Homebased Healthcare: Issues and Challenges

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Abstract

Healthcare costs in United States are projected to rise to 20% of GDP by 2015. This is a cause of major concern and current political debate. The largest contributor to this cost is the hospital cost accounting for 30% to the healthcare expenditure. Segmenting healthcare through new delivery mechanisms may be an answer to the rising cost. Disruptive innovations like Retail clinic’s is a prime example of this segmentation providing patients increased convenience at a reduced cost. This thesis presents the case of evolving Homebased healthcare as an alternative segment for healthcare with the objective that it would reduce the costs of healthcare by early monitoring, diagnosis and treatment of disease, a paradigm on which preventive healthcare is based. Synthesizing the information and research available this thesis proposes key elements of Homebased healthcare using which a model for Homebased healthcare is derived. Technology is discussed as a key enabler and a discussion is made regarding some of the current trends in evolving technology. Applying some lessons learned from other industry in high technology sector, this thesis then comment on the supply chain challenges arising due to homebased healthcare model.

Thesis Supervisor: Dr. Mahender Singh
Title: Research Director, MIT Center for Transportation and Logistics
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Finally, God, thank you for blessing me with such a wonderful family.
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Chapter 1 Introduction

Spiraling costs are creating immense pressure on the healthcare systems in developed countries. One of the major areas contributing to rising costs is the cost of healthcare delivery. Recent success of innovative healthcare delivery mechanisms like retail clinics (Listed by Forbes as last decades top 10 disruptors) amply demonstrate that there are opportunities to create alternative health delivery mechanisms which can reduce costs and improves access and convenience. Traditionally health establishments have focused on improving in-hospital setting efficiencies, however, with the recent advancement in communication technology it is possible to avoid or eliminate some of the cost burden and inefficiencies of in-hospital treatment in a Homebased treatment environment. Assuming that Homebased healthcare would become a reality in the future, it would be prudent to explore the role of technology in enabling Homebased healthcare.

Disruptive technologies in most industries have reduced costs, improved performance and increased access and convenience of the product or services. However, many researchers have attributed the rising costs of healthcare to technology. This trend is unusual compared to other industries. A few reasons could be proposed for such a behavior, namely

- Costly technology/techniques that improve the health outcomes
- Patent protection to reward the innovator for recouping R&D expenses
- Lack of substitutes with the same efficacy, reducing competition.

Espoused by few researchers that technology in general has increased the cost of providing healthcare, Porter believes that technology is an enabler and not a cause; he argues that it's the current structure of the healthcare delivery systems which is the root cause for high cost of healthcare [1]. He also believes that instead of focusing on reducing costs, healthcare reforms should focus on improving value. These seemingly conflicting view points make it pertinent to investigate the role of technology in a Homebased health care environment.
1.1 Motivation

Despite the rapid advancement in technology, there have been other socio demographic changes like aging population and increase in obesity driving increased incidences of chronic diseases and consumption of a large percentage of healthcare dollars. Preventive healthcare has the potential to affect the health outcomes in chronic diseases by timely intervention through continual monitoring of patients health status. Technology now has the ability to assist in such intervention. We have seen the impact the Internet and ATM machine has had on the Banking Industry. Plastic cards and Internet based transactions have in many cases completely eliminated the need to visit traditional brick and mortar bank branch. Orr states that electronic processing dramatically reduces the cost per transaction [2]. According to DiDio, the average transaction cost at a full service bank is about $1.07; it reduces to $0.27 at an ATM and falls to about a penny if the same transaction is conducted on the web [3]. Technology similarly has the potential to eliminate some of the efficiency issues in healthcare delivery and therefore needs to be investigated to determine its impact on healthcare delivery mechanisms.

To address and determine the potential issues that technology would have in a Homebased healthcare environment, MIT Efficient health delivery group (MEHD) under MIT’s center for transportation and logistics has commissioned a study of healthcare sector which would: [4]

1. Identify the Dynamics of the Current Healthcare Supply Chain:
   This research seeks to understand the forces that are creating and driving the current structures in Homebased healthcare. As Homebased healthcare is an ill defined concept it attempts to define Homebased health care and proposes a model for Homebased healthcare. The role of technology is further explored and its importance for Homebased healthcare is established. We explore the current service offerings using case studies from three different manufacturers.

2. Apply Scenario-Based Planning Methodologies to the Healthcare Supply Chain:
   Using the definition of Homebased healthcare a few future scenarios are presented which explores demand patterns, issues and environment. This helps to understand the value
chain of Homebased healthcare and associated supply chain implications for various organizations delivering this care.

3. **Recommend and develop game-changing Strategies, Policies, and Technologies:** The research attempts to define Homebased healthcare as another alternative channel for delivering healthcare. Disruptive technology has changed the competition and cost structures in several industries. It has the potential for improving efficiency in the healthcare sector too. This thesis explores and suggests ways of how home & healthcare could be integrated using technology and some lessons that we should draw so that the future supply chains are designed optimally and managed efficiently.

### 1.2 Healthcare in Crisis

From an estimated 4% of GDP in 1960, by 2007 the healthcare costs have increased to 9% of GDP in the OECD countries [5]. In the US alone, in 2005 the healthcare expenditure was 16% of GDP and in the next ten years, by 2016, is projected to rise to 20% of the GDP [6].

![Figure 1.1 US National Healthcare Expenditure](image)
Medical expenses as a percentage of household expenses have grown from 9% in 1970 to almost 18% in 2000 reducing the affordability for healthcare (Figure 1.2) and increasing the population of Un-insured Americans (Figure 1.3). Despite spending the highest healthcare dollars, lack of significant differences in health outcomes compared to other countries is a cause of concern [7].

<table>
<thead>
<tr>
<th>Percent of personal consumption spending</th>
<th>Medical care</th>
<th>Food/tobacco</th>
<th>Personal business</th>
<th>Recreation</th>
<th>Housing</th>
<th>Transportation</th>
<th>Clothing/accessories</th>
<th>Other</th>
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**Source:** U.S. Bureau of Economic Analysis.

**Notes:** "Other" includes religious activities, education and research, personal care, and foreign travel. Components add to 100 percent.

**Figure 1.2 Components of US Personal Consumption Spending 1970-2001**

The percentage of Americans with no health insurance continues to grow, and while the poor are disproportionately affected, even some higher earners are without insurance.

<table>
<thead>
<tr>
<th>WORKERS WITHOUT INSURANCE FOR EACH INCOME RANGE</th>
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<tbody>
<tr>
<td>Less than $10,000</td>
</tr>
<tr>
<td>$10,000 to $19,999</td>
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<td>$20,000 to $29,999</td>
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<tr>
<td>$90,000 to $99,999</td>
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<td>$100,000 and more</td>
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**Source:** Employee Benefits Research Institute estimates from Census Current Population Survey, 2006

**Figure 1.3 Continuing Growth of the Un-insured**
The healthcare Industry suffers from highly skewed distribution of demand with much of the demand being involuntary or unpleasant. This nature of demand introduces a third party like insurance. Medicare, a federal program that applies to retired people, has 130000 pages of reimbursement rules compared to 10000 pages for Internal Revenue Services. The complexity of healthcare system is further summed by following analogy

- Person “A” goes to a local franchise restaurant and sits down at a table to eat
- Person “B” arrives, looks at the menu, and places an order on behalf of “A”
- “B” orders a Diet Coke for “A”, but is told the restaurant only offers Diet Pepsi, not Diet Coke
- “B” leaves, and “A” consumes his/her meal
- After finishing eating, “A” pays only 15% of the restaurant bill, then leaves
- “C”, from Aggregated Eaters, Inc. arrives, picks up the restaurant bill, demands a volume discount, and then pays the restaurant the discounted amount

This is U.S. health care!

1.3 Research Scope

This thesis attempts to define what Homebased health care is and how it is different than the traditional definition of Homebased care. The research seeks to understand how Homebased healthcare would be enabled by technology. The technology aspect is further explored by investigating some learning from other industry and applying the same to Homebased health care environment. A further comment would be made on delivering Homebased healthcare and the resulting supply chain issues.

1.4 Methodology

Three methods were used for conducting research, namely

*Secondary Research*: Extensive search of published material from Trade Journals, Google Scholar and MIT’s various databases was conducted with various search terms like Homebased health care, home health care, home care, technology and home health care, remote healthcare, Tele-medicine etc
Interviews: Interviewed British Telecom expert to understand the implementation and issues on Tele-medicine.

Case Studies: To further validate and understand our findings, we developed the following three case studies based on companies providing products which are key enablers of Homebased health care.

Philips Healthcare (PHG) was chosen for its Remote Monitoring products which allows monitoring of patient’s health conditions remotely. A Homebased healthcare in the future would consist of some equipment as offered currently by Philips which would allow capture of the patients’ data remotely. This data then would be linked to patient’s health record and analyzed for any abnormality or deviation from normal and patients could be alerted for seeking medical help.

NxStage Medical (NXTM) is a medical device company that develops, manufactures and markets innovative systems for the treatment of end-stage renal disease, acute kidney failure and fluid overload. NxStage was chosen for the study as it manufactures portable dialysis systems which are approved for use at home. Such therapeutic systems present unique challenges in a Homebased environment.

T2 Biosystems, a startup company, headquartered in Cambridge Massachusetts has developed successful prototypes of miniaturized device which would provide lab quality diagnostics in a variety of remote settings including home. This is a technological disruptor and has the potential for making home diagnosis for most of the disease conditions a reality.

The organization of the thesis is as follows: In Chapter 2, a brief literature review of current publications in the academic and trade journals along with industry publications is presented. This is followed by a detailed discussion on the various drivers of the healthcare costs in Chapter 3 which creates a background for this research. Chapters 4 and 5 develops Homebased health care model and discusses the various technologies enabling Homebased healthcare. Chapter 6 discusses the lessons learnt from technology development in computer and mobile phone industries. Chapter 7 presents three case studies of companies providing devices and services for Homebased healthcare. Chapter
8 synthesizes the information and presents a model for Homebased healthcare along with implications for supply chain of organizations delivering it. Chapter 9 concludes the thesis with some observation regarding the future of Homebased healthcare.
Chapter 2 Literature Overview

This report studies the impact of technology in a Homebased healthcare setup and draws inferences for the supply chain of the organizations delivering it. With Homebased healthcare not a widely recognized concept, there is a paucity of available literature which defines Homebased healthcare. Therefore, a lot of inferences were drawn by using the information available at various government institutions like Medicare and Medicaid.

With the technology development happening in different sectors, such as Communications, Bio Technology, Nanotechnology, it was extremely difficult to select a set of research that would answer all questions. Hence the most relevant papers were selected from various Journals, databases and published book to comment on these developments. However, given the scope of this research not all relevant papers could be reviewed, hence the research is limited to only a subset of published material available.

The review is divided into four major sections: Review of cost issues in Healthcare Industry; Review of Homebased healthcare definitions; Review of Literature on technology, innovation & the future state of healthcare; and, Review of healthcare Supply Chain.

2.1 Healthcare Cost

An enormous amount of literature is available on healthcare costs and its various drivers. The key paper referred for studying the healthcare cost was Goethebeur, Forrest and Hay [8]. They provide a comprehensive view of the various hospital costs which constitute 30% of the overall healthcare cost. This paper was supplemented by a series of paper by Bodenheimer et al, to balance our view of the various rising healthcare costs [9]. A review of healthcare cost becomes necessary to create a perspective around various issues and the need for finding alternative healthcare delivery mechanism such as Homebased health care. We also used government and international publications to understand the current healthcare cost trends. A number of other papers were selected to specifically understand costs associated with various diseases.
2.2 Defining Homebased Healthcare

We studied available publications from government institutions such as Medicare, Medicaid and Department of Health (Center for disease control) to understand the current status of Homebased healthcare and how it is perceived by the existing institutions. There is a dearth of literature that accurately defines Homebased health care. As a result, we also reviewed some of the futuristic scenarios associated with pervasive healthcare and point of care from the book “Future of Health Technology” [10].

2.3 Technology, Innovation & the Future State of Healthcare

With technology being a vast subject, it was difficult to identify the most relevant academic research amongst the plethora of developments happening worldwide. However, the concept of technology development is interspersed with innovation; therefore we used the seminal work done on disruptive innovation by Christensen Clayton [11]. In this book Clayton shows how disruptive technology displaces the reigning competition and redefines the competitive market place. Christensen argues that two conditions are necessary for disruptive innovation to increase to scale:

- technological enablers (i.e., technologies that provide routine solutions to problems that previously required trial and experimentation); and
- a disruptive business model that can profitably deliver these routine solutions to customers in affordable and convenient ways.

Homebased healthcare would become reality primarily due to the power of disruptive technologies. Homebased healthcare has a compelling value proposition and, sooner than later a disruptive business model would be found to enable the diffusion of Homebased healthcare.

Another relevant article to this research is “Disruptive Innovation for Social Change” [12]. In this article Christensen et al. argue that “While incumbent organizations may do a good job serving a particular group, they are unlikely ever to reach the far broader populations that would be satisfied by simpler offerings.” Homebased health care would evolve due to technological forces which would provide simpler models of healthcare.
than traditionally provided by the current systems. We further reviewed the different technologies supporting e-health or remote health in the books "Future of Health Technology" and "Wearable e-Health Systems for Personalized Health" [10] [13].

2.4 Healthcare Supply Chains

We chose two primary reference sources for this review. One was the current research being conducted by MIT’s Supply chain 2020 project which has completed study on various sectors of healthcare. The second source was the concept of triple A supply chain promoted by Hau Lee [14]. The paper outlines three important tenets besides cost effectiveness which are important for supply chains of successful organizations.

- Agility: Respond quickly to sudden changes in supply or demand to handle unexpected external disruptions smoothly and cost efficiently, and recover promptly from shocks such as natural disasters, epidemics and computer virus.

- Adaptable: Evolve over time as economy progresses, political shifts, demographic trends and technological advances reshape markets.

- Aligned: Align the interest of all participating firms in the supply chain with their own. As each player maximizes its own interests, it optimizes the chains performance as well.

2.5 Other Relevant Literature

Industry and Trade publications became a vital source of some of the developments in the various technologies enabling Homebased healthcare. Besides Government sources like FDA (Federal Drug Authority), CDC (Center for Disease Control), Medicare and Medicaid were also referred to understand the overall structure of healthcare. For comparative studies between the various healthcare systems across the world, we used data from WHO (World health Organization) and OECD (Overseas Economic Cooperation and Development).
Chapter 3 Rising Cost of Healthcare

In this chapter we discuss various drivers of healthcare cost. Understanding these drivers will help us build a context for the importance of Homebased healthcare and how technology would enable Homebased health care.

Figure 3.1 shows a breakup of healthcare costs between 1980 and 2004, the highest contributor of health care costs continues to be Hospital care, followed by Physician Services [15].

Figure 3.1 National Expenditure for Health Services and Supplies by Category

Another major trend during the last two decades is the increasing costs of prescription drugs. It is important to examine the cost drivers of hospital and physician care and explore if Homebased healthcare could reduce or eliminate some of the costs. This thesis ignores the rising costs of prescription drugs that are largely driven by high cost of R&D and focus only on costs related to hospital care and physician services.
3.1 Key Drivers of Hospital Costs

3.1.1 Aging Population:
Aging of baby boom generation (born between 1946 and 1964), decreased fertility and increased life expectancy have led to the overall aging of population in America. Projections made by CDC (Figure 3.2) indicate that population above 65 and 75 years of age is growing at a faster rate between 2010 and 2050. A big factor contributing to the aging population is increasing longevity. The life expectancy between 1960 and 1998 for a 65 year old person has increased by over 24% (from 14.3 years to 17.8 years) and with age, people tend to use more hospital services. In 1999 persons over age 65 used three times the number of hospital days per 1000 than the general population and persons over age of 75 used four times more [16].

![Population Growth for 65+ Age](image)

**Figure 3.2 Population Growths for 65+**

Figure 3.3 shows the trend in the rate of hospitalization by age group from 1970 to 2000. The trend shows an increase in hospitalization from 1990 onwards [17].
Figure 3.3 Trend in the Rate of Hospitalization in various Population Age Groups

Conversely Reinhardt takes a demand centric view and argues that effect of aging is not the major driver of healthcare cost [18]. Using the data from MEPS (Medical Expenditure Panel Survey) he shows that the aging of the population is too gradual a process to rank as a major cost driver in health care and assess that aging would contribute only half a percentage point to the overall projected healthcare expenditure growth of 7.3% by 2012 [18]. He concludes that the bulk of rise in the healthcare expenditure is due to other factors like rising per capita incomes, availability of promising but costly new medical technology, workforce shortages and asymmetric distribution of market power in health care that gives the supply side of the sector considerable sway over the demand side. Within United States nothing more powerfully underscores the point made by John Wennberg and associates that spending in various regions of the country differs by a factor of three [19]. Recognizing the argument in the research aging population does present significant challenges for managing healthcare costs.

3.2 Diseases

It is estimated that 125 Million Americans suffer from at least one chronic disease and 60 million suffer from several disorders [20]. By 2020, it is expected that half of the US population will suffer from chronic disease and that management of these conditions will
represent 80% of health care spending. [21] With aging, increasingly sedentary lifestyles and the rising tide of obesity, chronic diseases will likely continue to be a major component of health care costs over the next few decades. A report by Miliken Institute (2007) indicates that the economic cost of chronic diseases is $1 Trillion (Figure 3.4) and is projected to increase to $6 trillion by 2050.

![Avoidable Treatment Costs and Output Losses, 2023](image)

**Figure 3.4 Avoidable Treatment Costs and Output Losses - 2003**

### 3.3 Key Disease Categories Driving Costs.

Cardiovascular diseases contributed more than 20 million days of hospitalization [22] [23]. This was followed by psychoses accounting for 11.34 million days, delivery at 9.25 million days, malignant neoplasm at 8.04 million days, pneumonia at 7.67 million days and fractures at 5.8 million days (Figure 3.5). Even though the comparison between 1999 and 2000 does not indicate diseases contributing to increase in hospital costs in short term, but with the increase in longevity the effect of these would become more pronounced.

---

1 Direct Costs include Cost of treatment, medicines etc and Indirect Cost include loss of wages, productivity loss etc.
Figure 3.5 Average Numbers of Days of Hospital Care for First-Line Diagnosis

Figure 3.6 provides the total hospital capacity by number of beds and beds per 1,000 population. There is a noticeable decline in the overall capacity of the system. This scarcity of beds is another reason for increased cost of healthcare.

Figure 3.6 Numbers of Beds and Number of Beds per 1,000 Persons, 1981 – 2006

3.3.1 Cardiovascular diseases: Cardiovascular diseases (CVD) in some form or another afflict greater than 20% of the American population. In a 2002 study, it was estimated that the direct costs and indirect productivity loss for CVD and stroke was $329.2 billion
Figure 3.7 show that the majority of costs are incurred in hospitalization and nursing homes in 1999-2001. The long term affects of heart condition on the costs cannot be ignored since CVD is a chronic condition which cycles between long period of stability and short acute period.

3.3.2 Cancer: Between 1990 and 2001, 16 million cases of cancer were diagnosed in the United States. The total costs for cancer in 2002 (direct and indirect) were estimated to be $180.2 billion [25]. With the lack of effective cure and increasingly aging population hospitals would continue to be burdened with increasing cancer patient populations.

3.3.3 Obesity and Related conditions: Obesity is considered a primary driver of a 36% increase in inpatient and outpatient spending and a 77% increase in medications [26]. A 1995 study estimated the national cost of obesity to be $99 billion in direct healthcare costs and the costs of lost productivity [27]. The direct costs are linked to treating Type 2 diabetes, coronary heart disease and hypertension. In the same study a comparison was made between obese and non obese patients for treating CVD, and it took 32.5 days of hospital care for the obese group versus 2.8 hospital days for non obese groups.

3.3.4 Musculoskeletal conditions: In 1996 more than 54 million Americans had musculoskeletal conditions and an estimated $193 billion was spent in treating these
conditions [28]. Hospital stays and ED visits (Figure 3.8) accounted for 40% of the total spend.

![Healthcare Expenditures for musculoskeletal conditions in 1996](image)

**Figure 3.8 Healthcare Expenditure for Musculoskeletal conditions in 1996**

3.3.5 *Respiratory disease*: Various types of respiratory diseases have the potential to affect inpatient expenditure. For example in 1998, 14 million Americans had asthma and it is projected that by 2020 this would double to 29 million patients. Asthma can largely be controlled in an outpatient setting provided national guidelines for the diagnosis, treatment and management of asthma are followed.

3.3.6 *Mental Health Disorders*: A 2001 report more than 54 million Americans per year experience an episode of mental disorder; though only 8 million access the health services [29]. For example, Alzheimer's disease (AD) afflicts almost 4 million elderly Americans and about 3% suffer aged 65 to 74 years with approximately half of those over 85 likely to suffer from the disease. According to the Alzheimer's Association, per capita Medicare expenditures in 1995 for beneficiaries with AD was 70% higher than for those without cognitive impairment [30].

3.3.7 *Infectious Diseases*: Several type of infectious diseases like flu, AIDS, pneumonia, sepsis etc impact the cost of inpatient healthcare. For example between 1997 and 1999 severe flu led to a dramatic increase in hospital use. Also, since the population is aging more patients would report to hospital with these conditions.
3.4 Un-insured

With the rising health coverage premiums, an increasing number of Americans are dropping out of insurance coverage. In 2001 close to 41.2 million (Figure 3.9) Americans were un-insured [31]. By deferring care, un-insured patients typically use less healthcare services than insured patients. In 1996, 62% of Un-insured patients had a medical expense compared to 84% to 88% of those with public and private coverage. Since Un-insured people have decreased access to outpatient care, this group has the potential to pressure hospital costs. Emergency departments are the safety nets for people who do not have access to primary healthcare. Un-insured individuals typically delay treatment and seek uncompensated care via Emergency department, which are required by law to treat indigent people regardless of whether they can afford to pay. In 2000, 12% of ED visits led to hospital admission [32]. Delayed care and uncompensated use of hospital Emergency department adds a significant cost burden for hospital inpatient admissions.

Figure 3.9 Growth in Un-insured

Figure 3.10 shows the rising trends of Emergency department visits and the declining emergency departments.
3.5 Patient Readmissions

Benbassat et al. estimate that approximately 13% of inpatient use is due to repeated admissions [33]. Almost a third of re-admissions occurred within a month of discharge, half occurred within 90 days and 85% within a year. In the study, the readmissions were largely due to patient frailty and disease progression; authors further suggested that early readmissions were likely due to non preventable progression of the disease or from a different diagnosis, while late admissions of patients with asthma or diabetes are more likely to be preventable through ambulatory services.
Figure 3.11 Number of Selected First-Line Diagnosis for Hospital Discharges

3.6 Hospital Trends

3.6.1 Hospital Expansion: Between 1998 and 2000 the amount invested (Figure 3.12) in hospital expansions and renovation increased by 47% [34]. This increase in the investment in 1998 was driven by low investments in early 1990’s making the current investment a necessity to keep up with the demand increase.

Figure 3.12 Hospital Expansion and Renovation 1998
3.6.2 Mergers and Acquisitions: When two significant competing hospitals merge, it has been demonstrated that prices tend to rise and the size of the merging hospitals have a positive relationship with the resulting market prices [35]. Price increases occur regardless of hospital ownership (profit or non-profit). Generally, for profit hospitals charge higher prices due to higher costs for equity capital and income taxes [35]. Another trend (Figure 3.13) indicates decrease in deals but increase in number of hospitals involved in mergers and acquisitions.

![Figure 3.13 Mergers and Acquisitions Deals and Number of Hospitals Involved](image)

3.6.3 Liability: Premiums are rising fast for professional liability insurance for both doctors and hospitals; rates have increased dramatically, by 30% in many states. Malpractice premiums for physicians, schools and hospitals have increased from 20% to 100% [36]. Legal costs, including those for class action suits that target high profile healthcare players as well as ridiculously trivial claims, are swelling uncontrollably. This situation creates some difficulties for hospitals to purchase coverage and contributes to rising costs. Liability issues have also led to the practice of “defensive medicine” where a physician prescribes unnecessary treatments and tests to avoid litigation. The cost of defensive medicine has been estimated to be $50 billion annually.
3.6.4 Competition: One effort towards the containment of hospital costs is intensifying price competition between hospitals [36]. Greater hospital competition has been found to be effective in controlling prices only in regions of high managed care penetration. However, mergers between hospitals reduce competition, and its role in controlling prices. In some cases merged hospitals raised prices by 20% to 40%. Market concentration was reported to affect hospital financial performance. According to a recent study by Kane, 69% of hospitals in less competitive markets had sustainable financial performance; this figure was only 29% for hospitals in highly competitive markets. In addition, hospitals in highly competitive markets had longer lengths of stay.

3.6.5 Technology: Technology has upward and downward effects on inpatient spending. Some new technology reduces hospital use through increased outpatient procedures such as outpatient chemotherapy and less invasive techniques. Purchase of new technology may increase hospital capital expenditures. For example (Figure 3.14), X-ray machines costing $175,000 are replaced with CAT scan machines, which cost $1 million and then by PET and SPECT imaging machines costing more than $2 million each [37]. The push towards new technology is frequently driven by increased patient demand and the hospital’s need to remain competitive.

![Figure 3.14 Cost of Sophisticated Technology](image)

3.6.5.1 Indirect effects of technology: The cost impact of new technology is not limited to the purchase price. New technology often increases the number of people treated due to a
“treatment expansion effect”. This effect occurs when new technological development leads to better, safer treatments thereby increasing the number of patients treated by diffusing into previously untreated groups such as patients with mild disease and those with advanced disease. Advances in diagnostics such as those made in imaging and medical informatics often increase detection and therefore diagnosis and treatment rates (e.g., the prostate specific antigen test for prostate cancer) which frequently require inpatient services and put upward pressure on certain hospital costs. In a survey asking 225 primary care physicians to report which medical technologies were most beneficial to their patients, MRI and CT scanning topped the list along with ACE inhibitors, balloon angioplasty, statins and Mammography [36].

A report by Cutler and Mchellan assessed technological change in five different conditions including heart attacks, low birth weight infants, depression, cataracts and breast cancer [38]. Assuming that the value of one year of life saved is $100,000, the authors concluded that for four of the five conditions, the benefit of technological change far outweigh the costs. For the fifth condition (breast cancer), cost and benefits were found to be equal value.

Another study by Mohr et al made following conclusion with regards to technology [39],

- “cost saving” technologies frequently spread costs in cost-increasing ways;
- technologies affect both volume and price;
- technologies are strongly linked to the systems governing their use (i.e., the incentives used in the healthcare systems are key).

3.7 Workforce

Workforce costs represent 50% of a hospital’s operating expense [38]. Payroll growth is a key driver of rising costs within the hospital sector and nursing and other personnel costs have increased faster than revenues. Hospital payroll growth rose from 2.6% in 1999 to 3.7% in 2000, and the trend is projected to accelerate to levels not seen since the early 1990s. This segment of healthcare spending has attracted substantial attention from both private and public sectors. Efforts to control these costs vary from legislation to new technology. The United States is facing a shortage of nursing staff that is causing a crisis
for quality healthcare and patient safety. Nursing staff shortages are increasingly problematic for hospitals. In 2001, there were about 126,000 vacant positions for registered nurses (RN), with a mean 13% vacancy at any given hospital [40].

Rising healthcare cost is cause of concern and a part of ongoing political debate. Solutions like universal health coverage may not change the long term trend of rising costs as healthcare costs drivers are many and varied. Changes done at policy level like legislation banning trans-fats in Denmark has reduced the exposure of IP-TFA at the individual level without noticeable effect on availability, price, and quality of foods previously containing high amounts of IP-TFA. The findings of high concentrations of IP-TFA in popular foods outside Denmark suggest that millions of people inside and outside EU have intakes of IP-TFA that may increase their risk of CHD. The Danish experience demonstrates that this risk can be eliminated [41].

Countries like Japan have imposed economic penalties on the firms who are not able to check the obesity in the firms. The firms have been given the target to reduce the obese workers and their dependents by at least 10 % per year, failure to do so would result in a penalty surcharge of 10 % on their contribution to the welfare fund for elderly [42].

Technology has provided many benefits in reducing the impact of diseases. Home health care traditionally has received less attention than hospital based care. In the next chapter we explore Homebased healthcare, its definition and future promise.
Chapter 4 Homebased Healthcare

Medicare defines home health care as a “part-time or intermittent skilled nursing care, as well as other skilled care services like physical and occupational therapy, and speech-language pathology (therapy) services [43]. Services may also include medical social services, and assistance from a home health aide (when needed, if patient is also getting skilled care).” To avail such services a patient needs to qualify certain eligibility criteria showing the necessity of such service for illness or injury including a doctor’s permission prescribing such services. Patient receiving such services also need to be home bound or with restricted mobility. National center for Health Statistics defines Home health care as “care provided to individuals and families in their place of residence for promoting, maintaining, or restoring health; or for minimizing the effects of disability and illness including terminal illness.”

A further distinction is made by United States Department of health [44] between Home care and Home health care as the one where the former is more medically oriented and the latter usually includes chore and housecleaning services. Between 1980 and 2004 (Figure 3.1) expenditure on home health care has grown from 1% to 2.5%. Within the context of the definition above it becomes important to define Homebased health care which reflects the changing trends in the healthcare. Before defining it we will briefly discuss the current cycle of care for a typical diseases. Figure 4.1 depicts a traditional approach of treating an illness. In this approach a patient typically would travel to various players like doctor, a diagnostic center, a hospital or a pharmacy for filling prescriptions.
The need for such a system is to more efficiently use the scarce resources like doctors, hospital beds, diagnostic equipments or pharmacy resources. However with the rising costs it becomes imperative to discover alternative methods of health delivery. An analogy with energy industry could be drawn, as rise in oil prices and concerns of climate are creating incentives to invest in alternative methods of energy like solar, wind etc. A recent example of such a trend is visible in healthcare industry too wherein retail clinics are addressing some of the issues with the traditional method of health delivery.

In typical supply chain parlance this could be defined as a new channel for serving healthcare demand. Drivers for Homebased healthcare could be summed as follows [45]

- Aging population placing increased demand for healthcare
- Shortage of Healthcare workers (Doctors and Nurses)
- Need for 24 x 7 monitoring of health status yet preventing overcrowding and bed blocking in the hospital
- With widespread Information availability through Internet individual would like to have more control on their own information and treatment
- Increase in chronic or lifestyle diseases like diabetes, heart ailment, depression etc. which needs increased compliance, remote monitoring, and change of lifestyle.
- A trend towards healthy lifestyle based on controlling one's diet, increased physical activity, and being aware of oneself rather than just taking prescribed medicines after a symptom develops.

Increasingly, individual and patient need to control their own health through active lifestyle by using the most current information. Patients for generations have used a simple device like a thermometer to measure fever. The rapid introduction of sophisticated technologies, new devices, treatments, and procedures is instrumental in expanding the footprint of home-based healthcare delivery. Despite the fact that the current trends indicate a movement towards home-based healthcare, it is not clear if it can replace the traditional mode of healthcare. To answer this, it would be worthwhile to segment the healthcare demand, as shown in the below 2 by 2 matrix depicting the segmentation based on intensity of disease, intensity of intervention, and intensity of relationship.

![Figure 4.2 Segmenting Healthcare](image_url)

**Figure 4.2 Segmenting Healthcare**
Homebased healthcare is most suitable when the intensity of intervention required is low but the intensity of the disease is high or low. Based on the segmentation above Primary healthcare and Lifestyle based health care are the most appropriate health conditions for Homebased healthcare. Furthermore Primary and Lifestyle conditions need high intensity of relationship with the care provider, they need additional information which could reduce the intensity and improve the life conditions.

In the statistics released by AHRQ an estimated 26.5 billion dollars were spent on 5 million patients admitted with preventable hospitalization in 2000 [46]. It is estimated that even if 5% of these could be prevented by better diagnosis, education and treatment in outpatient environment (& active participation from patients) it would save approximately $1.3 billion (using average cost of in patient treatment to be $5400). Human beings have evolved from malnourishment, to nourishment to over-nourishment & indulgence. This has resulted in increased incidences of lifestyle diseases. The current method of cure for a disease may work in short term, however long term prevention would be important. Homebased healthcare is an extension of preventative care where the entire human life is managed using Homebased tools, equipments and therapies. Indeed during a disease incidence it assists patients recover in a familiar environment at a lower cost as well.

To be sure, healthcare shouldn’t be viewed through the lens of efficiency only, the effectiveness of the treatment is equally important. Though some what contested “Quality adjusted life year” (QALY) is most frequently referred in literature as a measure of effectiveness. The outcomes from treatments and other health-influencing activities have two basic components – the quantity and the quality of life. A QALY embraces both of these components and is the arithmetic product of life expectancy and a measure of the quality of the remaining life years. A three month study done by Sackett and Torrance indicates the QALY’s are higher when the treatment is received in a Homebased environment [47].
Figure 4.3 QALY in Home Environment

In the entire spectrum of healthcare, home presents unique opportunity and challenges to deliver healthcare. The above sample data indicates that the QALY’s were higher when the treatment received was in a Homebased environment. With the rapid advancement in communication technology, healthcare delivery has taken new forms. One of the forms most often gets attention is Disease Management services. Disease management association (www.dmaa.org) defines Disease Management as “a system of coordinated health care interventions and communications for populations with conditions in which patient's self care efforts are significant” [48]. A large number of these services have communication infrastructure as a genesis, example like Tele-medicine, Tele-monitoring and Tele-radiology which could be delivered remotely. However, another silent revolution is underway in healthcare industry fuelled by the reducing form factor or miniaturization of the devices. We have seen that mobile phone based infrastructure and broadband has made communication ubiquitous. On one hand it fuels the growth of
software application and on the other hand it also fuels growth in new devices with sophisticated technology and new capability in increasingly smaller sizes.

Homebased healthcare in future would therefore be another channel for delivering Homebased healthcare. In the 2x2 matrix we can see that primary and lifestyle diseases could have home as an alternative channel for delivering healthcare. The Homebased healthcare would be very different than what is currently thought, understood and reimbursed. It would be technology enabled with devices that are able to communicate with the health providers. In order to understand what Homebased healthcare would look like in the future, the next chapter discusses enablers of Homebased healthcare technology and some applications of these technologies in a home environment.
Chapter 5 Review of Home Healthcare Technology

The general areas in which new technology will be integrated to advance health care are information infrastructure, health technology interfaces, advancement in understanding and treatment of diseases, and tools for understanding and guiding behavior changes. Section 5.1 discusses different technologies enabling Homebased healthcare and section 5.2 discusses services which are based on these enabling technologies.

5.1 Technology Enablers for Homebased Healthcare

5.1.1 Communication Infrastructure:

There are approximately 207 million Internet users in 2007-08 with approximately 75 million Broadband users [49]. The mobile phone subscription (penetration) per 100 users in 2007 was at 84.7 and is projected to increase to 113 by 2012. Communication technology is evolving further to provide high speed mobile data connectivity. Figure 5.1 below plots these technologies on two axes of mobility and high bandwidth [50]. On two extreme are GSM which offers high mobility with limited bandwidth and Wi-Fi which provides high bandwidths with limited mobility.

Home health care in the future would need technology with high mobility similar to one offered by mobile phones but at speed of data provided by high speed Internet. Wimax has the potential to offer high speeds with increased mobility. The need for such mobility and bandwidth is important for home healthcare as human life may be at risk if control signals sent to medical monitoring or dosage equipment is corrupted or degraded, or if electronic medical records cannot be accessed in a timely fashion [51].
5.1.2 Sensor Elements

Sensors and sensor systems [52] perform a variety of sensing functions allowing the acquisition, capture, communication, processing, and distribution of information about the states of physical systems. This information may relate to chemical composition, texture and morphology, large-scale structure, position, and also dynamics. Bio-sensors, bio-medical sensors and bio-chemical sensors are a set of sensors enabling measurement of the various vital biological and chemical parameters for healthcare interventions. Figure 5.2 below lists the various technologies involved in the development of sensory elements.
An alternative approach for developing sensor consists of studying the concepts mechanisms, materials, information and signal processing of living beings. Figure 5.3 shows strategies of man made sensing and natural sensing.

Figure 5.2 Sensor Technologies

Nature versus Human Approach to Sensors

Figure 5.3 Nature versus Human Approach to Sensors
Bio-inspired approach derived from nature would increase the usefulness and application of sensor devices. Figure 5.4 shows some of the main components of a bio-inspired approach. This is particularly useful for the design of Smart miniaturized and low energy devices.

![Figure 5.4 Components of Bio Inspired Approach for Designing Miniaturized Devices for Home Healthcare](image)

### 5.1.3 Nano-Biotechnology

Nano-biotechnology (Figure 5.5) is defined as a field that applies the nano-scale principles and techniques to understand and transform bio-systems (living or non-living) and it uses biological principles and materials to create new devices and systems integrated at the nano-scale. Nanotechnology provides the tools and technology platforms for the investigation and transformation of biological systems, and biology offers inspiration models and bio-assembled components to nanotechnology.
The integration of nanotechnology with biotechnology, as well as with information technology and cognitive science, is expected to accelerate in the next decade. Such integration has the potential to offer new micro scale devices that could diagnose a disease condition and provide information in a simple understandable format. With the ability to communicate remotely, such information would be used by remote caregiver to decide medical interventions, which is an important development for Homebased healthcare.

5.1.4 Computing Prowess

The increase in the computation power continues unabated. This increase in the computation power is enabling portable devices that can effectively serve the home or ambulatory medical needs. Figure 5.6 below depicts the exponential growth in the number of transistors on an integrated circuit. It is estimated that this trend will continue at least till the time when a fundamental limit of working at molecular levels is reached.
This computing trend has given rise to the concept called digital medicine defined as "the transformation of healthcare that is coming about as computer technology is used in the creation and application of medical knowledge" [53]. Homebased healthcare would need computing prowess to enable high speed capture of vital life data within the confines of home.

Moore's Law

Figure 5.6 Computation Power and Moore's Law

5.1.5 Medical Knowledge Management and Decision Support

Robert Greens from Harvard University and Edward Shortliffe from Stanford University define medical informatics as "the field that concerns itself with the cognitive, information processing, and communication tasks of medical practice, education, and research, including the information science and the technology to support these tasks" [54]. The scope of medical informatics has moved beyond the boundaries of traditional electronic medical records to an integrated clinical management and decision support systems. Internet based health sites, though controversial with respect to quality of information have made medical information directly accessible to patients [55].
WebMD.com is an example of highly rated website providing medical information directly to consumers. E-Diets is another website which provides weight loss programs for people suffering with obesity. Google and Microsoft have created health record systems which would allow users to manage their medical history and also control with whom this history is shared.

5.2 Home Healthcare Technologies

This section investigates in more detail various device and service outcome of the enablers listed in section 5.1.

5.2.1 Remote Care Services

Remote care services is a generic term used for various classes of remote health services offered using communication infrastructure such as Telephone, the Internet and video. The value offered by such services is similar or better health outcomes at reduced cost. A few studies done to evaluate the cost effectiveness of Tele-monitoring services have shown positive results. A study on cases of congestive heart failure showed Tele-monitoring less costly than hospitalization by reducing the number of hospital visits [56]. This study recommends post hospitalization Tele-monitoring rather than home care. Tele-hospices have shown dramatic cost savings according to some studies, reducing the cost per visit of traditional care of $126 and $141, for the first and second 3 month time periods respectively, to an average Tele-hospice visit cost of $29 [57].

Cardiotocography study, study of high risk pregnancy and study of home care of oncology indicates that Tele-homecare is less expensive than traditional home care. Another study has indicated that the specific application of Tele-medicine for the caring of the aged at home instead of hospitals in Japan would result in savings as high as 7.4% of the hospitalization costs of the aged by 2050 [58] [59] [60].

Some mention is made of ‘smart homes’ where intelligent monitoring, sensors etc are placed in the home which manages the individuals’ health, safety and other needs, but it is yet uncertain whether the concept will prove cost effective [61].
While many studies show the costs of Tele-homecare to be comparable or lesser than ordinary home care, newer studies place a greater focus on the linkage of costs with clinical outcomes. This has been attempted comprehensively in quasi-experimental studies such as the Kaiser Permanente Tele Home Health Research Project, which was amongst the first to demonstrate that Tele-homecare can maintain the quality of care while producing cost savings [62]. Another study of diabetic patients shows that cost effective care can be provided by Tele-homecare even under current reimbursement constraints [63]. This study illustrates that the potential savings through fewer home visits will offset the higher costs that Tele-homecare imposes on a home health agency. This study however leaves open the question of what the most appropriate means of using Tele-homecare is – substitution of traditional care by Tele-medicine or supplementation. It is inevitable that despite some initial adoption challenges, Tele or remote care would become widespread in not so distant future. The next subsections discusses various terms currently used in remote health services.

5.2.1.1 Tele-medicine

There have been many attempts at producing an all encompassing definition of Tele-medicine. The European Commission DG XIII (which deals, amongst other things, with health Telematics) has defined Tele-medicine as rapid access to shared and remote medical expertise by means of Telecommunications and information technologies, no matter where the patient or the relevant information is located and, more recently, as simply the use of Telecommunications for medical diagnosis and patient care [64] [65]. Even this definition does not do justice to the broad range of possibilities offered by Tele-medicine for diagnosis, treatment, health education and research. Indeed, the very word Tele-medicine is itself often felt to be too limiting, and definitions such as Tele-care and Tele-health’ are also used to refer to the availability of nursing and community support and other public health services. It seems reasonable to think of Tele-medicine as the remote communication of information to facilitate clinical care. Patients living with congestive heart failure are often in and out of the hospital for treatment, and that is problematic for people who live far away, as well as inconvenient for patients who are
already in physical discomfort. Whitten said "The comforts of home can be quite reassuring for someone who is ill" [66].

Tele-medicine services, such as home monitoring, allow people to receive medical care away from the hospital. Tele-medicine has been in existence for the last several decades, yet it has not seen the level of diffusion to make it a mainstream healthcare service. The primary barriers to Tele-medicine development and adoption are no longer technical—they are cost, risk aversion, policy and legal barriers [67]. Furthermore, a national survey of 80 Tele-medicine programs cited reimbursement as a major issue in its implementation [68].

5.2.1.2 Tele-radiology: Tele-radiology is the electronic transmission of radiological patient images, such as X-rays, CT Scans, and MRIs, from one location to another for the purposes of interpretation and/or consultation. Radiologists are increasingly a scarce resource given that imaging procedures are growing approximately 15% annually against an increase of only 2% in the Radiologist population.

Tele-radiology improves patient care by allowing Radiologists to provide services without actually having to be at the location of the patient. This is particularly important when a sub specialist such as a Neurology Radiologist or Pediatric Radiologist is needed, as these professionals are generally located in large metropolitan areas working during day time hours. Tele-radiology network is implemented using standard network technologies such as the Internet, Telephone lines, wide area network (WAN), or over a local area network (LAN). Highly specialized software is used to transmit the images and enable the Radiologist to effectively analyze what can be 100's of images for a given study.

Technologies such as advanced graphics processing, voice recognition, and image compression are often used in Tele-radiology. Through Tele-radiology, images can be sent to another part of the hospital, or to other locations around the world. Tele-radiologists can provide a preliminary read for emergency room purposes or a final read for the official patient record and for use in billing. In the United States, Medicare and Medicaid laws require the Teleradiologist to be on U.S. soil in order to qualify for
reimbursement of the final read. This has placed restriction on sourcing services from outside the country.

Tele-radiology is an important piece in the Home healthcare setting. A patient should be able to send scanned images to a Tele-radiologist who after investigating the reports would send interpretations to the patient’s doctor to provide medical intervention as required. From a technology point, the above scenario is distant as technologies such as MRI and X-rays are still highly complex with large form factors and therefore not amenable for home use. To enable home healthcare the devices and technology has to evolve wherein scanning of various body parts is feasible, safe and easy.

5.2.1.3 Tele-monitoring

Tele-monitoring is another aspect of Tele-medicine where the vital statistics of the patients could be monitored remotely. The key aspects of Tele-monitoring systems are;

- Wireless health status data capture devices: This consist of various portable devices like oxygen, weight, blood pressure monitors which records individual’s vital signs
- Tele-station which captures the information at a central location from the wireless health devices and transmits it to a provider
- IT and Server infrastructure to communicate the data to the providers
- Providers, who, on receiving such information acts as per the patient requirements
- Software and decision support systems to enable the providers to act efficiently

5.3 Intelligent Biomedical Clothing

Wearable health systems or intelligent biomedical (IBC) clothing refers usually to clothes with sensors that are close to, or, in contact with the skin. The sensors are enclosed in the layers of fabric, or it is the fabric itself that is used as the sensor. Such sensors can be piezo-resistive yarns, optic fibers, and colored multiple layers. IBCs have several advantages, starting with removing the task of placing the sensors by a nurse or a physician to providing a “natural” interface with the body (Figure 5.7).
Commonly, IBC is understood as the integration into textile of sensors, actuators, computing, and power source, with the whole being part of an interactive communication network. Such systems could only be conceived through a combination of recent advances in fields as diverse as polymer and fiber research, advanced material processing, microelectronics, sensors, nanotechnologies, Telecommunication, informatics, biochemistry, and medicine. Some significant prototypes being tested are VTAMN, WEALTHY, magIC (Europe), and the SmartShirt and LifeShirt (USA). A short description of various prototypes is as follows [69]:

- VTAM is a t-shirt made from textile with woven wires, incorporating four smooth, dry ECG electrodes; a breath rate sensor; a shock/fall detector; and two temperature sensors
WEALTHY (EC, FP5 Project) is a wireless-enabled garment with embedded textile sensors for simultaneous acquisition and continuous monitoring of biomedical signs like ECG, respiration, EMG, and physical activity. The “smart cloth” embeds a strain fabric sensor based on piezo-resistive yarns and fabric electrodes realized with metal-based yarns. The project was terminated in March 2005, and the prototype has since been further validated; marketing effort is under way.

MagIC, is a sensorized vest including fully woven textile sensors for ECG and respiratory frequency detection and a portable electronic board for motion assessment, signal preprocessing, and Bluetooth connection for data transmission.

SmartShirt is a wearable sensorized garment that measures human heart rhythm and respiration using a three lead ECG shirt. The conductive fiber grid and sensors are fully integrated (knitted) into the garment.

LifeShirt is a miniaturized, ambulatory version of respiratory inductance plethysmography. The garment is a lightweight, machine washable, form-fitting shirt with embedded sensors to measure respiration. A modified limb two-lead ECG quantifies cardiac performance and a three-axis accelerometer measures posture and activity.

The above prototype systems have reached a technological maturity and currently pursuing (without an EU or other public funding) either further performance validation in healthcare and other applications or a commercialization route.

5.4 Smart Bandages

The smart bandage is a thin sensor made of crystalline silicon and layers of porous silicon [70]. The porous silicon is treated with a liquid that contains probe molecules engineered to bind to fat molecules found on the surface of specific bacteria. When the bandage is placed over an infected area, bacteria from the wound move into the porous silicon and attach themselves to the probe molecules, altering the optical properties of the silicon. Doctors illuminate the bandage with light from a handheld semiconductor laser device,
and the bandage luminesces in a color that indicates the kind of bacteria that are present, for example red for *E. coli*, or yellow for strep. With the immediate diagnosis of the culprit germs, doctors won't have to wait for the results of laboratory cultures. Such smart bandages in future could eliminate the need to visit the doctor also and could be programmed to indicate if a bacteria develops.

5.5 Smart Beds

Smart beds like the one developed by Hoana Medical systems and approved by FDA can measure heart and respiratory rates without using cuffs, monitors and sensors [71] [72]. In this system, the patient lies on the bed with the sensors embedded in the mattress. These sensors can determine the patient’s condition despite multiple layers of linen, body clothes etc. Such beds in a Homebased healthcare environment could monitor patient’s recovery at home and improve the life of people attending them.

After reviewing the above products and enablers, some common technological themes emerge which are important for Homebased healthcare environment. The home of future would increasingly be equipped with multiple sensors which would enable capture of vital signs of people staying in the home. Through a universal device these signs would be communicated to a care provider, who would have very sophisticated decision support systems to continuously monitor and analyze the signs. A delivery infrastructure consisting of care takers in the proximity of home that could intervene when situation warrants external intervention will support this remote setup. In the next chapter we present some parallels that technology progress has seen in other industries and some lessons that could be derived for Homebased healthcare.
Chapter 6 Technology Diffusion and lessons from other industry

Last century has witnessed several technological revolutions, from computers weighing several tons to the portable handheld multipurpose devices, from physical mail dispatchers to e-mails, from brick and mortar retailing to online retailing etc. With the widespread adoption of communication technology and the creation of necessary infrastructure, technology is slowly increasing its penetration in home health sector. Tele-medicine, Tele-radiology is one of fastest growing services being offered remotely.

From an original focus on consultation and reminder services, the technology is slowly evolving into Tele-monitoring or e-health. This monitoring of an individuals' health is being made possible by the development of several medical grade sensors and equipments capable of communicating data over the high speed Internet to a provider. A further development has taken place in various therapeutic devices like heart defibrillators and hemo-dialysis devices suitable for Homebased medical interventions.

The development of these technologies is analogous to some of the developments we have seen in several other fields. Computers and Telephony are the most visible examples where development in technology has fuelled its rapid adoption in remote and Homebased locations. If we explore the history of computing for 50 years between 1946 and 1996, the earliest computers were large, occupied huge space and were managed by specialists. In fifty years, the computers have considerably reduced in size & costs, yet significantly improved in terms of performance. Figure 6.1 below compares the computers in terms of size and performance. During this time computers have reduced in size by 96000 times, are 60000 times faster and 100 times cheaper.
Figure 6.1 Evolution of Computers I

Figure 6.2 shows another comparison where the size of computer has decreased and performance has increased.

Figure 6.2 Evolution of Computers II
Mobile technology is another interesting technological development witnessed in the last few decades. Starting from bulky hand held equipments we now have ubiquitous handheld Telephony equipments. Figure 6.3 shows the earliest transportable phone equipment made by Spectrum cellular which used satellites to communicate.

![An Early Transportable Phone Unit](image)

**Figure 6.3** An early Transportable Phone unit

Figure 6.4 shows the evolution of mobile phones from bulky handhelds to the compact phones weighing less than 100g.

![Evolution of the Cellular Phone](image)

**Figure 6.4** Evolution of the Cellular Phone
The key theme that emerges from the developments in computers and mobile phones is the ease of use and convenience. With higher performance and increased convenience, cell phones and computers demand has proliferated from few 100 thousand units to millions and now in billion units. Figure 6.5 below contrast the change of price, weight and quantity in the evolution of cellular Telephony.

![Cellular Phone Evolution Table]

**Figure 6.5 Explosion in Demand**

This evolution in technology has changed the equation of demand and supply, from selling a few hundred thousand phones just over 20 years ago, the cell phone industry is selling a billion phones. The impact of this mega explosion in demand has given rise to unique supply chain challenges which were non existent till very recently. For example, cell phone industry has moved from a vertically integrated manufacturing in a single location to globally dispersed manufacturing. Terms like outsourcing and contract manufacturers were unheard of twenty years ago but are norm and necessary for low cost production today.

A scenario of millions and billions of home care devices is plausible in not so distant future. Indeed, unique nature of healthcare industry presents significant challenges in terms of regulatory compliance, disposal of hazardous waste, privacy of information, servicing of devices etc. Before analyzing these issues we will present three case studies of the home use healthcare devices from three different companies in the chapter 7.
Chapter 7 Case Studies

To gain a deeper understanding of the opportunities and challenges of Homebased healthcare environment we studied three different companies involved in this sector. These case studies were developed based on semi-structured interviews and company documents.

7.1 Philips Healthcare

Philips Healthcare with 2007 sales of € 6.47 Billion is one of the leading supplier of medical systems for professional and homecare segment. The home healthcare segment is primarily organized around three product lines, i.e. Philips Lifeline, HeartStart and Patient Monitoring Solutions.

7.1.1 Philips Lifeline

Philips lifeline is a patient alert service based on simple hardware which sends a message to health service provider by a simple push of a button during distress, who then alerts emergency systems, neighbors etc. Figure 7.1 shows a portfolio of products offered through this service. The target population essentially consists of elderly and patients living alone. In 2007, Philips had a subscriber base of 700 thousands and has primarily grown in this segment through acquisition [73]. This system offers great value to the family of the elderly who feel secure that technology is watching their dear ones and would be available for help when needed. Another major advantage of such a system is that the care system could respond immediately save lives.
7.1.2 HeartStart Home Defibrillator

Since sudden cardiac arrest is a major cause of death in United States, Philips HeartStart Home defibrillator is a boon for patients suffering from chronic heart conditions. FDA approved the OTC use for Philips AED (Automatic External Defibrillator) in 2004. The use of such a system in Homebased setting is made possible by the simple design and construction of the device. This device even could be used by people who have not used this before as the AED’s has voice based instructions which guides the person for hooking the device to the patients chest and delivering shock. The biggest advantage is the ability of the device to deliver shock only when required. Such intelligent interface is a breakthrough technology and is most important for any Homebased device. Success in a Homebased environment would need extremely simple health devices which could be used with minimal training.

Figure 7.1 Philips Patient Alert Devices
7.1.3 Patient Monitoring Solution

Figure 7.2 shows the Philips offering of remote patient monitoring solution, namely

Philips patient monitoring system consists of three components

1. Patient Home: The patients' home consists of various monitors like Blood pressure and pulse, Weight, ECG/Rhythm Strip, Glucose and Oxygen. These devices capture patient's vital signs and using a Tele-station (a form of data transfer device) transmits data to a data server.

2. Data Server: The data server is an interface between the service provider and patient's home.

3. Provider: The care team which receives the data from patients' home continuously monitors it and intervenes when required.

![Figure 7.2 Philips Patient Monitoring System](image)

In a recently released report based on a year long study on Telehealth solutions where Philips was a co-sponsor, the findings indicated that 88.6% respondents indicated an improved outcome in quality with 42.6% reporting reduction in cost [74]. Philips is
currently targeting these services towards the home care agencies that use some form of Tele-health solutions as part of their service offerings.

7.2 NxStage Medical

Chronic renal failure, or end stage renal disease (ESRD), impacts more than 1.7 million patients worldwide, including 453,000 in the U.S. (in 2003)—a number growing by 5% annually [75]. Annual care costs in the U.S. approach $70,000 per patient, for a total cost of care exceeding $20 billion in the U.S. alone. Yet the dialysis treatment itself represents less than 1/3 of this cost. With Daily Home Hemo-Dialysis, the cost of Hospital or in-center treatment could be reduced, resulting in an overall reduction in the treatment cost.

NxStage offers daily home dialysis equipment in a convenient portable format. Its trademark System One has the following characteristics

- Compact and portable. Allows for flexible therapy options either at home or away
- No special infrastructure requirements. No significant electrical, plumbing or water purification infrastructure changes are required. The System One plugs into any standard electrical outlet and drains without requiring plumbing changes
- Designed for ease of setup, training and use
  - Drop in cartridge allows one-step loading and safety system engagement.
- Simple compact water purification system for home use (SL package)
- Prepackaged fluids for travel (Express package)
- Simple intuitive controls for ease of use and training

- Designed for simple maintenance. Quick, wipe down disinfection makes maintenance easy and our service swap program helps prevent missed treatments

In a study for Daily Home hemo-dialysis (DHHD) it was found that DHHD was associated with a higher quality of life when compared to in-center hemo-dialysis [76]. Homebased healthcare therapies would be based on improving such quality and cost utilities.

### 7.3 T2 Biosystems

T2 Biosystems is an early stage company developing diagnostic equipment which could analyze practically any health condition anywhere [77]. The next-generation medical diagnostic are being made using proprietary technology, combining nanotechnology and miniaturized magnetic resonance (MR) technology, which would provide rapid, accurate and portable diagnostics.

T2 Biosystems' MRDTM detection technology consists of two main components, both revolutionary in their own ways:

- Magnetic nanoparticles designed to bind with specific analytes (markers in blood or other biofluid that indicate particular conditions)
- Small-scale magnetic resonance-based instruments that measure and record signals given off when the specialized nanoparticles bind with analyte

The nanoparticles can be designed to bind with a wide range of analytes to detect various targeted conditions. The particles are composed of a super paramagnetic metal core surrounded by a polymer layer decorated by multiple analyte-specific binding agents. Due to their coating and small size, the particles are highly soluble and offer rapid kinetics. In the presence of analyte, the particles transition between dispersed and clustered states. The presence of analyte results in a change in a characteristic signal that can be measured by magnetic resonance detectors.
T2Dx™ instruments, which detect the nanoparticle reactions, will be based on clinically-proven MRI technology. Whereas, conventional MRI instruments are used for whole-body imaging, require large components which limit their range of application. T2Dx instruments are highly miniaturized with much less complex electronics, as a result, it can be small and portable, and can analyze tiny samples.

More importantly, T2 Biosystems’ instruments are easy to use and provide rapid results. In Simple terms, technicians are required to place a small sample of a patient’s blood, saliva, urine or other bio-fluid in a small tube along with a solution containing the specialized particles. The T2Dx instrument is then used to analyze whether and, in some cases, to what extent the particles have bound with the analytes in question. The results are made available within minutes—thus allowing health professionals to make medical decisions almost immediately.

In the next chapter we present the synthesis of the information discussed so far. A Homebased healthcare model is proposed on this synthesis and some lessons for future supply chain issues are presented.
Chapter 8 Synthesis and Analysis

With the aid of insights gained from the discussion in the previous chapters, we present following propositions for Homebased healthcare.

*Proposition 1: Prevention is key to Sustainable Health*

Rising healthcare costs, aging population and lifestyle changes are the key impetus for finding alternatives to reduce costs and improve quality of health delivery. Increasingly, with the spread of the Internet and information explosion, patients want to get more involved in their treatment and health decision making. The society is demanding prevention than just treatment. Figure 8.1 highlights the changing healthcare needs; from negative needs of avoiding health issues the future need is to have good health.

![Figure 8.1 Changing Healthcare Needs](image)

Moving away from the concept of caring for a health condition, Homebased healthcare would enable health management of an individual. Briefly, health management is a
concept which would allow intelligent monitoring of health condition of healthy individual, notice if they are gaining or loosing weight abnormally or having frequent changes in the blood pressure and monitor various stress levels and other health indicators. Its integration with patient’s health record system would alert the individual and his primary physician about any abnormality. As with television, washing machine, dishwashers etc in homes, in the future a home health device we call as “Home Health Monitor” (HHM), would exist in each home. Such a device, using a smart card or a chip embedded under the skin would allow HHM to record the health status, advice changes in lifestyle etc in real time.

Proposition 2: Technology is the key Enabler for Homebased Healthcare

Communication technology has now matured enough to provide various wireless and embedded devices which can capture vital health information. Further changes are being driven by rapid developments in materials, Micro technology/Nanotechnology, Biomedical engineering, Physics, Chemistry etc. These developments are creating breakthrough devices, therapies and technologies in health monitoring, diagnostics, drug delivery, surgery etc. Several of these technologies would be increasingly used in ambulatory and Homebased environment. Disruptive technologies like the one offered by T2 Biosystems would virtually enable Homebased diagnosis for any disease.

Proposition 3: Convenience, Mobility and Small Form Factor are the key Attributes for Homebased Healthcare Devices.

NxStage’s Daily Home Hemo-dialysis system due to its portability and ease of use offers freedom to ESRD patients from visiting the clinics regularly. NxStage is attempting to get an approval for night time dialysis, which when approved would significantly improve the quality of life for ESRD patients. Such technologies even though costly compared to the existing treatments would initially found a niche of users willing to pay for the convenience it affords.

In this particular case, due to the reduction in hospitalization the new technology has overall lower cost compared to the existing treatment. Figure 8.2 below shows a comparative analysis of System One and other competitive home dialysis equipments
available in the market. System One is only 70 lbs and offers significant advantage with its small form factor (only 3 cu ft). Next development would lead to body wearable or implantable dialysis device which would significantly improve the quality of patient’s life.

<table>
<thead>
<tr>
<th>Table 6</th>
<th>NxStage Medical, Inc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Comparison (Home Hemodialysis and Peritoneal Dialysis Machines)</td>
<td></td>
</tr>
<tr>
<td><strong>Home Hemodialysis</strong></td>
<td><strong>Peritoneal Dialysis</strong></td>
</tr>
<tr>
<td><strong>NxStage</strong></td>
<td><strong>Fresenius</strong></td>
</tr>
<tr>
<td>Size (cu ft)</td>
<td>3</td>
</tr>
<tr>
<td>Machine Weight</td>
<td>70 lbs</td>
</tr>
<tr>
<td>Portable</td>
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<tr>
<td>Risk of Infection</td>
<td>Low</td>
</tr>
<tr>
<td>Mean Service Time</td>
<td>&gt; 1 year</td>
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<tr>
<td>Avg. Training Time</td>
<td>4 weeks</td>
</tr>
<tr>
<td>Weight Gain from Dialysate</td>
<td>No</td>
</tr>
<tr>
<td>Need for Residual Kidney Function</td>
<td>No</td>
</tr>
<tr>
<td>Installation Costs</td>
<td>Low</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>Good</td>
</tr>
<tr>
<td>Daily Dialysis</td>
<td>Yes</td>
</tr>
</tbody>
</table>
| Note: Gambro is currently not approved for use in the United States. Source: Industry sources, company Web sites, and William Blair & Company, LLC, estimates

**Figure 8.2 Product Comparison**

*Proposition 4: Homebased Healthcare would be Complementary to existing Healthcare Systems.*

Homebased healthcare would be an extension of the primary physician’s clinic into a home environment. With the help of technology primary physician could monitor the vital health signals and could intervene when something is amiss. With Homebased health system a primary physician could increase the number of people under his/her practice and yet serve them more effectively. This also has the potential of reducing the current shortage of primary physicians in America. Current healthcare system in US is highly acute care focused and almost 30% of the healthcare cost is contributed by hospitalization costs. Furthermore, the system is designed around responding to a disease
condition than to prevent the disease condition. Homebased healthcare would create necessary platform where prevention could be a focus. With the ability of monitoring data for patients, suitable lifestyle changes could be initiated and public policy be influenced.

Proposition 5: Need for a Coordinating Agency

Assuming that technology literacy would be low on sides i.e. patient and provider, a coordinating agency would be needed. This agency would provide technical support, training and other logistical support like medicine, devices, physical resources etc. Currently, the US have close to 17700 home healthcare and hospice agencies. These agencies could play the role of such a coordinating agency. The advantage of a coordinating agency is that these agencies already have an expertise in taking care of patient population in home. Augmenting them with the technical tools to serve home health segment would be ideal. However, Homebased healthcare would slowly evolve where the need for such agencies would be felt less and with the availability of information, device manufacturers, pharmaceutical companies and healthcare providers could develop direct relationships with the individual or family.

Proposition 6: Homebased Healthcare would need different Models for Sustainability and Innovation

Homebased healthcare business model would be entirely different from the current “pay per health event” model. It could be a service offered by a coordinating agency and the local primary physician on a monthly subscription basis. The monthly subscription fee would essentially be a part of the health insurance premium that an individual. As in the mobile Telephony industry, the service subscription would come with a free HHM. For patients who are following healthy regimes, insurance companies could incentivize them with lower premiums reflecting reduced probability of any disease.
8.1 Ten Commandments for Homebased Healthcare

1. *Care should be a continuous healing relationship.* Patients should receive care whenever they need it and in many forms, not just face-to-face visits. This implies that the health care system must be responsive at all times, and access to care should be provided over the Internet, by Telephone, and by other means in addition to in-person visits.

2. *Care should be customized according to patient needs and values.* The system should be designed to meet the most common types of needs, but should have the capability to respond to individual patient choices and preferences.

3. *The patient should be the source of control.* Patients should be given the necessary information and opportunity to exercise the degree of control they choose over health care decisions that affect them. The system should be able to accommodate differences in patient preferences and encourage shared decision making.

4. *Knowledge should be shared and information flows freely.* Patients should have unfettered access to their own medical information and to clinical knowledge. Clinicians and patients should communicate effectively and share information.

5. *Decision should be evidence-based.* Patients should receive care based on the best available scientific knowledge. Care should not vary illogically from clinician to clinician or from place to place.

6. *Safety should be system property.* Patients should be safe from injury caused by the care system. Reducing risk and ensuring safety require greater attention to systems that help prevent and mitigate errors.

7. *Transparency should be maintained in all respect.* The system should make available to patients and their families information that enables them to make informed decisions when selecting a health plan, hospital, clinical practice, or when choosing among alternative treatments. This should include information describing the system’s performance on safety, evidence-based practice and patient satisfaction.

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2 Adopted from “Crossing the quality Chasm: a new health system for the 21st century”
8. *Needs should be anticipated.* The system should anticipate patient needs, rather than simply react to events.

9. *Waste should be continuously decreased.* The system should not waste resources or patient’s time.

10. *Cooperation among clinicians should be a priority.* Clinicians and institutions should actively collaborate and communicate to ensure an appropriate exchange of information and coordination of care.

### 8.2 Homebased Healthcare Model

Figure 8.1 presents a high level model of a Homebased health care system. Homebased healthcare is an extension of primary health system into home. Such an extension would have following key components:

- Individual/Family: Homebased healthcare would have an individual and family at its core for providing care. All care services would have the ability to be customized for an individual’s condition. The focus of such services would be to change the lifestyles of individual’s using the latest approved research.

![Homebased Healthcare Model Diagram](image)

*Figure 8.3 Homebased Healthcare Delivery Model*
• Remote Health Advisor: A remote health advisor would either be an individual who would have access to the data and could advise remotely if any intervention is required. They would have sophisticated algorithms to detect any change in the health conditions. Another long term development would be creation of another set of professionals called “Health Advisors” or “Health Counselors”. These individuals unlike doctors or nurses would give detailed advice on changing lifestyle behaviors based on the interpretation of the health data

• Health Interventionist: The key component of Homebased healthcare would be the interventionist, traditionally called Doctors or Nurses. The primary doctor with access to the individuals and family health records will intervene when necessary. They would be instrumental in providing care in various health events in an individual’s life

• Coordinating Agency: The Homebased healthcare would depend on an intermediary. The rationale of this intermediary is to provide necessary infrastructural support, logistics and human resources to families. They would also provide the services & training for home healthcare devices. With increased diffusion of Homebased healthcare and experience, such intermediary services would be re-evaluated. Healthcare providers may want to have direct relationships with the families and patient populations, in which case this model of support would need to reprove its utility. Nonetheless, we foresee a role of intermediaries in short to medium term

• Portable Diagnostics /Therapeutic Devices & HHM: Technology is the key enabler for Homebased healthcare. With the developments seen in various scientific disciplines, Homebased health devices would become a pervasive reality. We envision a future of an integrated Homebased Health device acting as a health advisor. Such device would be use the latest approved therapies available and provide various monitoring and health advising activities based on the health data trends of the individual or entire family. Till the time we have an integrated device, Homebased healthcare would rely on multiple devices and sensors currently in
development. These devices would initially serve the needs for population who would like independence coupled with the need for staying connected and supported. Seniors and other disabled would be initial adopters who need support but cannot afford the costs of traditional homecare. Disruptive technology has a characteristic of serving unmet needs and reducing costs. A smart home in future would have many life assisting sensors, several of them would be capturing the health data and communicating to the centralized home health monitors. In the end, we believe potential of technology is unlimited but would have to encounter the barriers of adoption like reimbursements, costs, privacy, governmental regulations etc.

8.3 Future Scenarios

Based on model shown in Figure 8.3 above, we present futuristic scenarios of delivery of Homebased healthcare for an adult Mr. X in his middle age, a kid called KidZ and an elderly Mr. Z, father of Mr. X.

8.3.1 Scenario Mr. X

**Date : 5th January 2015, New York**

After coming back from a very fruitful day at work, Mr. X unwinds with a can of beer and his favorite movie. He is fast asleep at 11:00 PM in the night. The sensors embedded in his bed are monitoring the sleep pattern and recording the data in the “Home Health Monitor” (HHM). After 8 hours of blissful sleep, he is awoken by the soothing sound of Indian classical music which he has programmed in the HHM. He brushes his teeth with an intelligent brush system which has a sensor at the back of the brush which measures any mouth odor, checks for throat (like strep throat) status and his gums and teeth in a 5 second scan and sends the data to HHM. His intelligent toilet measures any abnormality in his stool and urine. After his morning ablutions, he moves for a 5 minute scan at his HHM of all the vital stats, weight, and blood pressure and oxygen levels. HHM records the data and flashes green health signal. His HHM also sends reminder to his advanced PDA for a doctor’s appointment for flu Shot and sets up a meeting with his doctor using the most convenient time slots available in both the calendars. Buoyed with his green health status Mr. X goes to his office and encounters an angry call from a customer. Mr. X spends next several hours in extreme stressful condition. He sets up a meeting with
client and immediately takes a flight to Baltimore. He reaches Baltimore at 1 PM and spends the next several hour resolving client issues. In the evening the client offers to take Mr. X to a local restaurant where they consume some beer and Sushi. Mr. X says goodbye to the client and takes an evening 7 PM flight back to New York. While in the flight he feels his stomach rumbling. Mr. X ignores it but on reaching home he develops mild fever. He uses his HHM for analyzing his health status. His HHM recommends a blood test number 23 based on his body temperature and quiz that it administered. He inserts his finger in a small keyhole shaped receptor which through a minor prick collects his blood sample. His HHM analyses the sample against the 10 most common bacteria, and indicates that he makes a phone call with the night call nurse for prescribing an antibiotic. His HHM dials a night call nurse who reviews the blood test results through her system which Mr. X has agreed to share with his nurse and primary doctor. She recommends an antibiotic which Mr. X could go and get filled from a local CVS. After about 5 minutes Mr. X receives a confirmation from CVS that his prescription would be filled in 20 minutes. It takes Mr. X 15 minutes to reach the CVS and within next five minutes he has prescription made available to him. Mr. X returns home and takes his medicine, and goes to bed, his bed sensors monitors a restless sleep for initial couple hours and feeds the data back to HHM. After the antibiotic kicks in Mr. X sleeps well for next couple hours. He is awaken by his favorite music in the morning but feels a little tired. His HHM scan indicates an additional rest for 3-4 hours. Mr. X decides to communicate to his office that he would be late today. He returns back to the bed and sleeps till 11 am. He is again reminded for a doctor’s appointment later in the evening and also plans to discuss his infection with the doctor today.

At 7 PM in evening Mr. X meets with doctor who checks him for the infection and is satisfied with the current prescription of the antibiotic. He then discusses his health trends and recommends Yoga looking at his stress charts. He also conveys that his other life indicators are in green zone. Reassured by positive report Mr. X decides to take a vacation in Hawaii for de-stressing and also decides to join a local yoga club.
8.3.2 Scenario KidZ

KidZ, son of Mr. X, is fascinated with the HHM; he likes the blinking green lights when he stands for his scans in the morning. He is 3 year old and has his health record linked with that of his mom. He does not understand what this machine does but likes to play the small games available in the machine. The machine plays some nursery rhymes and imitates his voice when he presses a yellow button. It also tells him short stories when he presses a blue button. Today he is excited as he sees a red light blinking. But the red light has his mom worried. She quickly looks for the instructions on the screen; it seems that KidZ had caught some infection. HHM has captured the data of infection from the brush scan of KidZ in the morning. HHM indicates a common form of infection and schedules a call with the nurse advisor, who confirms the illness and approves a prescription most suitable for KidZ as KidZ has allergic reactions to sulphur based drugs. HHM also sends an appointment on to the Mom and Dads PDA for the forthcoming vaccination. Since Mom has an important presentation, Dad accepts the task of taking KidZ for vaccination to his doctor.

8.3.3 Scenario Mr. Z

Mr. Z, Mr. X's father lives close to his son. He frequently does baby sitting for KidZ. After his long walk in the morning, today he is feeling a shortness of breath. He goes to his HHM which checks for his vital health signals. It indicates an increase in his blood pressure and reports that the Mr. Z has not taken his prescription for Blood pressure yesterday. Mr. Z realizes that he ignored his alerts on the PDA yesterday. He quickly takes his prescription and messages his son that he would be not be coming for baby sitting today. His HHM also realize that Mr. Z needs a refilling of his prescription and sends a request for refill directly to the appropriate brand manufacturer, which would fill its prescription through mail within next 3 days. Mr. Z realizes that HHM has made his life more convenient and made him more compliant with the therapies that he is required to take to control his blood pressure and heart condition. He is happy that the medical alert system can directly contact his son and friends in the neighborhood any time he needs their help. After resting for a couple of hours, Mr. Z plans to go out for a game of Poker in the evening today with his friends.
Even though the above scenarios have one in several million chances to be realized in the future, we can draw some conclusion regarding various Homebased healthcare delivery challenges. In the next section we will review various healthcare delivery challenges arising out of such Homebased healthcare scenarios.

8.4 Homebased Healthcare Delivery Challenges

8.4.1 Creating Sustainable Business Model

Despite good progress in the technology, home as a center of healthcare faces the problems in terms of paying for the services. Reimbursement continues to be a major issue with Homebased healthcare as we have seen through Tele-medicine programs. Once the reimbursement issues are resolved innovative business models are likely to be introduced by new and traditional companies. They could be direct, indirect or hybrid models. However, we predict Homebased healthcare to have a big service component and the devices would mostly be free. We will have to leave the exact nature of the model to evolutionary forces, yet section 8.5 presents few scenarios of various possible business models, to explore the supply chain challenges.

8.4.2 Liability Issues

Healthcare being a highly regulated field suffers from the liability issues which may occur due to failure of any technology or treatment. Homebased healthcare would similarly be exposed to liability claims which would impact the adoption rate.

8.4.3 Flexibility

Homebased healthcare would witness various evolutionary changes. Large investments in supporting processes and infrastructure may run the risk of becoming obsolete in a very short span. The processes and infrastructure would need to be highly flexible with minimal investment which would allow various business models to be tested and validated till this sector matures.
8.4.4 Workforce

Besides medical staff, the new workforce in healthcare would include technicians who will support health infrastructure of networks, devices etc. In the short term, however, it would hinder the growth of Homebased health care. As new investments in trainings are made, the situation may start improving. We foresee an opportunity for various players to offer training services.

8.4.5 Sales

Insurance and payers would be the sellers of such services supported by technology providers. An insurance company would incentivize devices such as HHM with low premiums which would help them monitor the health status of its subscriber population and focus more attention on patients in the high risk groups.

8.4.6 Privacy

The biggest challenge for Homebased healthcare would be privacy of health data. Special protocols would be needed to secure this data from online hackers and other nefarious elements.

8.5 Future Homebased Healthcare Business Models

Supply chain challenges for Homebased healthcare would largely depend on the kind of business model that are put into place. Though there are some challenges which are generic and would apply to any model, yet it is important to explore if the change in business model would have any unique impact on the supply chain. Before doing so, it would be prudent to discuss a few plausible business models.

- Hospital Driven Homecare: Local community/Private hospital could be the provider of Homebased healthcare. The coordinating agency would be a part of such a hospital. Such a service would extend the reach of the local hospital and would provide opportunity to sell additional services such as health counseling, lifestyle change services, health risk assessments etc
• Physician Practice Driven Homecare: Several primary physician practices would be interested in expanding their services using Homebased healthcare. They would affiliate with the co-coordinating agency and provide primary physician support to the local population

• Consumer Led Healthcare: With the aid of home health monitors consumer can directly access the providers of their own choice. This would be a choice led business model for consumers or consumer driven healthcare model

8.6 Comments on Supply Chain Challenges

8.6.1 Demand Explosion

Based on the implications of the likely business model, demand for Homebased healthcare is expected to explode. With 100 million households in US, the demand could grow exponentially. Since healthcare is a highly regulated industry, demand fulfillment would depend on the approval of new devices by FDA. Unless these devices are approved for over-the-counter sale, there would be new challenges for agencies fulfilling this demand. The traditional pharmacies would need to have technical workforce capable of addressing any issue associated with the operation of devices. Unlike a pill, a devices needs technical support, this support would need establishment of various call center and other service support infrastructure. Along with the device there would be constant demand for consumables. Managing the demand of consumables having a defined shelf life would be major concern for manufacturers and retailers alike.

8.6.2 Supply

Depending on the success of a business model, suppliers would need to have right supply chain design to support the demand. Medical device industry traditionally has supplied direct either to large hospitals or large distributors. With the explosion in demand and need to support wider geography, millions of devices and individual customers they would need an entirely different supply chain than that existing today. Such a supply chain would bring unique challenges in terms of inventory visibility as has been
witnessed by various other electronic device manufacturers in other computer and mobile phone industry.

8.6.3 Service

Homebased healthcare would have a large service component. After the initial investment in a device or devices, a consumer would essentially be paying subscription based fee to various home health providers. Such subscription based services would entail various products, such as emergency alert, flu shot alert, vaccination alerts, diet advice, disease advisory, lifestyle management, new development and research information. Again the infrastructure would allow new service based models to evolve which would overshadow the device revenues in a very short period of time.

8.6.4 Excess and Obsolescence

Managing electronic products in a competitive environment is a significant challenge. In this industry companies try to maintain differentiation by frequently introducing new products in the market. Homehealth device market would encounter a shortening product development lifecycle. This would create significant excess and obsolescence issues.

8.6.5 Service of Devices

Technical support would be the biggest issue as any device failure can have serious repercussion on the individual health and lead to liability issues. Service chains for rapid replacement and repair capability would be required. Some providers may create differentiation using their strength in service and repair.

8.6.6 Reverse Logistics

Due to hazardous material, reverse logistics and disposal would become huge issue and a big opportunity for some firms. Countries are increasingly mandating tougher legislations around hazardous materials. A Homebased healthcare model is likely to increase the consumption of several hazardous chemicals and compounds. Disposal of these compounds and chemicals in a safe and secure way would be key challenge.
Chapter 9 Conclusion

In this thesis we explored the slow breeze of change happening in the healthcare Industry. We have already witnessed disruptive innovations like Retail Clinics to create a new channel for delivering healthcare. In short, Homebased healthcare is up for grabs for innovative institutions and corporations.

With aging and increase of chronic diseases, the cost of healthcare is only going up. This increase is likely to force millions of Americans to live without insurance. With the aid of technology, home and healthcare solutions (Figure 9.1) it is possible to reduce the cost of healthcare.

![Figure 9.1 Home, Healthcare & Technology](image)

We have seen examples of services, such as Tele-medicine which have integrated home, healthcare and technology. Homebased healthcare is the next stage in the evolution of preventive healthcare. Companies like NxStage have amply demonstrated that therapies like daily home hemo-dialysis provide high quality outcomes at overall lower cost. We also saw how Philips Healthcare, traditionally a player in higher end diagnostic equipment is targeting home to expand their healthcare product offerings. The recent
change in the name from Philips medical systems to Philips healthcare is a significant
development suggesting that home is next bastion of growth for Philips.

The developments in core and applied sciences would bring several disruptive
technologies which would assist Homebased healthcare. T2 Biosystem’s disruptive
diagnostic technology has the potential to eliminate several efficiency issues in large
centralized diagnostics, from a cycle time of 5-7 days the test would be conducted in less
than hour.

This thesis presents Homebased healthcare as a new channel for delivering healthcare. A
possible further research question could be to determine the deficiency of the current
healthcare delivery systems and identify new channels for healthcare delivery. Another
major area of research is to identify the key metrics associated with the current healthcare
delivery system. A SCOR based metrics for healthcare delivery would be a great addition
to our understanding of healthcare delivery challenges.
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