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Cengiz Kahraman
Y. Ilker Topcu *Editors*

Operations Research Applications in Health Care Management

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I dedicate this book to my Professors:

Prof. Coşkun Külür,
Prof. Necmettin Ongar,
Prof. Ataç Soysal,
Prof. Ahmet Fahri Özok,
Prof. Ethem Tolga,
Prof. Nahit Serarslan,
Prof. Haluk Erkut.

Prof. Cengiz Kahraman

I dedicate this book to
my late grandparents
who had been my inspiration and motivation
for continuing to improve my knowledge and
move my career forward

Prof. Y. Ilker Topcu

Preface

Healthcare management is composed of management activities and functions involved in various departments of healthcare systems. The objective of healthcare management is to influence the growth, development, and operations of healthcare systems. In recent years, there has been a significant increase in the interest for designing healthcare systems in order to address complex healthcare problems.

Operations research (OR) aims at developing mathematical and computational support for the optimization of problems in industry, service, and business. OR techniques have been used in the solutions of various healthcare problems in the literature. These studies have been published in some journals, proceedings, and books whose focus area is not totally healthcare systems. The motivation for editing this book has been the need for collecting the OR techniques applied to healthcare systems in a single source.

Twenty-two chapters have been submitted from various countries, namely, Turkey, the UK, the USA, Belgium, Croatia, Portugal, the Netherlands, Canada, Iran, Singapore, and Italy. This book is composed of eight main sections and two or three chapters under each main section.

The first chapter presents the taxonomy of operations research methodology in healthcare management to provide a common terminology and a classification mechanism.

The second chapter summarizes quantitative and qualitative techniques used in healthcare management, including OR techniques, statistical techniques, multicriteria decision making techniques, and others and presents graphical analyses of the survey results.

The third chapter proposes online optimization approaches for real time management of operating rooms. Real time management is capable to deal with the elective and non-elective patient flows within a single surgical pathway and with the resource sharing among different surgical pathways of elective patients. The authors assess the effectiveness of the proposed solutions on simulated surgical clinical pathways under several scenarios.

The fourth chapter presents two novel approaches for the identification of Takagi-Sugeno fuzzy models with time variant and time invariant features. The mixed fuzzy clustering algorithm is used for determining the parameters of Takagi-Sugeno fuzzy models in two different ways. The fuzzy modeling approaches are tested on four healthcare applications for the classification of critically ill patients.

The fifth chapter reviews OR literature applied to hospital wards. The authors distinguish intensive care, acute medical units, obstetric wards, weekday wards, and general wards. They aim at guiding both researchers and healthcare professionals in identifying which OR technique/model suits best for each specific hospital ward setting.

The sixth chapter monitors the impact of interrelations in the development of an efficient and proactive system of chronic care management through Social Network Analysis.

The seventh chapter evaluates healthcare system efficiency of 34 OECD member countries using Data Envelopment Analysis (DEA). The base model is an output-oriented Banker-Charnes-Cooper model that uses the number of physicians, nurses, beds per 1000 population as inputs, and life expectancy at birth, infant survival rate as outputs.

The eighth chapter aims at predicting the healthcare expenditure per capita. Accurate estimation of healthcare expenditure can guide efficient healthcare policy making and resource allocation. Three different strategies are proposed to improve the forecasting accuracy of gray forecasting models. Genetic algorithm is applied for training data size and parameter optimization.

The ninth chapter focuses on vaccination and investigates the vaccine supply chains. This chapter aims at classifying some problems of the vaccine supply management which can be solved by mathematical programming tools.

The tenth chapter discusses the challenges and research opportunities in the blood collection operations and explores the benefits of recent advances in the blood donation process.

The eleventh chapter aims at introducing the recent developments in organ transplantation network planning as well as presenting relevant case studies. It focuses on mathematical programming and computational models proposed in the recent literature for organ transplantation network planning.

The twelfth chapter investigates a fuzzy decision tree algorithm applied to the classification of gene expression data. The fuzzy decision tree algorithm is compared to a classical decision tree algorithm as well as other well-known data mining algorithms commonly applied to classification tasks.

The thirteenth chapter presents an overview of disease screening problems and operations research applications on different aspects of the problems. The authors first discuss operations research applications in evaluation and optimization of screening policies and then organization of screening services for reaching out to the population and improving the effectiveness of screening.

The fourteenth chapter presents an analysis of the efficiency of diabetes treatment in the UK healthcare facilities using TOPSIS and neural networks. The authors provide a rational framework for policy makers to rank the efficiency of diabetes care facilities and also highlight the most important contextual variables that impact on the efficiency as issues of interest for future policies.

The fifteenth chapter uses achievement scalarization to obtain efficient solutions for radiation treatment planning. The authors adapt the parameters of the achievement scalarization to address a solution in a rectangle that is defined by the bounds on the objective functions. They compare the proposed method with multiobjective solution algorithm from the literature and clinical plans.

The sixteenth chapter introduces and discusses the recent developments of OR techniques for emergency medicals service management. Two selected mathematical models from the relevant literature are also elaborated. In addition, a real emergency medicals service location problem is described as a case study.

The seventeenth chapter is on medical informatics. A review of medical informatics is presented and a multidisciplinary point of view is given based on different approaches.

The eighteenth chapter aims at identifying the prevalent challenges of pharmaceutical supply chains at three different decision levels, i.e., long-term (strategic), mid-term (tactical), and short-term (operational) decisions.

The nineteenth chapter proposes a categorical data envelopment analysis framework for evaluating medical tourism performance of top destinations. Research hypotheses are created to analyze the relationship between the countries' medical tourism performance and their political, regulatory environment, technology, and knowledge outputs.

The twentieth chapter discusses different analytical techniques used in healthcare human resource planning. Two case studies are presented to provide examples of real-world applications across different institutional contexts.

The twenty-first chapter discusses the lean management techniques, their applications in the healthcare systems and how they can improve the performance of these systems by providing better patient service, better utilization of assets, and better patient care.

The twenty-second chapter introduces the procurement management in healthcare systems and discusses the related challenges together with some optimization approaches on procurement management problems in healthcare systems.

This book will provide a useful resource of ideas, techniques, and methods for the research on the theory and applications of OR techniques in healthcare management. We thank all the authors whose contributions and efforts made the publication of this book possible. We are grateful to the referees for their invaluable and highly appreciated works contributed to select the high quality of chapters published in this book.

Macka, Istanbul, Turkey

Cengiz Kahraman
Y. Ilker Topcu

Contents

About the Editors

Cengiz Kahraman is a full professor at Istanbul Technical University. His research areas are engineering economics, quality management, statistical decision making, multicriteria decision making, and fuzzy decision making. He has published more than 200 journal papers, about 150 conference papers, and 80 book chapters. He has guest-edited some issues of many international journals. He is the editor of many international books from Springer and Atlantis Press. He is the member of editorial boards of 20 international journals. He was the vice dean of ITU Management Faculty between 2004 and 2007 and the head of ITU Industrial Engineering Department between 2010 and 2013.

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Part I
Overview

Chapter 1
A Taxonomy of Operations Research Studies in Healthcare Management

Serhat Tüzün and Y. Ilker Topcu

1.1 Introduction

The goal of researchers working in healthcare management is to control the rising costs and to increase accessibility for healthcare services. They try to do this by integrating the aspects of management with Operations Research (OR) techniques to determine the most efficient (or optimal) methods of providing patient care delivery (Langabeer 2007). The studies of OR in healthcare are not only about determining the methods for healthcare delivery, but also about simulating clinical systems to observe long-term risks.

Operations Research reached the stage of maturity in a very short time after it was first applied during WWII (Kirby 2003). It has been considered a discipline hard to grasp even though it spread to a wide application area. OR techniques are used to model and solve real-world problems in different areas such as production, logistics, etc. (Hillier and Lieberman 2005). Healthcare is yet another area, a relatively new one that Operations Research techniques are used in.

Healthcare is a business-like no other. Carter (2002) pointed out that it has multiple decision-makers with conflicting goals and objectives. Moreover, healthcare business has a high level of uncertainty as well as dynamic relationships among its components. Also, the managers in healthcare demand to lower the costs and increase the service quality. These aspects render management of healthcare and its operations reasonable to be studied with OR techniques.

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The objectives of OR studies in Healthcare Management are to control the costs and to improve the quality of healthcare services (Mclaughlin and Hays 2008). For the last two decades, hundreds of articles were published, special journal issues were put together, and conferences were organized. Various studies are carried out in different areas of healthcare. Some of these areas are resource allocation, scheduling, managing waiting lists, streamlining patient flows, facility location, cost-effectiveness analysis, triage in emergency services and disease treatment investigations (Pierskalla and Brailer 1994).

Although a comprehensive taxonomic classification was made by Hulshof et al. (2012), an up-to-date taxonomy is still a necessity. This chapter aims to provide a general overview of OR studies in healthcare management, using a different taxonomy approach than that of Hulshof et al. The literature has been thoroughly reviewed, and by classifying previous studies according to their preferences, a taxonomy for OR studies in healthcare management has been prepared.

1.2 OR Studies in Healthcare Management

Healthcare management research was first established in the 1930s. Although there had been some studies before, application of operations research in healthcare is accepted to have started during the 1970s. First publications were mainly about health planning and administration (Stimson and Stimson 1972; Shuman et al. 1975; Fries 1981). Later on, research areas on healthcare widely spread from top management to the smallest operation.

OR studies in healthcare management became popular during the 1990s. Using OR techniques in healthcare attracted a lot of attention in many countries and lots of studies are currently carried out (Luss and Rosenwein 1997). Many universities and research groups have shown interest in the subject. For example, McGill School of Environment (MSE) has a program called "Healthcare Operations & Information Management," directed by Vedat Verter. Although research is generally centered in the USA and Canada, a working group of Association of European Operational Research Societies (EURO) called Operational Research Applied to Health Services (ORAHS), which was initiated in 1975, provides a network for researchers involved in the application of systematic and quantitative analysis in support of planning and management in the health services sector.

There are already some bibliographic studies that organize the papers and classify them (Flagle 1962) classified the problems encountered in the area. Fries (1976) organized the papers before 1975; and the literature between 1970 and 1989 was classified by Corner and Kirkwood (1991). Also, minor classifications were made in the following years. Preater prepared a bibliography on the application of queuing theory in healthcare and medicine (2002); Cayirli and Veral reviewed the literature of outpatient scheduling in healthcare (2003); Lowery (1996) and Jun et al. (1999) investigated the simulation applications in health services. Due to these bibliographic studies, this study excludes papers published before 2000, and focuses on more recent years where the literature is building up more quickly than ever.

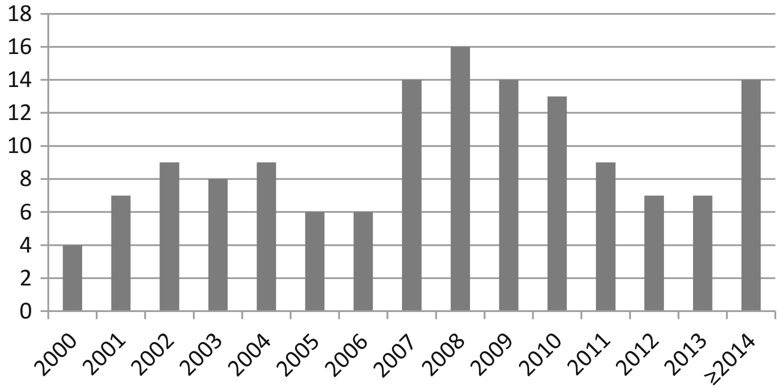

Fig. 1.1 Number of publications by years

The following keywords were used to find research papers published in the literature: healthcare operations management, healthcare management, health services, healthcare applications, health workforce planning, ambulance allocation, hospital resource allocation, outpatient scheduling, nurse–patient assignment, healthcare delivery, doctor/nurse workload, operating room planning, healthcare operations, doctor/nurse scheduling, health care production, emergency patient flow, health care services, and management decision support in the health service. The results of the search yielded over 500 articles, mainly in these journals: Annals of Operations Research, Artificial Intelligence in Medicine, Computers & Operations Research, European Journal of Operational Research, Expert Systems with Applications, Health Care Management Science, Health Policy, IIE Transactions, Interfaces, Omega, Social Science & Medicine, and Socio-Economic Planning Sciences. Before proceeding to the taxonomy, some exclusion criteria were determined in order to narrow the findings. Thus, we ended up with articles that were more related to the subject of "application of OR to healthcare management". These exclusion criteria were studies not in English, studies without models (Review papers), studies about improving treatment and diagnosis (screening, analyzing outputs, etc.), models based on probability and statistics, and models based on economic theory. As a result, 142 articles were within the criteria. Their distribution by the year of publication may be seen in Fig. 1.1.

1.3 Necessity for a Taxonomy: A Discussion

The size and growth rate of the literature demands a systematic way to classify various contributions in a manner that will vividly provide a panoramic view of what exists and will also clearly identify any existing gaps as suggested by Reisman (1992) and Reisman (1993).

Taxonomy may be defined as the science of identifying objects, and arranging them in a classification. According to Gattoufi et al. (2009), it is not only an efficient and effective tool for systematic storage as well as a tool for teaching/learning, and a tool for recalling knowledge, but it is also a neat way of pointing to knowledge expansion. It identifies voids, potential increments (or developments) in theory, and potential applications involving the existing theory. The basic motivations and uses for taxonomy may be listed as follows (Eksioglu et al. 2009):

- It defines or delimits the boundaries of a subject domain, and that is, in itself, useful information.
- It vividly, efficiently and effectively displays all of that domain's attributes/dimensions.
- It vividly, efficiently and effectively displays that any one of the possible combinations of these attributes/dimensions defines or delimits the boundaries of a subject sub-domain.
- It allows one to have a panoramic view of the entire "forest" while examining and classifying a given "tree."
- It allows one to unify disjointed and disparate subfields or sub-disciplines into a meaningful whole.
- It allows one to organize one's knowledge about the domain, and this has major implications for teaching, learning, storing, and recalling information.
- It allows one to identify voids and well explored territories in the extant literature base, which is very important for researchers, funding agencies, and other decision makers.

What is presented here is open for incremental evolution, as is the case in one of the greatest and best-known taxonomies of all time: The Periodic Table of Elements. The classification developed in this study is open to expansion when the scope of OR studies in healthcare management is enhanced, since any taxonomy is delimited with the boundaries of the universe it classifies.

OR studies in healthcare management have already generated a large enough literature to allow it to be considered as a separate and distinct field of knowledge. The increasing interest in the OR studies in healthcare management makes a systematic elaboration of this field more crucial to helping current researchers as well as attracting potential newcomers to the field.

Defining a taxonomy for OR Studies in Healthcare Management may seem to be overly detailed in terms of branching levels, as a result of trying to cover all literature in every subarea of healthcare management research. Although this detailed branching results in a taxonomy that is hard to work with, it increases its descriptive powers. Furthermore, it gives researchers the ability to aggregate sub-classifications and/or pruning outer branches easily. The taxonomy proceeds in a way illustrated by Reisman (1992), which can be seen in Fig. 1.2.

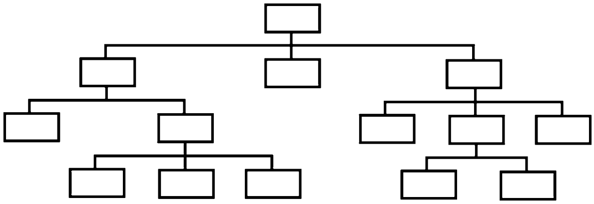

Fig. 1.2 Attribute vector description based taxonomy

1.4 A Taxonomy for OR Studies in Healthcare Management

In this section, the taxonomy for OR studies in Healthcare Management (HCM) is presented, and the main features that were considered while building it are introduced. We provide definitions as well as justifications for those main features and provide identification codes for some terms within the context of the taxonomy.

The full taxonomy is illustrated in Fig. 1.3. In the proposed taxonomy, each contribution can be given an identification code based on domains grouped in five classes:

Class 1: Study Specifications. This class shows how the study is specified. This is subdivided into three domains. The first domain describes the type of study; the second describes the source of the data used; and the third describes the type of problem treatment.

Class 2: Subject. This class shows what is analyzed. Each research paper analyzes one or more subjects. There are seven main subjects and the rest is grouped as "other".

Class 3: Methodology. This class shows the methodology used in the research. Each research paper consists of one or more methods. There are eleven main methods; and the rest is grouped as "other".

Class 4: Problem Specifications. This class shows who and what the problem is analyzed for. This is subdivided into three domains. The first domain describes the people affected by the problem; the second describes the area that the problem occurred in; and the third describes the affected facility by the problem.

Class 5: Location Specifications. This class shows where the research was carried out. The model constructed or the problem analyzed can be applied to large, medium or small scale; or it can be non-location-specific.

1.5 Results of the Taxonomy with Selected Articles

In this section, by using a group of articles which represent rather different approaches and which address different issues of OR studies in HCM, the taxonomy of Fig. 1.3 is tested for its robustness and its ability to discriminate in a rigorous manner.

1. Study Specifications
    - 1.1. Type of Study
        - 1.1.1. Model Construction using an Existing Method
        - 1.1.2. Model Construction using a Modified Method or Integration of Methods
        - 1.1.3. Method Comparison
    - 1.2. Data Used
        - 1.2.1. Real Data
        - 1.2.2. Both Real and Synthetic Data
    - 1.3. Problem Treatment
        - 1.3.1. Situation Analysis
        - 1.3.2. Decision Making (Problem Solving)
2. Subject
    - 2.1. Planning and Design
    - 2.2. Performance Measurement
    - 2.3. Capacity Management
    - 2.4. Scheduling and Assignment
    - 2.5. Resource/Budget Allocation
    - 2.6. Patient Flow and Waitlist Management
    - 2.7. Location
    - 2.8. Other
3. Methodology
    - 3.1. Linear/Integer Programming
    - 3.2. Multi Objective Programming
    - 3.3. Simulation
    - 3.4. Data Envelopment Analysis
    - 3.5. Queuing Theory
    - 3.6. System Dynamics
    - 3.7. Stochastic Methods
    - 3.8. Multi Attribute Decision Making
    - 3.9. Game Theory
    - 3.10. Bayesian Belief Network
    - 3.11. Artificial Neural Network
    - 3.12. Other
4. Problem Specifications
    - 4.1. Concerning People
        - 4.1.1. Management
        - 4.1.2. Doctor/Physician
        - 4.1.3. Nurse or Non-Medical Staff
        - 4.1.4. Patients
    - 4.2. Concerning Area
        - 4.2.1. Hospital/Clinic
        - 4.2.2. Non-hospital Organizations
        - 4.2.3. Public Health
    - 4.3. Concerning Facility
        - 4.3.1. Entire Clinic/Hospital
        - 4.3.2. Emergency Room
        - 4.3.3. Operating Room
        - 4.3.4. Ambulance
        - 4.3.5. Nursing Home
        - 4.3.6. Hospital Room
        - 4.3.7. Other
5. Location Specifications
    - 5.1. Large Scale
        - 5.1.1. Worldwide
        - 5.1.2 Continent Based
    - 5.2. Medium Scale
        - 5.2.1. Country Based
        - 5.2.2. State Based
    - 5.3. Small Scale
        - 5.3.1. City/Town Based
        - 5.3.2. Specific Location Based
    - 5.4. No Location Specific

Fig. 1.3 A taxonomy of OR studies in healthcare management

One hundred forty-two articles were investigated in detail to see the general idea of the researchers that contributed to the OR-in- HCM literature. In the first class, there are three domains; type of study, data used, and problem treatment. In the type of study domain, the most observed attribute is “model construction using a modified method” or “integration of methods” (1.1.2), followed by “model construction using an existing method” (1.1.1). “Comparison of methods” (1.1.3) is slightly less frequent than these two, since there are not enough studies to make a clear comparison. In data used, “usage of both real data and synthetic data” (1.2.2) is more frequent than “just using real data” (1.2.1), which can be explained by the difficulty of collecting real data as well as the highly popular usage of simulation that easily creates loads of synthetic data. For treating the problem, it is mostly “decision making” (1.3.2) rather than “situation analysis” (1.3.1). So, speaking for the study specifications, the papers mostly consisted of “decision making” with the “usage of both real and synthetic data” by “constructing a model using a modified method”.

The second and third classes are the classes that give researchers direction. It is better to interpret these two classes by looking at them together. Thus, the researcher may be able to pick the method to use for the subject he/she works on. However, first, one would need to check where previous studies have focused on. In the second class, “patient flow” and “waiting list management” (2.6) is the most researched subject. This is followed by “scheduling and assignment” (2.4), and “performance measurement” (2.2). “Resource/budget allocation” (2.5), “planning and design” (2.1), and “capacity management” (2.3) are more generalized subjects, for which researchers need to consider more factors, which means they are harder to model. Thus, they are not as attractive as the first three subjects. “Location” (2.7), and “other” (2.8) subjects have found fewer study areas than the rest, but these studies have been done mostly in recent years, which can be considered new research areas introduced to the discipline.

In class three, where methods are compared, “simulation” (3.3) is the most common method used to model in healthcare management, both alone or integrated with other methods. Simulation is mostly used to model “planning and design” (2.1), “scheduling and assignment” (2.4) and “patient flow and waiting list management” (2.6). Mathematical programming models such as “linear/integer programming” (3.1) and “multi-objective programming” (3.2) are also frequently used in order to model “scheduling and assignment” (2.4), “resource/budget allocation”, (2.5) and “location” (2.7). Following common methods are “data envelopment analysis” (3.4), which is used mostly for “performance measurement” (2.2) and “stochastic methods” (3.7), mostly to model “capacity management” (2.3) problems. “Multi attribute decision making” (3.8), “game theory” (3.9) and “artificial neural networks” (3.11) are the least used methods as they have been introduced to healthcare operations management area in recent years.

Fourth class is where the problem details are explained. It includes three domains. In the first domain, concerning people, the most affected and investigated group in the papers is “management “(4.1.1). It is followed by “patients” (4.1.4), affected mostly in modeling “patient flow and waiting list management” (2.6) problems. “Doctor/physician” (4.1.2) and “nurse or non-medical staff” (4.1.3) groups are included generally in “scheduling and assignment” (2.4) problems. The second domain seeks whether the problem occurred inside or outside the hospital. Most of them are “hospital/clinic” (4.2.1) problems; the rest is “non-hospital” organizations (4.2.2) or “public health” (4.2.3). Concerning facility is the third domain in this class. Most of the studies include “the entire facility” (4.3.1). “Emergency room” (4.3.2) and “operating room” (4.3.3) are also important research areas for operations research methodology, especially for “linear/integer programming” (3.1) and “queuing theory” (3.5). “Ambulances” (4.3.4) and “nursing homes” (4.3.5) are the facilities that have been gaining importance in recent years.

The last class is the location where the research in a given paper is carried out. This resulted in “specific location based” (5.3.2) to have the highest frequency. “Country based” (5.2.1) is the second one, because researchers do research under the regulations of specific countries. “Worldwide” (5.1.1) and “continent based” (5.1.2) are the lowest location types that appear in these papers, since it is hard to construct a model that can be applied to a very large scale in a world with so many varieties.

1.6 Conclusions and Further Suggestions

Selection of papers for any taxonomy is a subjective work. The taxonomy described in this chapter tries to represent a variety of studies with different journals, different authors from different countries, differing paths to theory extension, differing application sectors and differing research strategies.

Being a new Management Science sub-discipline, the OR literature in healthcare management is growing exponentially like the other new sub-disciplines. This literature is recording advancements in theory and in solution methodology while at the same time expanding its domain of applications. When the previous bibliographic studies are compared with this taxonomy, it can be seen that new research areas are added to the discipline; new methods are used to model problems, and new approaches are applied to improve outputs. In spite of all these developments, research subjects are still divided as Fries (1976) stated; and simulation is still the most commonly utilized method to model problems as Jun et al. (1999) mentioned.

This taxonomy is formed with the motivation to determine application areas and specifications of OR studies in healthcare management as guidelines for future avenues of research. For future research, the most focused areas can be determined and the deficiencies in those areas can be satisfied with different approaches. For example, performance measurement problems are usually modeled with data envelopment analysis and from the management point of view. Therefore, using different methods or looking from a different angle, management can help eliminate the drawbacks of the previous studies. Or the least focused areas can be chosen to work on, such as performance measurement of the emergency room, which has not yet been studied. Also, with the addition of new areas as a result of the growing literature, improvements on this taxonomy can be made.

Appendix

The articles selected for the taxonomy can be seen in the following tables, with their classifications. The domains or attributes corresponding to endnodes are marked with ‘X’. Shaded columns represent domains or classes which branch, so that shading suggests why these columns are not marked. This representation scheme enables us to assign more designations in a confined space.

Table A.1 Summary of illustrative classifications of the first 70 articles (attributes 1–3.12)

	Article	1.	1.1.	1.1.1.	1.1.2.	1.1.3.	1.2.	1.2.1.	1.2.2.	1.3.	1.3.1.	1.3.2.	2.	2.1.	2.2.	2.3.	2.4.	2.5.	2.6.	2.7.	2.8.	3.	3.1.	3.2.	3.3.	3.4.	3.5.	3.6.	3.7.	3.8.	3.9.	3.10.	3.11.	3.12.
1	2000. Beaulieu et al.			x				x				x					x							x										
2	2000. Flessa			x				x			x							x						x										
3	2000. Rossetti et al.			x					x			x			x										x									
4	2000. Siddharthan et al.			x				x			x				x											x								
5	2001. Björkgren et al.			x				x			x				x			x								x								
6	2001. Congdon				x				x			x							x						x							x		
7	2001. Jacobs					x			x		x				x											x			x					
8	2001. Marshall et al.				x			x			x					x		x														x		
9	2001. Ratcliffe et al.			x					x		x							x	x						x									
10	2001. Swisher et al.				x				x		x			x											x									
11	2001. Vasilakis and El-Darzi			x					x		x					x			x						x									
12	2002. Chan et al.				x				x			x					x						x		x									
13	2002. Everett			x					x		x						x		x						x									
14	2002. Hofmarcher et al.			x				x			x				x											x								
15	2002. Kommer			x					x			x							x						x									
16	2002. Marshall et al.				x			x			x					x			x													x		
17	2002. Rauner			x					x		x			x				x							x									
18	2002. Rohleder and Klassen			x					x		x						x								x									
19	2002. Swisher and Jacobson			x					x			x		x	x										x									
20	2002. Verter and Lapierre			x				x				x								x			x											
21	2003. Chu et al.			x				x				x			x											x								
22	2003. De Angelis et al.				x				x		x			x									x		x									
23	2003. Flessa			x				x				x						x						x										
24	2003. Lane et al.			x				x			x								x									x						
25	2003. Mikkola et al.			x				x			x										x				x									
26	2003. Mullen					x						x					x		x															x
27	2003. Rauner and Bajmoczy				x			x				x			x								x											x
28	2003. Sendi and Al				x				x			x						x					x											
29	2004. Acid et al.					x			x		x				x																	x		
30	2004. Akkerman and Knip				x			x			x					x			x						x				x					
31	2004. Chang et al.			x				x				x			x											x								
32	2004. Grunow et al.			x				x				x					x	x					x											
33	2004. Gupta and Li			x					x			x									x		x											
34	2004. Hougaard et al.				x			x			x							x								x								
35	2004. Masterson et al.			x				x						x		x									x									
36	2004. Sibbritt and Gibberd				x				x		x										x													x
37	2004. Stummer et al.			x				x				x		x						x				x										
38	2005. Bard and Purnomo			x				x				x					x						x											
39	2005. Beynon and Kitchener				x				x			x			x															x				
40	2005. Harrison et al.				x				x		x					x									x				x					
41	2005. Koizumi et al.				x				x			x							x								x							
42	2005. Kontodimopoulos et al.			x				x			x				x											x								
43	2005. Marshall et al.					x						x				x			x						x				x					
44	2006. Aaby et. al				x				x			x		x		x									x		x							
45	2006. Akcali et al.			x					x			x				x							x											
46	2006. Bard and Purnomo				x				x			x					x						x											
47	2006. Cayirli et al.			x				x				x					x								x									
48	2006. Cochran and Bharti				x			x				x				x			x						x		x							
49	2006. Mitropoulos et al.			x				x				x								x				x										
50	2007. Aktas et al.			x				x			x							x														x		
51	2007. Anderson et al.			x					x		x										x				x									
52	2007. Cipriano et al.				x			x			x							x	x						x		x							
53	2007. de Bruin et al.			x				x			x					x			x								x							
54	2007. Denton et al.				x			x				x					x						x						x					
55	2007. Earnshaw et al.			x					x			x						x					x											
56	2007. Kopach et al.			x					x		x						x								x									
57	2007. Matta and Patterson			x				x			x				x										x									
58	2007. Molema et al.			x					x			x		x			x								x									
59	2007. Rohleder et al.			x					x			x		x														x						
60	2007. Santibáñez et al.			x				x				x					x		x				x											
61	2007. Testi et al.				x				x			x					x								x									
62	2007. VanBerkel and Blake			x					x		x					x			x						x									
63	2007. Vos et al.			x					x		x			x											x									
64	2008. Barros et al.				x			x			x				x								x											x
65	2008. Brasted			x				x				x							x						x									
66	2008. Clement et al.			x					x		x				x											x								
67	2008. Desai et al.			x					x			x		x														x						
68	2008. Dexter et al.				x				x		x										x					x								
69	2008. Goodson and Jang			x					x		x				x																	x		
70	2008. Ingolfsson et al.			x					x			x								x			x											

Table A.2 Summary of illustrative classifications of the first 70 articles (attributes 4–5.4)

	Article	4.	4.1.	4.1.1.	4.1.2.	4.1.3.	4.1.4.	4.2.	4.2.1.	4.2.2.	4.2.3.	4.3.	4.3.1.	4.3.2.	4.3.3.	4.3.4.	4.3.5.	4.3.6.	4.3.7.	5.	5.1.	5.1.1.	5.1.2.	5.2.	5.2.1.	5.2.2.	5.3.	5.3.1.	5.3.2.	5.4.
1	2000. Beaulieu et al.				x				x					x												x				
2	2000. Flessa			x							x								x			x								
3	2000. Rossetti et al.			x					x				x																	x
4	2000. Siddharthan et al.			x						x									x						x					
5	2001. Björkgren et al.			x						x			x												x					
6	2001. Congdon						x				x			x											x					
7	2001. Jacobs			x					x				x												x					
8	2001. Marshall et al.			x					x										x										x	
9	2001. Ratcliffe et al.						x			x									x										x	
10	2001. Swisher et al.			x					x				x																x	
11	2001. Vasilakis and El-Darzi						x		x									x											x	
12	2002. Chan et al.					x			x										x										x	
13	2002. Everett						x		x						x															x
14	2002. Hofmarcher et al.			x					x				x															x		
15	2002. Kommer						x				x								x						x					
16	2002. Marshall et al.			x			x		x									x											x	
17	2002. Rauner			x							x																	x		
18	2002. Rohleder and Klassen						x		x										x											x
19	2002. Swisher and Jacobson			x					x				x																x	
20	2002. Verter and Lapierre			x					x				x																x	
21	2003. Chu et al.				x				x																x					
22	2003. De Angelis et al.			x					x				x												x					
23	2003. Flessa			x							x															x				
24	2003. Lane et al.						x		x					x															x	
25	2003. Mikkola et al.										x														x					
26	2003. Mullen																													x
27	2003. Rauner and Bajmoczy			x						x									x						x					
28	2003. Sendi and Al			x																										x
29	2004. Acid et al.			x					x					x															x	
30	2004. Akkerman and Knip						x		x						x										x					
31	2004. Chang et al.			x					x				x												x					
32	2004. Grunow et al.				x					x									x											x
33	2004. Gupta and Li						x			x															x					
34	2004. Hougaard et al.						x				x						x		x						x					
35	2004. Masterson et al.			x						x									x						x					
36	2004. Sibbritt and Gibberd			x					x										x										x	
37	2004. Stummer et al.			x					x				x															x		
38	2005. Bard and Purnomo					x			x				x																x	
39	2005. Beynon and Kitchener									x															x					
40	2005. Harrison et al.						x		x									x											x	
41	2005. Koizumi et al.						x		x																	x				
42	2005. Kontodimopoulos et al.			x					x				x												x					
43	2005. Marshall et al.						x		x									x												x
44	2006. Aaby et. al			x							x			x														x		
45	2006. Akcali et al.						x		x									x												x
46	2006. Bard and Purnomo					x			x																					x
47	2006. Cayirli et al.				x		x		x										x										x	
48	2006. Cochran and Bharti						x		x									x							x					
49	2006. Mitropoulos et al.			x					x																	x				
50	2007. Aktas et al.			x					x										x										x	
51	2007. Anderson et al.			x							x											x								
52	2007. Cipriano et al.						x		x						x											x				
53	2007. de Bruin et al.						x		x					x															x	
54	2007. Denton et al.								x						x														x	
55	2007. Earnshaw et al.			x							x															x				
56	2007. Kopach et al.				x		x		x																					x
57	2007. Matta and Patterson			x					x				x																x	
58	2007. Molema et al.			x	x				x						x				x										x	
59	2007. Rohleder et al.			x						x																			x	
60	2007. Santibáñez et al.				x		x		x						x														x	
61	2007. Testi et al.								x						x														x	
62	2007. VanBerkel and Blake						x		x						x														x	
63	2007. Vos et al.			x					x				x																x	
64	2008. Barros et al.			x					x				x												x					
65	2008. Brasted						x		x										x										x	
66	2008. Clement et al.			x					x				x												x					
67	2008. Desai et al.						x				x						x											x		
68	2008. Dexter et al.				x				x						x															x
69	2008. Goodson and Jang									x							x								x					
70	2008. Ingolfsson et al.									x						x												x		

Table A.3 Summary of illustrative classifications of the last 72 articles (attributes 1–3.12)

	Article	1.	1.1.	1.1.1.	1.1.2.	1.1.3.	1.2.	1.2.1.	1.2.2.	1.3.	1.3.1.	1.3.2.	2.	2.1.	2.2.	2.3.	2.4.	2.5.	2.6.	2.7.	2.8.	3.	3.1.	3.2.	3.3.	3.4.	3.5.	3.6.	3.7.	3.8.	3.9.	3.10.	3.11.	3.12.
71	2008. Jiang and Giachetti					x		x				x							x						x		x							
72	2008. Lim and Kirikoshi				x			x			x										x												x	
73	2008. Little and Coughlan			x				x				x						x						x										
74	2008. Mayhew and Smith			x					x		x								x								x							
75	2008. Mazur and Chen				x			x				x		x																				x
76	2008. Puenpatom and Rosenman			x				x			x				x											x								
77	2008. Sobolev et al.				x				x		x								x						x									
78	2008. Utley et al.				x				x			x				x													x					
79	2008. van de Klundert et al.				x				x			x		x									x											x
80	2009. Adan et al.				x			x				x					x	x					x						x					
81	2009. Augusto and Xie				x			x				x		x						x			x		x									
82	2009. Brunner et al.			x				x				x					x						x											
83	2009. Chand et al.				x			x				x							x						x									x
84	2009. De Grano et al.				x			x				x					x							x										
85	2009. Hare et al.				x				x		x					x													x					
86	2009. Lavieri and Puterman			x				x				x		x			x						x											
87	2009. Marjamaa et al.			x					x			x		x			x								x									
88	2009. Restrepo et al.				x				x			x						x		x			x											
89	2009. Santibáñez et al.			x				x				x						x	x						x									
90	2009. Sharma			x				x			x							x	x										x					
91	2009. Sundaramoorthi et al.				x				x		x						x								x				x					
92	2009. Testi and Tànfani			x					x			x		x									x											
93	2009. Tiwari and Heese			x					x			x		x																	x			
94	2010. Blank and Valdmanis				x			x			x				x											x								
95	2010. Garg et al.				x				x		x								x										x					
96	2010. Joustra et al.				x			x				x							x				x		x									
97	2010. Kristensen et al.			x				x			x				x											x								
98	2010. Linna et al.			x				x			x				x											x								
99	2010. Mukherjee et al.			x				x			x				x											x								
100	2010. Persson and Persson			x				x				x					x		x						x									
101	2010. Rönnberg and Larsson			x				x				x					x						x											
102	2010. Sundaramoorthi et al.					x		x				x					x								x									
103	2010. Varela et al.			x				x			x				x											x								
104	2010. Yaesoubi and Roberts				x				x		x							x			x										x			
105	2010. Zhang et al.				x			x				x		x						x				x										
106	2010. Zonderland et al.				x				x			x					x		x								x		x					
107	2011a. Büyüközkan et al.				x				x			x			x															x				
108	2011. Carpenter et al.				x			x				x					x	x					x											
109	2011. Conforti et al.			x				x				x					x						x											
110	2011. Dursun et al				x			x				x		x																x				
111	2011. Garavaglia et al.				x			x			x				x											x								
112	2011. Kreng and Young			x				x				x						x																x
113	2011. Lasry et al.					x			x		x							x					x											x
114	2011. Rohleder et al.				x			x				x							x						x									
115	2012. Büyüközkan and Çifçi				x				x			x			x															x				
116	2012. Defechereux at al			x					x		x			x																x				
117	2012. Goetghebeur et al			x				x			x										x									x				
118	2012. Grigoroudis et al.			x					x			x			x															x				
119	2012. Kuo et al				x			x				x		x																				x
120	2012. Thokala and Duenas					x			x			x									x									x				
121	2012. Zhang and Huang				x				x		x			x																x				x
122	2013. Abo-Hamad and Arisha				x			x			x				x				x						x									
123	2013. Chen et al				x				x			x									x									x				x
124	2013. Hulshof et al			x					x			x							x				x											
125	2013. Marsh et al			x					x			x		x																x				
126	2013. Özkan					x			x			x									x									x				
127	2013. Toro-Díaz et al				x				x			x						x		x													x	
128	2013. Zeng et al				x			x				x		x																x				
129	2014. Akdag et al					x			x		x				x															x				
130	2014. Amaral and Costa			x					x			x							x											x				
131	2014. Choi and Wilhelm				x				x			x					x							x										
132	2014. Lashgari et al					x			x			x				x														x				
133	2014. Mitton et al				x						x							x																x
134	2014. Robinson et al			x					x		x				x										x									
135	2014. Sun et al				x			x				x						x						x										
136	2015. Khaki et al				x				x			x								x										x				x
137	2015. Hernandez et al				x				x			x					x							x	x									
138	2015. Kanuganti et al				x				x		x									x										x				x
139	2015. Girginer et al				x				x		x				x											x								x
140	2015. Rashwan et al			x				x			x					x												x						
141	2015. McCormack and Coates				x			x				x						x							x								x	
142	2015. Xu et al					x			x		x				x											x			x					x

Table A.4 Summary of illustrative classifications of the last 72 articles (attributes 4–5.4)

	Article	4.	4.1.	4.1.1.	4.1.2.	4.1.3.	4.1.4.	4.2.	4.2.1.	4.2.2.	4.2.3.	4.3.	4.3.1.	4.3.2.	4.3.3.	4.3.4.	4.3.5.	4.3.6.	4.3.7.	5.	5.1.	5.1.1.	5.1.2.	5.2.	5.2.1.	5.2.2.	5.3.	5.3.1.	5.3.2.	5.4.
71	2008. Jiang and Giachetti						x			x									x											x
72	2008. Lim and Kirikoshi				x					x									x						x					
73	2008. Little and Coughlan			x					x										x										x	
74	2008. Mayhew and Smith			x							x			x											x					
75	2008. Mazur and Chen			x					x										x										x	
76	2008. Puenpatom and Rosenman			x					x		x		x												x					
77	2008. Sobolev et al.						x		x						x										x					
78	2008. Utley et al.			x						x								x							x					
79	2008. van de Klundert et al.			x					x						x				x											x
80	2009. Adan et al.			x					x						x														x	
81	2009. Augusto and Xie					x				x									x										x	
82	2009. Brunner et al.				x				x																				x	
83	2009. Chand et al.						x		x																				x	
84	2009. De Grano et al.								x					x															x	
85	2009. Hare et al.						x			x							x									x				
86	2009. Lavieri and Puterman					x					x															x				
87	2009. Marjamaa et al.			x	x	x			x						x														x	
88	2009. Restrepo et al.			x						x						x												x		
89	2009. Santibáñez et al.			x			x			x			x																x	
90	2009. Sharma						x		x						x										x					
91	2009. Sundaramoorthi et al.					x	x		x				x																x	
92	2009. Testi and Tànfani			x					x						x														x	
93	2009. Tiwari and Heese			x					x				x																	x
94	2010. Blank and Valdmanis			x					x				x												x					
95	2010. Garg et al.						x																							x
96	2010. Joustra et al.						x		x										x										x	
97	2010. Kristensen et al.			x					x																x					
98	2010. Linna et al.			x					x		x		x										x							
99	2010. Mukherjee et al.			x							x														x					
100	2010. Persson and Persson				x		x		x						x														x	
101	2010. Rönnberg and Larsson					x			x										x										x	
102	2010. Sundaramoorthi et al.					x	x		x									x											x	
103	2010. Varela et al.			x							x															x				
104	2010. Yaesoubi and Roberts						x		x	x															x					
105	2010. Zhang et al.			x						x			x													x				
106	2010. Zonderland et al.			x			x		x						x														x	
107	2011a. Büyüközkan et al.			x					x				x															x		
108	2011. Carpenter et al.					x			x										x										x	
109	2011. Conforti et al.						x		x				x																x	
110	2011. Dursun et al			x						x									x									x		
111	2011. Garavaglia et al.			x						x							x								x					
112	2011. Kreng and Young			x							x														x					
113	2011. Lasry et al.			x						x															x					
114	2011. Rohleder et al.						x		x				x																x	
115	2012. Büyüközkan and Çifçi			x					x										x											x
116	2012. Defechereux at al			x							x														x					
117	2012. Goetghebeur et al			x						x															x					
118	2012. Grigoroudis et al.			x					x		x		x																x	
119	2012. Kuo et al						x				x						x								x					
120	2012. Thokala and Duenas			x							x														x					
121	2012. Zhang and Huang			x							x																	x		
122	2013. Abo-Hamad and Arisha			x					x					x																x
123	2013. Chen et al				x				x										x										x	
124	2013. Hulshof et al			x					x				x																	x
125	2013. Marsh et al			x							x														x					
126	2013. Özkan			x						x									x						x					
127	2013. Toro-Díaz et al			x					x					x																x
128	2013. Zeng et al			x							x														x					
129	2014. Akdag et al								x				x												x					
130	2014. Amaral and Costa			x					x					x															x	
131	2014. Choi and Wilhelm			x					x						x															x
132	2014. Lashgari et al			x						x			x																x	
133	2014. Mitton et al			x							x											x								
134	2014. Robinson et al			x					x				x																x	
135	2014. Sun et al						x		x					x												x				
136	2015. Khaki et al										x			x												x				
137	2015. Hernandez et al				x	x					x			x														x		
138	2015. Kanuganti et al						x		x				x													x				
139	2015. Girginer et al			x					x						x													x		
140	2015. Rashwan et al			x							x			x											x					
141	2015. McCormack and Coates						x									x												x		
142	2015. Xu et al			x					x				x															x		

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Chapter 2
A Comprehensive Survey on Healthcare Management

Sezi Cevik Onar, Basar Oztaysi, and Cengiz Kahraman

2.1 Introduction

Healthcare management is the scientific field which provides leadership and direction to healthcare organizations. The public health systems, healthcare systems, hospitals, and hospital networks are the main research areas in healthcare management. In these healthcare organizations, there usually exist numerous types of healthcare problems which might be micro such as scheduling of an operating rooms or macro such as layout of the whole healthcare organization. These problems can be solved by quantitative and qualitative techniques such as operations research techniques, simulation or decision making techniques.

Management of healthcare organizations needs complex and dynamic operations. Managers in these organizations should perform a successful leadership, supervision, and coordination of the employees. They should be aware of the quantitative and qualitative techniques that can be used in the solutions of various problems of healthcare organizations. In the literature, there are many healthcare applications of these techniques. However, there is a need for a work classifying these studies based on the types of techniques and the healthcare problems solved by these techniques.

Figure 2.1 illustrates the increasing trend of healthcare management publications over the years. The statistics in Fig. 2.1 are from Scopus database with the keyword *healthcare management* in the title of the publications. This search gave us 2,250 papers. There is a significant increase in the number of publications after 1998. This proves that a significant importance is given to healthcare management research in the literature for the last two decades.

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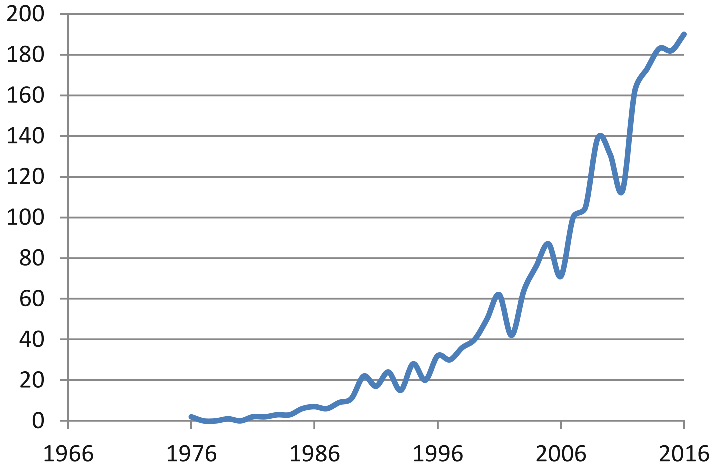

Fig. 2.1 Healthcare Management publications with respect to years

The aim of this chapter is to exhibit the existing position of healthcare management in the literature. We classified the healthcare problems and their solution techniques in the literature in order to see the general frame of healthcare management. OR techniques are also included within this classification. This aims at showing the place of OR in the whole picture. A comprehensive and up to date literature survey is conducted by using a broader perspective that considers both qualitative and quantitative techniques.

The rest of the chapter is organized as follows. Section 2.2 presents the literature review results based on the classifications with respect to papers conducting a review of qualitative and quantitative techniques on HCM. Section 2.3 classifies the techniques used in healthcare management. Finally, Sect. 2.4 concludes the chapter and presents future directions.

2.2 Sub-classifications of HCM Studies

There is a significant increase in the HCM studies in the recent years. United States and United Kingdom are the first two by far leading countries in publishing healthcare works. In this manner, the second class of countries includes Finland, Canada, India, Italy, France, and Germany; the third class includes Brazil, Australia, Israel, Netherlands, and Taiwan. Figure 2.2 illustrates the countries most publishing healthcare works. It is interesting that China, one of the leading countries in many research areas, is about 20th place in this list. A publication is counted more than one if its authors are from different countries.

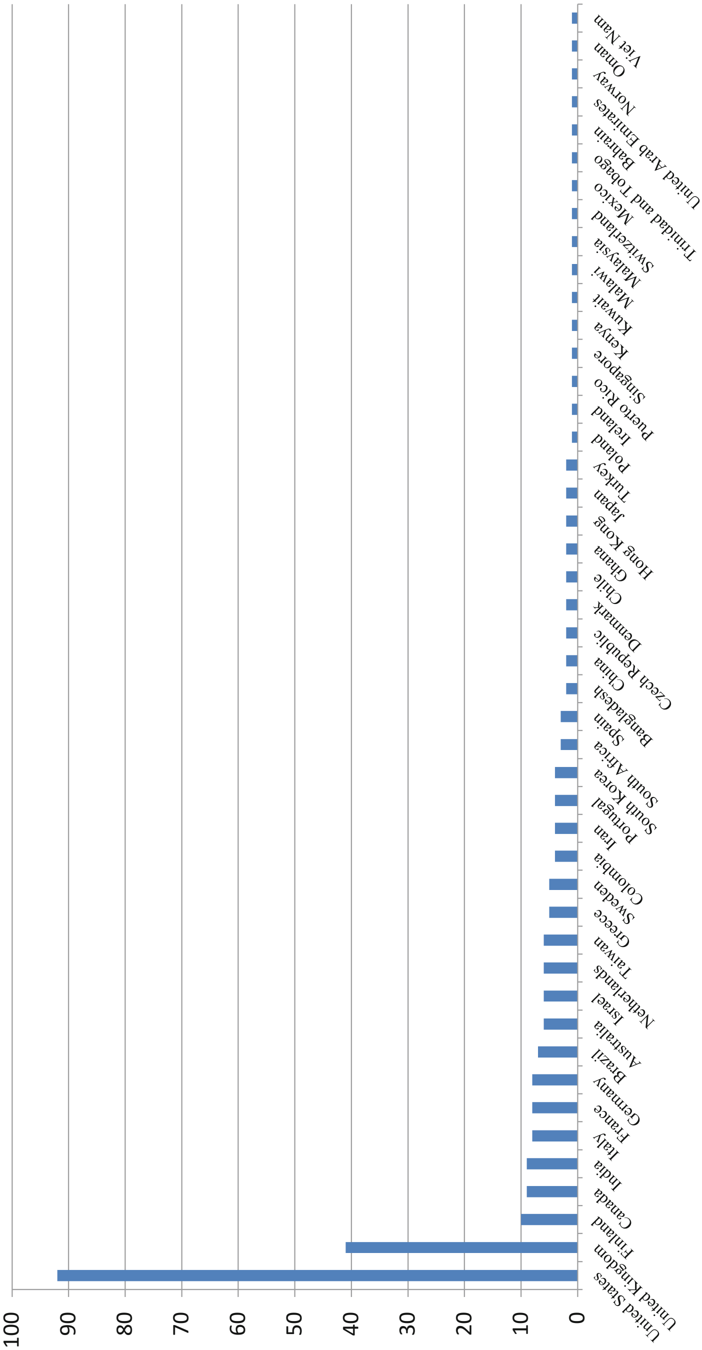

Fig. 2.2 Countries publishing in Healthcare Management

Some institutes focus on healthcare research more than the others. Texas A&M University, University of Southhampton, Ben-Grurion University of the Negev, Cardiff University, and VA Medical Center are the leading institutes publishing healthcare papers.

In the following, HCM papers are classified as literature review papers, qualitative and quantitative techniques, case studies, and performance measurement paper, and some representative papers are given.

2.2.1 HCM Papers Making Literature Review

Some researchers have attempted to review the literature on qualitative and quantitative techniques utilized in healthcare management systems. Fakhimi and Mustafee (2012) focus on synthesizing extant literature in healthcare OR by classifying papers based on OR techniques, application category, healthcare specialty, among others. The scope of this review article is limited to OR studies undertaken in the UK. Ozcan (2009) presents the quantitative methods used in healthcare management with their applications, including decision trees, forecasting techniques, facility layout and facility location techniques, and scheduling techniques. Tanfani and Testi (2012) edit a book on advanced decision making methods applied to healthcare, including the applications of operational research, statistical and economic decision-making tools in the field of healthcare delivery. Cox (2006) presents the traditional quantitative risk assessment techniques for the human health consequences of using antibiotics in food animals. These techniques include Bayesian Monte Carlo analysis, rapid risk rating technique, etc.

Some other researchers made literature reviews on various healthcare problem areas. Lavis et al. (2005) review studies of decision-making by health care managers and policy-makers. They claim that literature reviews are necessary for developing better inform health care management systems and effective policy-making. Kontio et al. (2007) present a literature review on the benefits of healthcare information systems and enterprise resource planning (ERP) systems in healthcare. The study is conducted using a meta-summary technique for qualitative research. Kamarudeen (2010) reviews the literature to reveal the impact of healthcare system on the amenable mortality rates in the OECD countries. Rais and Vianaa (2011) review key contributions addressing contemporary optimization issues in the domain of healthcare. The study focusses on the optimization problems in current research activities and the solution techniques used for solving the optimization problems. Wang et al. (2011) present a literature review and analyze papers which use industrial and systems engineering and operations management methods to improve psychological healthcare. Matopoulos and Michailidou (2013) investigate the collaborative practices in the healthcare supply chain and give insights into hospital-vendor operations. Ashrafi et al. (2013) conduct a systematic review in order to reveal decision support applications and their effects on healthcare. The results indicate that decision support systems are applied to the five main areas, namely, disease progress management, care and treatment, drug prescribing, evaluation and prevention. Fakhimi and Probert (2013) review the operations research techniques that are used in healthcare, and categorize these studies based on the application type and operation research technique employed. The results indicate that the majority of studies focus on simulation. Dobrzykowski et al. (2014) conduct a structured literature review on operation management and supply chain management (SCM) studies for healthcare. Al-Balushi et al. (2014) conduct a literature review in order to define the readiness factors that are critical to the application and success of lean operating principles in healthcare organizations. The above literature reviews focus on best practices and specific techniques and areas such as ERP usage and SCM practices in healthcare management. Their focus is not directly the quantitative and qualitative techniques used in healthcare management.

2.2.2 Quantitative and Qualitative Techniques in HCM

Since the 1960s, quantitative techniques and mathematical models, such as operations research models, have been applied to a range of healthcare problems. However, OR techniques have not been frequently used in the solution of healthcare problems by clinicians, health managers and policy-makers. Brailsford (2005) focuses on simulation models in healthcare management and briefly describes one successful implementation and suggests some potential ways forward. Green (2012) describes the essential features and critical issues of the United States (US) healthcare system that provide opportunities for operations researchers to make significant contributions. Garg et al. (2012) develop an intelligent patient management and resource planning model for complex, heterogeneous, and stochastic healthcare systems. Motamarri et al. (2014) analyze patients' perceptions on mobile healthcare services by multiple discriminant analysis. Sadatsafavi et al. (2015) investigate employees' perceptions of healthcare facilities and differences across demographic groups by using principal component analysis, confirmatory factor analysis, and invariance analysis. Xie and Lawley (2015) indicate that innovative OR techniques are developed for operating room planning, emergency department staffing, breast cancer screening, radiotherapy treatment planning, home healthcare planning, long-term care planning and scheduling.

In the following, we present some statistics based on the operations research applications in healthcare management. The data are obtained from Scopus database with the inputs healthcare and operations research. The distribution of the healthcare publications in OR is composed of articles with a percentage of 55; conference papers with a percentage of 31; review papers with a percentage of 7; book chapters with a percentage of 4; and books, notes, and editorials with a percentage less than 3. The main research areas of the operations research based healthcare publications are medicine, engineering, computer science, business and management, decision sciences, social sciences, health professions, mathematics, and nursing, respectively.

Qualitative methods for the solutions of healthcare management problems have been employed in some works. Robert et al. (1999) use Delphi study for identifying new healthcare technologies. Zonca et al. (2015) specify the competition in healthcare with a focus on surgery in the Czech Republic and use Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis.

2.2.3 Case Studies in HCM

Case studies in healthcare management have been also handled in numerous papers. Lavy and Shohet (2009) develop an integrated facilities management (FM) model for healthcare facilities and investigate the effectiveness of the model in terms of maintenance and performance management in a real world case study. Krey et al. (2010) provide an overview of the interrelated information technology (IT) governance frameworks and best practice models, analyze the potential impacts of IT governance on the Swiss healthcare and give an outlook of the related future research. Foster et al. (2010) illustrate the use and value of the tools of operations research in healthcare and focus on queuing theory. Applying queuing theory in a hypothetical drug treatment facility, some of the key performance measures, such as average waiting time for admission, are modeled using mathematical expressions. McAlearney et al. (2010) focus on potential links between high-performance work practices and quality of care and patient safety in US healthcare organizations. After an extended literature review the authors generate a model and confirm the model by five case studies. Nemeth and Cook (2010) focus on Resilience engineering in healthcare enterprises. Based on a 5-year case study, the authors present a concept for an infusion device interface that would contribute to resilience. Ahsan et al. (2010) design and provide the insight of an Enterprise architecture approach to process architecture for healthcare-IT alignment. They analyze healthcare organizational processes using a specific case study and conceptualize this analysis in order to provide an overview of healthcare processes in the context of enterprise architecture to improve healthcare management. Van Vactor (2011) presents a collaborative communications model which provides information to healthcare supply chain managers and administrators. Using the data obtained from a case study including healthcare supply chain managers in the US Army, the effects of collaborative communications on healthcare supply chain management is pointed out. Bora et al. (2011) describe a methodology to support the evaluation of the benefits provided by Radio Frequency Identification (RFID) on product traceability applications in healthcare sector and provide a real world case study. Bullock et al. (2013) analyze a United Kingdom (UK) knowledge exchange program designed to bring together healthcare managers and researchers with a case study.

2.2.4 Performance Measurement in HCM

There are several quantitative and qualitative techniques aiming at measuring the performance level of a healthcare organization or comparing its relative position with the other organizations. A healthcare organization should measure its performance since measuring performance provides quality improvement, transparency, accreditation, recognition as a patient centered medical home, and participation in financial incentive programs or demonstrations. Literature review reveals the common performance measures for healthcare organizations as in Table 2.1.

A performance measurement system should take care of all the indicators given in Table 2.1. The performance of healthcare organizations can be compared based on a multicriteria decision making (MCDM) technique which can consider all the criteria given above. Some examples of MCDM techniques are analytic hierarchy process (AHP), simple additive weighting (SAW), Preference Ranking Organisation Method for Enrichment Evaluations (PROMETHEE), Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), ELimination Et Choix Traduisant la REalité (ELECTRE), or VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR).

2.3 Classification of Techniques Used in Healthcare Management

In this section, we classify HCM techniques as follows: Simulation, multicriteria decision making, mathematical programming, statistical decision making, data envelopment analysis (DEA), data mining, engineering economics, human factors engineering, structural equation model, design of experiments, system dynamics, case study, qualitative research and other approaches. Figure 2.3 illustrates the literature review results on qualitative techniques used in HCM research. This literature review is based on the search conducted in Scopus database. The keywords used are the name of the techniques and *healthcare*, which are searched in the title of the publications. The related studies under each technique are briefly given in the following.

2.3.1 Simulation

The objective of simulation is to imitate the real-world processes or systems over time, and it is based on repeated trials. A simulation model can quickly investigate the effects of a change in a real life situation that may take place over several years. It can be used to study complex systems like healthcare systems that would

Table 2.1 Common performance measures for healthcare organizations

Quality of care	Utilization-cost-efficiency	Satisfaction- reports of care	Financial performance	Others
Hospital-level mortality, complication, and infection rates	Cost per adjusted discharge	Patient-reported satisfaction	Operating revenues	Availability of foreign-language written materials
Rates of specific medical errors or other patient safety issues	Bed occupancy rate	Communication/information and consistent messages from multiple providers and wait times and ease of access	Operating expenses	Availability and ease of use of translation services
Five-year survival rates for specific cancers	Length of stay	Appearance of facilities and parking/food/other services	Pharmacy cost	Number and scope of cultural competence training program
Low birth-weight or pre-term birth rate	Patients per physician per day	Control of pain or other symptoms	Total cost per patient	Uncompensated care
Unexpected return to surgery	Nurses per service	Coordination of care	Medical cost per medical visit	Care provided in public programs
Reducing variability in clinical care	Physician per service and Patients per service per day	Respect for values and preferences	Long term debt to equity ratio and Change in net assets to expense ratio	Numbers served in free clinical service programs

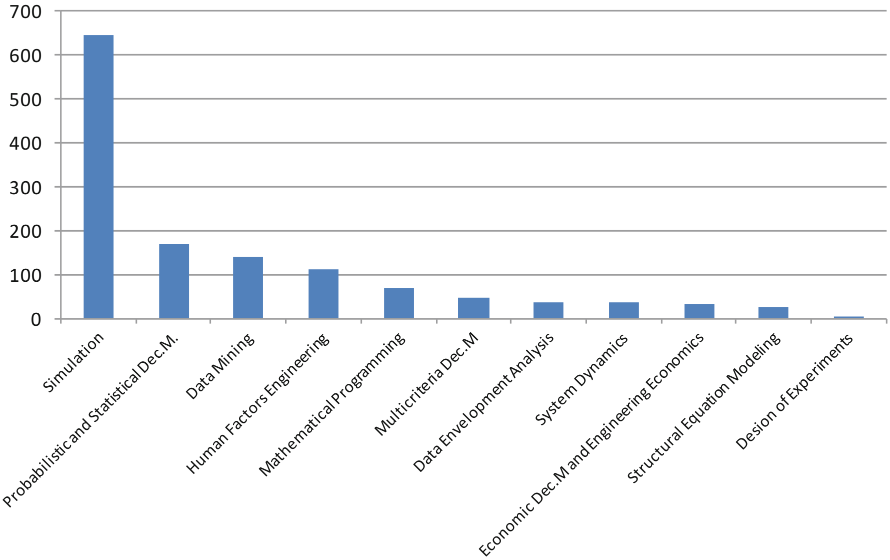

Fig. 2.3 Frequencies of qualitative techniques used in HCM literature

otherwise be difficult to investigate. However, simulation may not well model a complex multidimensional system if we do not have sufficient data to produce a mathematical model.

Simulation in healthcare is often used in safety and quality-oriented training programs, development of educational and competency assessment standards, virtual reality, epidemiologic modeling, and molecular, pharmacologic, and disease modeling. Simulation in healthcare provides a range of readily available learning opportunities, and the freedom to make mistakes and to learn from them. The learning experience can be customized, and thus, complex procedures and rare diseases can be tried by simulation training methods. Simulation also provides a detailed feedback and evaluation.

In the following, we summarize the literature on simulation-based solutions of healthcare problems.

Ramakrishnan et al. (2004) present the results of a collaborative research effort with a healthcare provider for a digital image archiving system within its radiology services. The objective is to maximize patient throughput and minimize report generation time. They build a simulation model to evaluate the different scenarios expected to ‘optimize’ the response variables. Lavy and Shohet (2007b) develop a model to adjust the allocation of maintenance resources to prevailing service conditions in healthcare facilities. The configurations integrating occupancy and environmental conditions are investigated through simulations and compared to a reference configuration. Sachdeva et al. (2007) try to combine OR methodologies to achieve greater acceptance of results for an organizational change. Patient flow is modeled using simulation. Results from simulation, particularly for politically sensitive issues, are persuasive but inadequate to result in change. Eldabi et al. (2007) use simulation within healthcare settings based on the survey data obtained from the experts composed of academics and industrialists, a critical analysis is applied to find the differences between what exists and what could be created based on outlining some major themes. Chandra (2008) presents a healthcare supply chain template utilizing e-commerce strategy. By using simulation, optimization and information-sharing techniques are used to optimize purchasing and inventory policies. Gonsalves and Itoh (2009) propose a simulation model that contains both the subjective and objective elements in the patients' evaluation of healthcare services. The proposed model is simulated via discrete event simulation, and Genetic Algorithm is used to optimize the model. Brailsford et al. (2010) focus on the idea of combining discrete-event simulation and system dynamics and describe two practical healthcare examples of combined discrete-event simulation and system dynamics models. Gaion et al. (2009) model and simulate an alarm management system in a Colored Timed Petri Net framework to be used for testing scenarios of alarm management of healthcare devices with different levels of workload and resources. Cabrera et al. (2012) present an Agent-Based modeling simulation to design a decision support system for Healthcare Emergency Department (ED). The objective of the proposed procedure is to optimize the performance of such complex and dynamic Healthcare EDs by optimal staff configuration including doctors, triage nurses, and admission personnel. Knight et al. (2012) propose a simulation model to study the effects of patient behavior using discrete event simulation. Instead of utilizing some probability distribution for individual decisions, a decision making model is used based on system observations. The proposed model can be used for decision makers to improve overall system performance and for solving location-allocation problems. Robinson et al. (2012) utilize simulation in the implementation of lean in healthcare. The study uses both the impact of discrete-event simulation and lean approaches to the improvement of healthcare systems. Buyurgan and Farrokhvar (2015) develop a simulation model to investigate adverse events and patient safety in healthcare due to poor supply chain management practices, and inadequate and disorganized product validation procedures and compare different scenarios for patient safety, care delay, and system efficiency. Baril et al. (2016) aim at allowing a rapid and successful implementation of the solutions developed during the Kaizen. They develop a discrete event simulation to test scenarios defined by team members during a Kaizen event. Before Kaizen, some problems with the system are the limited treatment room capacities in the mornings and computerized appointment system that can schedule one treatment at the same time. Applying Kaizen, patient delays before receiving their treatment are reduced by 74% after 19 weeks.

2.3.2 Multicriteria Decision Making

MCDM is the optimum decision making process under the existence of various and conflicting criteria. MCDM is divided into two subgroups called multi-attribute decision making (MADM) and multi-objective decision making (MODM). MADM includes the techniques composed of discrete decision spaces whereas MODM includes the techniques composed of continuous decision spaces. MCDM methods are widely used in public and private sector decisions on transport, education, investment, environment, energy, defense, and so forth.

The health care industry has been relatively slow to apply MCDA. But as more healthcare researchers and practitioners have become aware of the techniques, there has been a sharp increase in its healthcare applications. Decision criteria must be weighted, and goal achievement must be scored for all alternatives. Methods of multi-criteria decision making are available to analyze and appraise multiple clinical endpoints and structure complex decision problems in healthcare decision making.

Bose (2003) presents and describes the knowledge management capabilities, the technical infrastructure, and the decision support architecture for such an HCM system and provides a decision support infrastructure for clinical and administrative decision-making. Aktas et al. (2007) propose a management-oriented decision support model to assist health system managers in improving the efficiency of their systems. The conditional dependencies and uncertainties are represented by using Bayesian Belief Networks. Zeng et al. (2013) propose an improved VIKOR method with enhanced accuracy to support the decision making in healthcare management. Dehe and Bamford (2015) compare two multiple criteria decision analysis models for a healthcare infrastructure location decision. Evidential Reasoning (ER) is used to solve the model, and Analytical Hierarchy Process (AHP) is used to compare the processes and results. Hussain et al. (2016) develop a framework to assist lean deployment in Abu Dhabi public healthcare delivery systems. Twenty one healthcare wastes are ranked based on the evaluations of local situations by experienced healthcare professionals. Marcarelli (2016) evaluate healthcare policies with benefit/cost analysis by the analytic hierarchy process. The effectiveness and efficiency of some policies and their costs are considered in the evaluation process.

2.3.3 Mathematical Programming

Mathematical programming requires the use of a computer program to make an optimum decision. It includes probability and mathematical models to solve the problems. It is one of several OR techniques whose particular characteristic is that the best solution to a model is found by optimization software. Mathematical programming enables simultaneous consideration of multiple constraints and sensitivity analysis and provides an efficient tool for healthcare professional (Earnshaw and Dennett 2003).

Rönnberg and Larsson (2010) aim at developing an optimization tool that automatically delivers a usable schedule based on the schedules proposed by the nurses. The authors develop a mathematical model for a typical Swedish nursing ward and analyze the results. Adasme et al. (2015) develop a minmax robust formulation for routing in healthcare wireless body area networks. The proposed formulation minimizes the highest power consumption of each biosensor node placed in the body of a patient subject to flow rate and network topology constraints. The formulation includes an equivalent polynomial formulation of the spanning tree polytope to avoid having an exponential number of cycle elimination constraints and a mixed integer linear programming (MILP) formulation of the traveling salesman problem. Paschou et al. (2015) develop a personnel rostering system for healthcare units, which incorporate mobile technologies. This system minimizes the time and other bureaucratic delays in personnel scheduling.

Operating room planning is another area that OR techniques are often used. Landa et al. (2016) deal with the operating room planning problem at an operational planning level. The problem addressed consists of two interrelated subproblems usually referred to as "advance scheduling" and "allocation scheduling." In the first sub-problem, the decisions considered are the assignment of a surgery date and an OR block to a set of patients to be operated on over a given planning horizon. The second aims at determining the sequence of selected patients in each OR and day. Roshanaei et al. (2017) aim at selecting patients with the highest priority scores and schedule them in the current planning horizon. They determine the number of surgical suites and operating rooms required to accommodate the schedule at minimum cost.

A focus in global healthcare today is on the task of improving inventory management. The main challenges in this task include uncertainty in demand and limited human resources.

Danas et al. (2006) identify the inefficiencies of the logistics systems of Greek hospitals through the management of medicine stock within the hospital pharmacy. Fortsch and Khapalova (2016) address the challenges faced by blood centers by introducing practical methods for accurate blood demand forecasting, which will allow for lowering of costs, reduction of blood wastage, and conservation of limited resources. In all locations, demand-forecasting is completed using the popular Microsoft Excel spreadsheet software; however, this field research study shows the demand for blood is non-stationary and cannot be accurately forecasted using Excel, at least not without writing a macro. Hence, they use multiple approaches to predict blood demand. At the end of the study, the Box-Jenkins methodology is shown to be the optimal choice to forecast demand. Saedi et al. (2016) develop a stochastic model to find the optimal inventory policy for a healthcare facility. They proactively minimize the effects of drug shortages under uncertain disruptions and demand.

2.3.4 Probabilistic and Statistical Decision Making

Statistical decision making is the process of analyzing data and using methods of statistical inference in making business decisions. Both probabilistic and statistical techniques such as statistical sampling and sampling distributions, point estimation and confidence intervals, hypothesis testing, correlations among variables and multivariate analysis are used in this process.

The capability of making statistical analyses has an extreme importance in healthcare management. Healthcare professionals generally use empirical information via statistical summaries to make decisions rather than deep data analyses. If statistical education of healthcare professionals falls short, finding the possible relations among diseases, estimation of parameters, making inferences about these parameters, multivariate analyses including clustering, factor analysis, etc. may not be possible.

Guo et al. (2008) develop a community healthcare competency scale for public health nurses (PHNs). They explore community healthcare competency of PHNs in Taiwan by using a cross-sectional research design to collect data. Chandrasekaran et al. (2012) investigate the effect of process management on clinical and experiential quality. The data gathered at various time intervals is used to statistically test the developed hypotheses. Four important implications emerge from this work. Uddin et al. (2012) measure the effectiveness of static clinic and satellite clinics to provide primary healthcare services to street-dwellers. Data collected before and after the implementation of the clinics are compared with a t-test. Vozikis et al. (2012) propose a specialized partially observable Markov Decision Process form in order to determine an optimal or nearly optimal policy for the treatment of patients with ischemic heart disease. The proposed approach has a practical advantage over clinical studies such as no risk for the life of patients and low cost. Weidmer et al. (2014) develop a system for the consumer assessment of healthcare providers for in-center hemodialysis patients. The reliability and validity of the survey are assessed with statistical methods. Van Minh et al. (2014) evaluate the primary healthcare system capacities for responding to storm and flood-related health problems by using self-administered questionnaires, in-depth interviews and focus groups discussions. Dobrzykowski and Tarafdar (2015) develop and test research hypotheses linking information Technologies. They use a paired sample of primary survey data and secondary archival data for 173 hospitals in the US. They find that increased information exchange relationship drives provider-patient communication, and increased social interaction ties drive information exchange relationship. Michailidou et al. (2015) compare the hospital charges accrued following appendectomies operations in the pediatric population. A total of 264 cases from 2007 to 2013 are reviewed, and the results indicated higher costs at laparoscopic operations. Fervers et al. (2015) examine the effects of globalization on healthcare expenditure. The research problem is whether the relationship changes with respect to the types of healthcare systems. They analyze 22 OECD states between 1980 and 2009 in pooled time-series regressions. They find that an increase in economic openness leads to lower spending growth and to stronger in countries with social health insurance systems.

2.3.5 Data Envelopment Analysis (DEA)

Data envelopment analysis is a linear programming based technique for measuring the relative efficiencies of decision making units by employing multiple inputs and outputs. Two types of scales are used in DEA: constant returns to scale (CRS), and variable returns to scale (VRS). In CRS approach, the output changes by the same proportion as inputs are changed. In VRS approach, production technology may exhibit increasing, constant and decreasing returns to scale.

Malhotra et al. (2015) use data envelopment analysis to benchmark the performance of 12 publicly managed care organizations against one another for the period 2009–2011. They find that only six companies out of 12 are 100% efficient. They also identify the areas in which inefficient companies are lagging behind their efficient peers. Davey et al. (2015) use DEA technique by using the constant ratio to scale to compare four decision making units for the efficiencies of two private health centers of a private medical college and two public health centers. DEA technique reveals that the government health facilities group are more efficient in the delivery of primary healthcare services with respect to private training health facilities group.

2.3.6 Data Mining (DM)

Data mining is the process of analyzing and discovering patterns in data by using different perspectives such as artificial intelligence, machine learning, statistics, and database systems. It aims at extracting information and transforming data into an understandable structure for further use.

DEA enables using multiple inputs such as the number of beds, doctors and nurses and outputs such as patient days and total immunization for measuring the performance of healthcare systems. In some of DEA applications, the weights of inputs and outputs can be defined (Al-Shayea 2011).

Huang et al. (1995) propose an agent-based system in order to help manage the care process in real-world settings by combining artificial intelligent and agent techniques. Swangnetr et al. (2010) compare two simulated robot medicine delivery experiments with different participant age groups and robot configurations by using a meta-analysis of data and statistical and machine learning methods. Utter et al. (2010) conduct a retrospective cross-sectional study including 11 indicators from 18 geographically different academic medical centers based on the medical records using a standard instrument and descriptive analysis. Darrel et al. (2014) present a literature review on the quantifiable and measurable benefits of big data analytics in healthcare systems. The main advantages of big data analytics usage are obtained in the improved outcomes for patients and lower costs for healthcare providers. Ramírez-Ríos et al. (2015) examine DM algorithms as a feasible and necessary strategy for optimal management of databases (DB) in the national healthcare systems. They deal with the management of multiple DB that considers patient's affiliation information under the supervision of the authorities in healthcare. Their DM analysis detects frauds and other type of duplicities.

2.3.7 Economic Decision Making and Engineering Economics

Engineering economics is the science of giving economic decisions based on discounted cash flow techniques such as present worth analysis, annual worth analysis, the rate of return analysis, etc. Time, cash, and interest are the three parameters of engineering economics. The economic analysis methods can also be used under risk and uncertainty conditions.

Through better healthcare system design and capital investments in new health technologies, such as electronic medical records, telemedicine, and imaging systems, healthcare managers can manage disbursements and benefits. The time value of money can be considered through engineering economics science, and thus correct economic decisions can be made. Sensitivity analysis should be conducted before giving risky investment decisions since health technologies are too expensive. Multiparameter sensitivity analysis rather than one-at-a-time sensitivity analysis should be applied to analyze the effects of changes in two or more parameters.

Johnson (2008) develops some spreadsheet functions that enable queuing theory in healthcare systems. The proposed functions can be used for better process understanding leading to better decision making and optimization of the healthcare budget. Dortland et al. (2013) reveal the position of real estate departments through an exploratory survey among health organizations. They consider the type of project coalitions and the rationale behind this choice and the flexibility regarding a real option. Devaraj et al. (2013) examine information technology investments among hospitals and how it influences patient care and financial performance with an operations management-based perspective on the effect of IT in streamlining hospital operations. Zadeh et al. (2015) describe a framework that can facilitate the implementation of evidence-based design (EBD), and clarify the related safety and quality outcomes for the stakeholders. They use engineering economy tools including present values, internal rates of return, and payback periods to evaluate the return on investments, in which facility design and operation interventions resulted in reductions in hospital-acquired infections, patient falls, staff injuries, and patient anxiety.

2.3.8 Human Factors Engineering

Human-factors engineering is the science that deals with the application of information on physical and psychological characteristics to the design of devices and systems for human use. In order to provide safety, effectiveness, and ease of use, human factor engineering focuses on both human strengths and limitations in the design of interactive systems.

Human factors engineering has recently been used in healthcare management to increase reliability, especially in the operating room. Human factors engineers test new systems and equipment under real-world conditions in order to identify potential problems and unintended consequences of new technology. These usability tests can be applied to various healthcare management problems such as data and information processing.

Boston-Fleischhauer (2008) uses human factors engineering and reliability science for enhancing existing operational and clinical process design methods in healthcare. Van De Weerdt and Baratta (2012) focus on analyzing working conditions of home healthcare services, which is a growing service area in Europe, such as aides and nurses. The authors analyze the impacts of home healthcare works regarding job satisfaction, well-being, emotions at work, relationships with the others and occupational stress.

2.3.9 Structural Equation Modeling (SEM)

Structural equation modeling is composed of a diverse set of mathematical models, computer algorithms, and statistical methods such as confirmatory factor analysis, path analysis, and partial least squares path analysis that fits networks of constructs to data. SEM can deal with measurement error, enables examining, and modelling complex healthcare problems (Beran and Violato 2010).

Gowen et al. (2006) examine healthcare quality program practices, employee commitment, and control initiatives, and perceived results based on the responses from Quality and Risk Directors of 372 U.S. hospitals. The results of SEM indicate that both quantitative and qualitative quality program results are mainly related with employee commitment and control initiatives. Haggerty et al. (2011) compare how well accessibility is measured in four different subscales that evaluate primary healthcare from the patient's perspective based on SEM analysis. They use the results of a survey of 645 adults with at least one healthcare contact in the previous 12 months.

2.3.10 Design of Experiments (DOE)

The design of experiments deals with the determination of the relationship between factors affecting a process and the output of that process. The primary purpose is to find cause-and-effect relationships between the process inputs and outputs. DOE techniques are commonly used in clinical evaluations but their usage in the production and design phases are limited. Designing effective experiments increases the reliability and efficiency of healthcare management.

Ramakrishnan et al. (2005) focus on identifying appropriate modifications to the existing workflow at the computed tomography (CT) scan area of a healthcare provider while transitioning from a film-based image archiving system to a digital system. Apart from the workflow, the flow of information also needs to be modified and streamlined. The ultimate goal is to maximize patient throughput and minimize report generation time. Industrial engineering tools such as process mapping and time study are used to understand the initial flow of operations. A Design of Experiments based approach is used to identify the effect of the variables in the system and the interaction amongst them. Modeling and simulation are used to analyze and quantify the potential benefits that can result from the implementation of the digital image archiving system. Savsar and Al-Ajmi (2012) determine the significant factors that cause delays in surgery operations and affect the productivity of surgery clinics in a hospital. Based on data collected from surgery clinics of an international hospital, design of experiment approach is used to determine the significance of the effects of the factors.

2.3.11 System Dynamics

System dynamics aims at understanding the nonlinear behavior of complex systems over time based on flows, internal feedback loops, and time delays. It is a computer-aided approach applied to dynamic problems arising in complex social, managerial, economic, or ecological systems. It first defines problems dynamically and proceeds through mapping and modeling stages. System dynamics enables modeling complex healthcare problems such as multiple interacting diseases, supply chain problems, and expansion of diseases (Homer and Hirsch 2006).

Lane et al. (2000) develop a system dynamics model of the interaction of demand pattern, resource deployment, hospital processes and bed numbers. They find that some delays to patients are unavoidable and reductions in bed numbers do not increase waiting times for emergency admissions. Brailsford (2008) illustrates several examples of system dynamics in healthcare organizations and discusses the possible reasons for the popularity of system dynamics for healthcare modeling. Samuel et al. (2010) analyze health service supply chain systems using system dynamics, where three service stages are presented sequentially. Zamora Aguas et al. (2013) develop a system dynamics model in order to assess supply risk impact in the oncological medicine supply chain in Colombia. Supply networks, supply chain costs, improving service, quality and opportunity performance indexes are included into the model. Rich and Piercy (2013) develop a systems dynamics model of hospital healthcare in order to capture the problems in the existing system and their inter-relationships.

2.3.12 Qualitative Approaches

Qualitative methods are used to gain an understanding of primary reasons, opinions, and motivations about research problems. Qualitative research is also used to uncover trends in thought and ideas, and exhibit details about the problem. Some standard qualitative approaches include focus groups, individual interviews, and participation/observations.

Qualitative approaches are relatively rarely used in healthcare management but they add significant value to healthcare management. Especially, social and cultural aspects of healthcare management can be revealed with qualitative research. Qualitative approaches provide important insights into health-related phenomena, generating new ways for empirical questions. Qualitative research is based on health related lived experiences and relational processes as the basis of social phenomena.

Finstuen and Mangelsdorff (2006) identify the mentoring and executive competencies required among preceptors of a graduate program in health and business administration. They specify the requisite skills, knowledge, and abilities needed to achieve those competencies by using a Delphi methodology through e-mails. Hunt (2009) focus on relief operations and aims at exploring the moral experience of Canadian healthcare professionals during humanitarian relief work. The authors conduct 18 semi-structured individual interviews based on Interpretive Description methodology. Bauernschmitt and Conradie (2010) establish a descriptive research to present to what extent private healthcare providers have contemporary knowledge and understanding of supply chain practices and what extent these providers adopt and apply such knowledge to recognized practices and concepts. Farinella et al. (2011) describe the outcomes of a case study on the regional differences in implementation of "stroke networks" in Italy, which is one of the most important health issues in Italy. The results of 52 in-depth interviews and six focus groups indicate that early diagnosis, delivery of treatment and rehabilitation therapy can reduce the risks of death and disability. Papadopoulos et al. (2011) conduct a qualitative study in order to explore the dynamics in the implementation of a process improvement methodology using actor-network theory. They illustrate the utility of actor-network theory in articulating the dynamic nature of networks underpinning socio-technical change. Nelson (2011) presents a descriptive study and describes the perceptions of staffing adequacy of healthcare team members working together after conducting semistructured interviews in a cancer center. Hadziabdic et al. (2011) focus on exploring the problems reported by healthcare professionals in primary healthcare concerning the use of interpreters and what the problems lead to. The authors use qualitative content analysis of 60 real-life incident reports to find out the major problems. Jaafaripooyan et al. (2011) identify performance measures to evaluate accreditation programs in healthcare based on qualitative methods, including snowball sampling technique, email interviews, and thematic content analysis.

2.3.13 Other Approaches

Some healthcare management papers cannot be classified with respect to the above-mentioned approaches. We categorize these works as follows:

2.3.13.1 Cost Analysis in Healthcare

Nicholson et al. (2004) focus on inventory costs and service levels in a healthcare organization. The authors compare two models, three-echelon distribution network managed by the healthcare organization, and two-echelon distribution network outsourced to a third party, for non-critical inventory items. The results indicate that outsourcing distribution of non-critical medical supplies reduce inventory cost savings while service levels are not changed.

2.3.13.2 Quality in Healthcare

Dey and Hariharan (2006) propose a model for identifying problems and evaluating the performance of healthcare services. The authors apply the model, logical framework analysis in three services of a hospital and show the effectiveness of the proposed method with the case study. Mohammadi et al. (2007) suggest a quality based outline for a customer-driven health system. The authors determine six types of customers, nine types of outputs and the various operations associated with them. De Mast et al. (2011) focus on healthcare processes in order to provide a unifying and quantitative framework. In their proposed methodology, the authors integrate the various process improvement approaches such as six sigma, lean thinking, and total quality management in order to provide conceptual models and practical templates for diagnosis in healthcare processes. Culcuoglu et al. (2012) propose a modified Kaizen approach that utilizes a series of two to four hour Kaizen Sessions for healthcare delivery systems. The authors also present how to document and measure the success of the sessions' effect.

2.3.13.3 Information Technologies in Healthcare

Lubitz and Wickramasinghe (2006) propose an integration of information technologies into healthcare operations. The proposed network-centric healthcare operations support system provide information flow among all users of the system and enable relevant knowledge to be generated and exchanged among the users. Later, Von Lubitz et al. (2008) extend the network-centric approach and give a new definition of Worldwide Healthcare Information Grid which is a global system for the efficiently conducting of healthcare operation around the world. Kuan (2009) proposes an RFID integrated healthcare system. The proposed service management system can handle operations such as revenue management, expenditure, service timing and provide analytics for managerial decision. Machado et al. (2010) focus on Ambient Intelligence based monitoring techniques in healthcare environments. They address the different methodologies put into operation in the healthcare sector, supported by a putative architecture which is used in various healthcare institutions to support RFID monitoring systems. Wu et al. (2011) suggest a remote healthcare platform for people with chronic disease living at home or inpatients living in the hospital. The proposed approach is based on open service platform and aims to overcome integration problem and improve ease of use. Shie et al. (2011) focus on electronic health information system and information exchange and give insight into the architecture, potential benefits, and challenges. The authors also present the current state of the applications while providing insight on the future research by highlighting the difficulties and potentials. Simonen et al. (2012) define the information concerning factors that promote the use of effectiveness data in healthcare management. The results show that the use of effectiveness data in healthcare management can be limited due to research, managerial work, and the organization. Grandinetti and Pisacane (2012) analyze the web services for healthcare management, and use operations research approaches in order to increase the effectiveness of the web services. Lillrank (2012) presents a definition of integration and coordination in health service production. The author identifies purposes, contexts, and design rules for integrated healthcare by applying a design science methodology. Chen (2012) integrates geographic information system, radio frequency identification and grid computing technology to provide an information system which can monitor and detect infectious events. Bhagya Lakshmi and Rajaram (2012) examine the impact of innovative approaches and information technology applications on the acceptance of rural healthcare services. Data is collected from 465 rural health personnel and analyzed statistically.

Liu and Park (2013) define the challenges and requirements of an e-Healthcare interconnection infrastructure and provide a framework. In their design, the authors take into account dimensions such as; security, integrated service management, on-demand access to the network, quality-of-service, accounting. Shi et al. (2013) investigate electronic health record systems and health information exchange by presenting their architecture, benefits, challenges, and other related issues. Lucas et al. (2013a) examine the relationship between facility management and healthcare delivery. A case study is used to define different types of information needed to perform maintenance tasks satisfactorily. Lucas et al. (2013b) propose a healthcare facility information management prototype, which allows facility managers to respond more efficiently and effectively to facility related events. Sobol and Prater (2011, 2013) analyze healthcare practices of two countries, the United States and Taiwan, in order to provide a formal benchmark of information technology usage. The authors compare the countries regarding adaptation of information systems and the efficiency created by the usage. Banerjee et al. (2013) propose an architecture of a cloud-based healthcare application intending to serve patients in emergency conditions. Under the emergency, the patient's medical history can be tracked by the cloud system and better decisions can be given. Healthcare management is an important interest area of supply chain management literature. Chen and Chang (2013) propose using RFID technology to produce a healthcare monitoring system which can trace every event the same times as the events happen. The applicability of the system is demonstrated in a pilot study. Ker et al. (2014) focus on the efficiency of logistic systems of medicals and evaluate the effectiveness of information systems used in pharmacies. Browne et al. (2015) focus on primary healthcare organizations. The authors summarize innovative intervention called EQUIP which designed to improve the capacity of primary healthcare clinics. The authors also provide information about real-world examples from four different clinics, which adopt the intervention.

2.3.13.4 Tactical and Strategic Decision-Making in Healthcare

Lavy and Shohet (2007a) develop a decision-making model which can integrate various parameters into a facility management tactical and strategic decision-making process. In the study, the authors provide the architecture and procedures of the proposed model.

2.3.13.5 Lean Management in Healthcare

Enache-Pommer and Horman (2008) integrate lean approach with green principles and apply them in children' hospitals. The results of the application of the proposed approach in three hospitals show that with the proposed approach the hospitals may become more efficient and healthful. Hicks et al. (2015) provide a case study on applying a lean approach to production, preparation, and process (3P) to design a new endoscopy unit in England. The result of the analysis shows that this 3P participative design method is an effective tool for meeting the requirements of multiple stakeholders. Healthcare management uses the principles of system analysis and design.

2.3.13.6 Environmental Management in Healthcare

Kagioglou and Tzortzopoulos (2010) examine the business flow of healthcare infrastructure sector from a built environment perspective. The authors give insight into the trends in healthcare, explain the alternative models of healthcare delivery; current building and investment programs; clarify the procurement process, and describe facilities management activities, give details about related financial models, risk evaluation on healthcare. De Fátima Castro et al. (2015) propose a benchmarking approach for healthcare buildings. The authors take Building Sustainability Assessment methods as a baseline and try to reduce the subjectivity given in the definitions. As a result, the authors define criteria for healthcare buildings in four main groups namely, consumption of resources, waste production, costs and environmental impacts.

2.3.13.7 Risk Analysis in Healthcare

Sørup and Jacobsen (2013) focus on employee absence in the healthcare sector. The authors initially define the main factors of employee absence using satisfaction scores, and then they use these findings to form a management framework, which provides information about risk factors associated with employee absence. Technology management is also an important aspect of healthcare management.

2.4 Conclusions

In this chapter, we reviewed the literature review on healthcare management. The review results can be classified as follows: the works on quantitative and qualitative techniques in healthcare management; the works on healthcare case studies; and the works on healthcare literature reviews. We later classified the techniques and approaches used in healthcare research and gave some related recent papers under each class.

The common aims of the HCM studies in the literature can be classified as the quality of health care, efficiency improvement, patient satisfaction and financial performance. Literature review reveals that quantitative techniques are more frequently used than qualitative techniques in HCM. Within quantitative techniques, the most commonly used ones are simulation, statistical decision making and data mining. The common feature of these techniques is that they are data driven.

Data analysis is a critical component of healthcare management works. Data analysis has gained acceleration in the recent years from data mining to big data. Especially, with the emergence of IOT (internet of things) technologies, new sources of data related to healthcare management are included in these studies. For instance, IOT and Big Data technologies will provide improved patient care, flexible patient monitoring, and improved drug management. These emerged technologies will take an important place in the future of HCM research areas. Hence, we suggest data mining and big data analyses to be utilized in healthcare for further studies.

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