crucial when many stakeholders' views have to be taken into account and when the problem is complex in nature. Soft OR methods can be used as a tool to help understand the issues at hand and provide a range of reasonable solutions in how to overcome them.

The table below highlights assumptions made in classical hard OR and neo-classical soft OR methods which clearly explains the differences between these two types of OR methods (Munro & Mingers, 2002).

Hard Operations Research Methods	Soft Operations Research Methods
• There is a single decision maker (or consensual group) with a clear objective.	• There are a range of decision makers or groups with differing or conflicting objectives.
• The nature of the problem is agreed.	• The nature of the problem is not well defined.
• The most important factors in a problem can be quantified and reliable data collected.	• Many important factors in a problem cannot be quantified.
• A model, often mathematical or computer-based, can be used to generate solutions.	• Mathematical models, therefore, cannot be used.
• Future uncertainties can be modeled using probability theory.	• Uncertainties cannot be reduced to probabilities.
• There is no need for the methods used to be transparent to clients and stakeholders.	• The methods used must be transparent and accessible to clients and stakeholders.
• The role of the hard OR specialist is one of expert analyst.	• The role of the soft OR specialist is one of facilitator with a group of participants.
• Hard operations researchers, generally speaking, require good analytical skills and a sound knowledge of mathematics and computing.	• Soft operations researchers, generally speaking, require sound people skills and the ability to facilitate often stressful and contentious workshops.

5. Conclusion

Composite OR methods: the future of OR application

I fully agree with the feeling of Ken Bowen in his article 'Sixty years of Operational Research' when he said "we are all looking for theories of decision aiding rather than theories of decision" (Bowen, 2004).

- The classical OR methods are based on quantitative and objective information used for developing decision making solutions. That is the reason they are called hard OR. Moreover, hard OR methods are problem oriented having complex mathematical

formulations. And, hard OR methods have difficulties in capturing the real world situation, especially at strategic level. But, these hard OR methods are very much useful for optimizing many operational level problems.

- The neo-classical OR methods are based on qualitative and subjective information for facilitating decision makers to make decisions. That is the reason they are called soft OR. Moreover, soft OR are people oriented having system thought formulations. And, soft OR methods have difficulties to really optimize the real world problems, especially at operations level. But, these soft OR methods are very much useful to develop alternative better solutions for problem solving which will be agreed by implementers as well as stakeholders in consensus.
- We need to use both hard and soft OR methods individually and or collectively as the situation demands for decision making. Multi OR methods (Munro & Mingers, 2002) integrating hard OR and soft OR which can also be called **Composite OR methods** can formulate the real world problems capturing the perceptions of all stakeholders as well as can model quantifiable relationships between factors at operational level. This way, the solutions or action plan derived from the composite OR methods will not face any problem in implementing for better change.

If OR theorists and practitioners agree to the importance of both task (problem solving) as well as perception (people) in equal footing for managing the change for betterment, the composite OR methods or multi OR models is the future of OR. Composite OR method may be exemplified as combination of hard and soft OR methods like simulation and SSM, statistics and SSM, statistics and cognitive mapping, statistics and influence diagrams (Abdel Malek et al, 1999, Munro & Mingers, 2002). It will be a new kind of science, not just general interdisciplinary but a rich composite of engineering, science, arts and humanities based both on theory and experience.

OR is not a dying science, but it is flying upward with new wings- Composite of hard & soft OR methods. The analogy of composite OR methods having hard and soft OR methods modeled and served to decision makers is just like a dessert served after dinner- Apple pie and Ice cream. Apple pie is the base of the dessert, hard and warm like hard or classical OR. Ice cream is the topping of the dessert, soft and cool like soft or neo-classical OR methods. Apple-pie with Ice-cream is yummy-eye teasing as well as appetizing, which is a favorite dessert to many.

Strategy for crearion and application of Composite OR methods in Nepal

I propose the I^3 model, or the Industry-Institue Interface collaborating model as a strategic move for creating new knowledge on composite methods for facilitating industries (Chapagain, 2006). As the interface between industries and academic institutions increases it is possible to develop new knowledges appropriate to particular industry. To initiate this strategy,

a. Academic institutions like universities, institutes and colleges need to establish self funding autonomous OR laboratories in their permisses. Institution needs to provide space and educational logistics like computers, networking, journals, printers and others. Professor need to lead the laboratory activities. Students need to work at these laboratories under the supervision of professor for their OR thesis and desertation. As the composite OR methods are more than interdisciplinery field, the professor should facilitate students with a network of interdisciplinery professors as well as industries.

b. Industries need to provide fund for consulting cum research projects to the capable laboratory at the academic institution. The fund thus collected for the project need to be used for particular research works as well as overhead of the laboratories. Industries need to provide opportunities to professors and students for collecting information and work as apprenticeship at their industries. The OR project need to work as a co-construction project, which will be more practice oriented having theoretical base so that any knowledge thus developed will have high applicablity ratio.

Role of ORSN for facilitating the I^3 strategy for OR development

I presume the main purpose of the professional society which is especially devoted to operations research in Nepal, the ORSN, is to create new knowledge on OR, apply the created knowledge in the field for community, corporation and national development, and enhance the knowledge and status of the members and of course market the profession nationally and internationally. Recently, the professional organizations in Nepal is increasing exponentially which shows a voluntary spirit and eagerness of the population to create, learn and share the knowledge as well as desire to uplift the society through their respective professions. Here, I like just to propose the following roles for ORSN to play for facilitating the strategy required for OR development in the nation.

- The professionals working in industries as well as academic institutions both need to upgrade their knowledge on OR regularly and apply the knowledge for their individual as well as institutional development. ORSN needs to motivate the professionals from academic institutions as well as those working in the fields for participating in the activities of ORSN as active members.
- OR professionals in Nepal, whether academicians or users need to learn a lot on the subject of OR - the classical, neo-classical as well as the upcoming views on OR. ORSN needs to organize regular international conferences, inviting distinguished academicians and practitioners as keynote speakers. International papers and national papers need to be invited and provided enough opportunity to exchange ideas. Here, quality must be addressed rather than quantity.
- OR professionals in Nepal need to be motivated enough to sustainably work for the development of OR and compete internationally. ORSN needs to provide enough opportunity to Nepalese professionals to participate in the international conferences organized outside the country and also periodically organize national conferences at different parts of the country.
- All professionals in Nepal may not get chance to attend the international and national conferences. Documentation of knowledge is very necessary for those who cannot attend the conferences. ORSN needs to publish regular referred journal and news letter of OR and distribute to all professionals working in Nepal, members as well as non-members. The knowledge can be the outcome of the researches done inside and outside the country, both. Here, again the quality of papers and articles matters most than the quantity.
- Industries generally may not have the time for creating enough theoretical knowledge. It is the academic institutions that have access and capability and so it is called the knowledge creating industry. However, the industry is the user of the knowledge. ORSN needs to visit industry regularly and develop networking. ORSN needs to provide better solutions for better decision making as well as facilitate the mangers for problem solving. ORSN needs to be a bridge between industry and academic institution for adopting the I3 model of collaboration.

In the end,
I congratulate ORSN and also plead you to prepare and serve the yummy Apple-pie with Ice-cream, the Composite OR methods which is the combination of hard and soft OR methods to promote the OR professions in a developing country like Nepal.

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