Chapter 1

Introductory Chapter: Operations Research

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http://dx.doi.org/10.5772/66835

1. Introduction

Operations research (sometimes referred to as management science or decision science) is a subject that deals with the art of making good decisions under specified constraints. In real life, we are often faced with complex situations for which no simple answer can be found. Thus, the topic of making good decision (operations research) is both intriguing and relevant. Most people consider operations research as a subfield of mathematics. As pointed out below, the criteria of good or bad decisions are often affected by culture, viewpoints, and other factors.

Other than moral issues, there are **two important keys** to make good decisions: **good information** and **the skill of making good decisions** based on the information at hand. By "good information," we mean that all essential factors are captured (tools used to obtain quality information could be verification and validation); by skilled decision making, we mean the application of appropriate solutions to different problems (e.g., to solve well-formed mathematical optimal problems, we use calculus or the simplex algorithm; to solve poorly defined problems, we use empirical trial-and-error methods or ad hoc methods). The subject of operations research covers both the acquiring of "good information" and "the skill of making good decisions." **Figure 1** shows the relationship among these entities.

Depending on the problem domain, decision-making skills can be regarded as either a science or an art. When a problem is a well-defined mathematic problem, we are able to use scientific methods such as calculus, linear programming, integer programming, dynamic programming, and simplex algorithm; on the other hand, when a problem is poorly defined, we can only use trial-and-error methods, heuristic methods, or ad hoc methods. Since trial-and-error methods and ad hoc methods are non-repeatable, they are regarded as art. Making a good decision under multiple constraints (especially where different criteria are involved) is never easy; the topic of operations research is not easy and has a lot of variations.

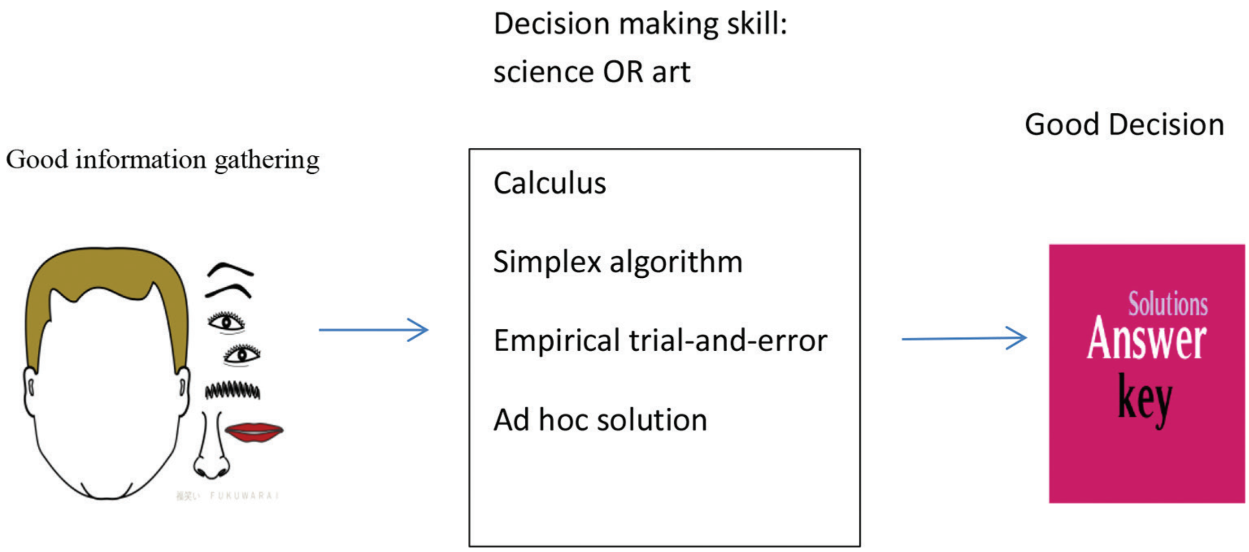

Figure 1. The relationship among obtaining information, decision process, and tools.

In this book, we cover a wide range of applications that employ a variety of decision-making skills (including problems that are poorly defined). Therefore we subtitled the book as "an art of making good decisions."

Since decision making is an essential part of our life, the application of operations research covers a wide range of areas such as military, business, mathematics, and resource allocation among competing parties, just to name a few.

When focusing on decision making, operations research has a long history.

2. History

Chinese people used good decision-making strategies to military more than 2000 years ago. In the book "Master Sun's Art of War" by Master Sun (also called Sun Tzu), important aspects of warfare are summarized into 13 chapters. The essence of the book is the strategies of how to motivate soldiers and leverage tactical advantages (win the battle of wits). The first chapter of the book talks about "Detail Assessment and Planning," and the last chapter of the book talks about "Intelligence and Espionage." From the available evidence, we know that the book was completed sometime between 500 and 450 BC. Some of the well-known strategies are as follows [1]:

> 故曰:知彼知己, 百戰不殆;不知彼而知己, 一勝一負;不知彼, 不知己, 每戰必殆。
>
> *So it is said that if you know your enemies and know yourself, you will not be put at risk even in a hundred battles.*
>
> *If you only know yourself, but not your opponent, you may win or may lose.*

If you know neither yourself nor your enemy, you will always endanger yourself.

This has been more tersely interpreted and condensed into the Chinese modern proverb:

知己知彼, 百戰不殆。 *(Zhī jǐ zhī bǐ, bǎi zhàn bù dài.)*

If you know both yourself and your enemy, you can win numerous (literally, "a hundred") battles without jeopardy.

Other two high-order thinking of military campaign contained in that book are the following [2]:

*"The supreme art of war is to subdue the enemy without fighting."***—Sun Tzu, The Art of War**

"If your enemy is secure at all points, be prepared for him. If he is in superior strength, evade him. If your opponent is temperamental, seek to irritate him. Pretend to be weak, that he may grow arrogant. If he is taking his ease, give him no rest. If his forces are united, separate them. If sovereign and subject are in accord, put division between them. Attack him where he is unprepared, appear where you are not expected."—**Sun Tzu, The Art of War**

The effectiveness of Master Sun's idea is well tested. At his time, Master Sun helped the warlord of his state Wu to defeat the much stronger enemy state Chu. Even today, many people benefit from the strategies of Master Sun. The following episode is taken from the History website and illustrates the point [3]:

Ever since The Art of War was published, military leaders have been following its advice. In the twentieth century, the Communist leader Mao Zedong said that the lessons he learned from The Art of War helped him defeat Chiang Kai-Shek's Nationalist forces during the Chinese Civil War. Other recent devotees of Sun Tzu's work include Viet Minh commanders Vo Nguyen Giap and Ho Chi Minh and American Gulf War generals Norman Schwarzkopf and Colin Powell.

Meanwhile, executives and lawyers use the teachings of The Art of War to get the upper hand in negotiations and to win trials. Business-school professors assign the book to their students and sports coaches use it to win games. It has even been the subject of a self-help dating guide. Plainly, this 2,500-year-old book still resonates with a 21st-century audience.

People around the world have been using optimization for a long time. For example, the sizes of some jade items excavated from Han dynasty's bury sites in China are optimal in terms of their surface areas vs. their weights. Ancient Egyptians built remarkable structures called pyramids as shown in **Figure 2**.

These types of structures were built with the correct proportion and angle, which is 52.606° for their top angle. When a pyramid is built that way, it will preserve certain energy. Some interesting aspects of pyramids discussed by the website are as follows [5]:

Some of the effects are:

Food kept under the pyramid will stay fresh for two to three times longer than uncovered food. Artificial flavorings in food will lose their taste, but natural flavors are enhanced.

Figure 2. A picture of pyramids [4].

The taste of foods change; they become less bitter and acidic.

When we take a spectrographic reading of the treated item, it will show a change in the molecular structure.

The pyramid will dehydrate and mummify things, but it will not permit decay or mold to grow on them.

There is also a slowing or complete stopping of the growth of microorganisms.

Kirlian photographs of human subjects show the aura to be significantly brighter after a 15-min exposure period.

Pyramid research:

Bill Kerell has been a pyramid researcher for about 17 years. He has performed many experiments using brine shrimp. Brine shrimp usually live for 6 to 7 weeks, but under the pyramids, Bill observed that brine shrimp can survive for over a year. He also noticed that pyramid-grown shrimp grew two to three times larger than the normal ones. Bill has also conducted a lot of researches with humans.

Bill and his associates also have found that hypertensive individuals become tranquilized, but lethargic people become energetic again.

All these show that humans have been using the knowledge of optimization for a long time and some of their creations are still not fully understood and still have research value for us.

However, "the first formal activities of Operations Research (OR) were initiated in England during World War II, when a team of British scientists set out to make scientifically based decisions regarding the best utilization of war materiel. After the war, the ideas advanced in military operations were adapted to improve efficiency and productivity in the civilian sector" [6].

3. What is a good decision?

In this section, we will answer the question "what is a good decision?" At a first look, it appears simple. But, when taking a closer look, you will find that the answer is not so simple. First, before you are able to answer the question, you have to understand the concept of decision criteria. Second, you need to understand the dynamics of requirements, relationships between natural laws and decision criteria, the point of views, and the culture. Third, when moral is involved, there is no simple binary answer, and instead, it becomes a philosophical answer.

In decision science, a criterion is a reference yardstick against which the quality of a decision is measured. If the criterion is met, the decision is good; otherwise, the decision is bad. Now, you may wonder: how decision criteria are made.

3.1. Relationship between natural laws and decision criteria

Whether you admit it or not, in this universe, there are a lot of natural laws in existence and these laws affect our decision-making processes. The effects of natural laws manifest themselves by rewarding those decisions conforming to the laws and punishing those decisions violating them. Throughout the years, people create decision criteria with natural laws in consideration. In fact, natural laws determine and affect decision criteria. For example, when standing on the surface of the earth, we will feel something pulling us down and we call this non-visible force "gravity." The law of gravity helps to produce decision criteria that avoid fall but favor safety.

One directional passing of time makes death irreversible. This will produce decision criteria that favor life but recoil from death.

Another example is the conservation law. In a closed system, we cannot create something from nothing nor can we destroy something and make it disappear; we can only change its existing form from one to another. Criteria nurtured by this law are the human disposition toward resource saving and refraining from wasting. When applying criteria derived from the conservation law, we position ourselves to problems that exhibit themselves as optimal problems. This is why most people think operations research is equal to optimality finding. As you can see, in reality, operations research (or decision science) is more than that.

One natural phenomenon that interests us is the randomness. This phenomenon expresses itself in different ways: when generating a random number, tossing an unbiased die, or flipping a fair coin. It manifests itself as if there were a designer of this law in the universe who is fair. Anyone with a clear mind, regardless whether he or she believes there is a designer or not, would have faith that the number of heads he or she would get when flipping a fair coin is approximately half of the total tosses, given that the number of try is large. It is this subconscious belief that affects our statistic criteria.

3.2. Decision criteria are affected by cultures and view points

Decision criteria are affected by cultures. By culture, we mean the norms of a community and its sanctioned customs. As we are brought up in a community, we carry the fingerprints of that community. These fingerprints will be reflected in our decision criteria. For example, most of Chinese will not donate their body parts after their death. The mainstream Chinese culture values whole body (the belief of reincarnation and a perfect body in the next life cycle). As a result, you will hardly see a Chinese who selects organ donation on the back of his or her driver's license.

In terms of viewpoints, I will use the following true story to illustrate their effects on decision criteria:

In ancient China, there was a period called "Spring and Autumn" (771-476 BC). During that time, there were two opposing states Wu (the state king is named Fuchai) and Yue (the state king is named Goujian). The king of Yue was captured and humiliated by the king of Wu. After returning to his state, Goujian (the king of Yue) vowed revenge. One of his high-ranking officers named Weng Zhong conceived 10 strategies to weaken and destroy the enemy state Wu. In fact, he only used 3 of his 10 strategies. By the end of his third strategy, the enemy state Wu was destroyed and the king Fuchai was captured and killed.

Now, let's take a look at one of Weng Zhong's strategies: causing famine in Wu. In one autumn season, Weng Zhong picked tons of high-quality un-threshing rice (rice with skin so they can be used as seeds for next year) freshly out of the rice fields. He secretly steamed them and made them inert. Then, he gave these rice to the enemy king Fuchai as a token of obedience. Sure enough, Fuchai took the bait and asked the farmers of his state to use these high-quality rice as the seeds for next year's crop. Thus, a big famine ensued in Wu the following year.

To judge Weng Zhong's famine-causing strategy, we will have different results depending on how you look at it. It would be an effective and good decision if you are from a view point that wants Wu to be destroyed; on the other hand, it would be a bad one if you are judging it from the conservation law's point of view or from Fuchai's point of view.

3.3. Decision criteria are affected by the requirements

When talking about good decisions, we need to be aware of the requirements attached. In many problems, the same objective variable will take different optimal values when the requirements are different.

For example, let us assume that we have a wire with length of 10 inches. and we ask the following two questions (see **Figure 3**):

1. What is the largest area that can be formed by using this wire (given that you can use any two-dimensional shapes)?

http://dx.doi.org/10.5772/66835

2. What is the largest area that can be formed by using this wire (given that you can use any different rectangular (including square) shapes)?

Answer 1: From the knowledge of algebra, we know that the circle will give us the maximum area. The problem boils down to solving the following two equations:
$D\pi = 10$
Area $= \pi D^2/4$
Thus, we get area $= \pi D^2/4 = [\pi(10/\pi)^2]/4 = 100/4\pi = 7.96$ inch^2

Answer 2: From the knowledge of algebra, we know that the square will give us the maximum area given that the shape must be rectangle. The problem boils down to solving the following two equations:
$4b = 10$
Area $= b^2$
Thus, we get area $= b^2 = (10/4)^2 = 6.25$ inch^2

As you can see, these two problems have the same optimization objective variables, but we get different results because of the different requirements. Thus, we conclude that the requirements in a decision problem play important roles.

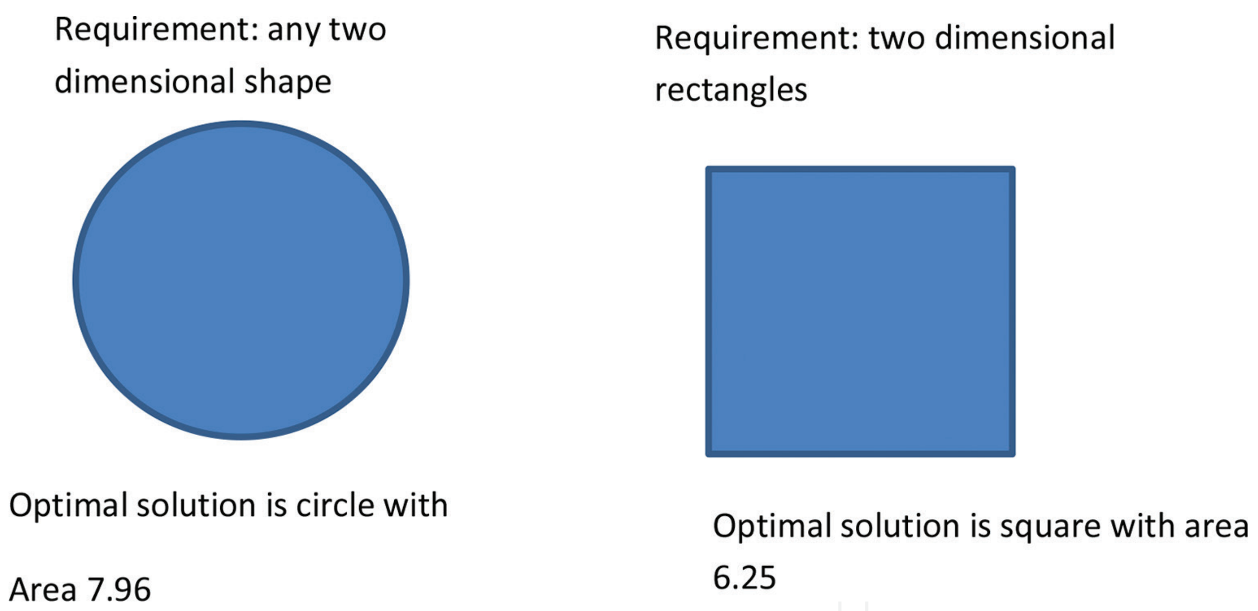

Figure 3. The effects of requirements.

3.4. Decision criteria are affected by moral beliefs

People are often faced with situations in which there are no right or wrong answers. We usually call these moral dilemmas. The criteria used here are mainly affected by a person's moral beliefs. For example, when a doctor is treating a terminally ill patient suffering from pain, the decision of whether to prescribe pain-relieving drugs such as Marijuana or morphine is affected by his/her belief system. Depending on how strongly he/she feels (pain vs. controlled drugs), the doctor acts accordingly to what he/she thinks appropriate (meeting his/her decision criteria).

Allowing a terminally ill patient to die at his/her will is also a decision affected by moral beliefs. When morals are involved, decision criteria are complicated since we are carrying the whole baggage of our belief systems. A lot of times, there are no simple answers (we only see and pick aspects that make us comfortable—beauty is in the eye of the beholder).

4. Overview of the chapters

In this book, we have carefully selected a set of manuscripts that are written by authors from different backgrounds. The selected articles have a broad spectrum of topics ranging from theory to application. On the other hand, all the topics are centered on the main theme of making good decisions. Thus, readers get the benefit of wide exposure to the ins and outs related to the subject. In the following, I will give you a brief introduction to each of the remaining chapters.

Chapter 2 "Improving Informational Bases of Performance Measurement with Grey Relation Analysis" written by Thorben Hustedt, Ossadnik Wolfang, and Burrey Fabian. The main contribution of the chapter is the presentation that provides a partial view on Grey Systems Theory (GST) as a conception to improve poor data situations for Performance Measurement (PM) and to operate with a few data already at hand. The chapter gives not only concepts related to GST, GST's element called Grey Relation Analysis (GRA), Performance Measurement (PM), and Key Performance Indicators (KPIs) but also an example of applying GRA analysis to a PM problem.

Chapter 3 "Application of Lean Methodologies in a Neurosurgery High Dependency Unit" written by Ricardo Balau Esteves, Susana Garriddo Azevedo, and Francisco Proenca Brojo. The main contribution of the chapter is the application of **Lean methodologies** to a Neurosurgery High Dependency Unit (NHDU). The manuscript presents the results; shows the research results; does the statistical analysis on the results; and points out the benefits of applying lean methodologies. The research method used is "an action research supported by a longitudinal mixed method approach with a one-group within-subjects pretest-posttest experimental type."

Chapter 4 "Iteration Algorithms in Markov Decision Processes with State-Action-Dependent Discount Factors and Unbounded Costs," written by Fernando Luque-Vasquez, and J. Adolfo MinJarez-Sosa. The main contribution of the chapter is the study of control models with state-action-dependent discount factors, focusing mainly on introducing approximation algorithms for the optimal value function (value iteration and policy iteration).

Chapter 5 "Mathematical Modeling of Isothermal Drying and Its Potential Application in the Design of the Industrial Drying Regimes of Clay Products," written by Milos Vasic, Zagorka Radojevic, and Robert Rekecki. The main contribution of the chapter is the creation of a link between the comprehensive theory of moisture migration during drying and the setup of the non-isothermal drying process.

Chapter 6 “Financial Feasibility Analysis of Natura Rab Business—Case Study,” written by Karmen Pazek, Matija Kastelan, Martina Bavec, Crtomir Rozman, and Jernej Prisenk. The main contribution of the chapter is the case study on the economic validity of the three projects related to a family firm called Natura Rab and the model developed using Microsoft Excel on Net Present Value assessment. The model could be used in other similar projects and investment to support decision making.

Chapter 2 “Influence of Phosphorous Precipitation on Wastewater Treatment Process,” written by Jan Derco, Rastislav Kuffa, Barbora Urminska, Jozef Dudas, and Jana Kusnierova. The main contribution of the chapter is the contribution of the methodologies for decision making related to finding most effective ways of removing phosphorus from wastewater, related to the selection of precipitating agents such as Fe^{2+}, Fe^{3+}, and Al^{3+} salts on sedimentation and thickening characteristics of sludge in wastewater treatment.

The above chapters cover a wide range of topics that are centered on the theme of operations research (decision science). We wish you enjoy reading rest of the book.

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