THE EVOLUTION OF AND TRENDS IN MOBILE HEALTH - A CASE STUDY OF APPLICATION TO DIABETES

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Submitted to the System Design and Management Program
in Partial Fulfillment of the Requirements for the Degree of

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ABSTRACT

The escalating costs of healthcare have created an urgent need to develop innovative solutions that can improve the quality of healthcare delivered and quality of health outcomes. This thesis explores the role that smartphones can play in creating innovative solutions to help meet these goals.

The thesis begins with an analysis of the structure of the healthcare industry and emerging trends. The next section introduces to the reader to the concept of dominant architecture and the analysis of glucose monitors using this framework. The latter part of this section highlights the industry landscape of the mobile health industry in general. This is followed by an analysis of mobile health solutions specific to diabetes based on which recommendations for future solutions are drawn. The final sections of this work provides the reader with some insights on emerging trends with some emphasis on potential solutions that can be developed to address existing gaps in the market.

Thesis Advisor: James M. Utterback

James M. Utterback, David J. McGrath jr (1959) Professor of Management and Innovation, MIT Sloan School of Management, and Professor of Engineering Systems, MIT School of Engineering
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I would also like to thank the program Director, Pat Hale, who gave me an opportunity to immerse myself in a field of study that no doubt will help me accomplish my goals. My gratitude goes out to all of my SDM friends and classmates, who willingly and selflessly, shared their own knowledge, wisdom and vision from which I have drawn elements for this thesis. My thesis would remain incomplete had it not been for the clinical insights provided by Dr. Maulik Majmudar, Dr. Emilie Johnson and Dr. Taylor Kelly who so graciously gave me their time. I would also like to thank Dr. Joseph Jasinski of IBM who was gracious enough to have a discussion with me on the trends within the healthcare industry.

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## Table of Contents

**ACKNOWLEDGEMENT** .................................................................................................................................... 4  
**TABLE OF FIGURES** ........................................................................................................................................ 8  
**LIST OF TABLES** ............................................................................................................................................. 9  
**CHAPTER 1: INTRODUCTION** .......................................................................................................................... 10  
  - BACKGROUND ............................................................................................................................................. 10  
  - MOTIVATION ................................................................................................................................................. 12  
  - RESEARCH METHODOLOGY ...................................................................................................................... 13  
  - THESIS OUTLINE ....................................................................................................................................... 14  
  - CHAPTER 1 .................................................................................................................................................. 14  
  - CHAPTER 2 .................................................................................................................................................. 14  
  - CHAPTER 3 .................................................................................................................................................. 14  
  - CHAPTER 4 .................................................................................................................................................. 15  
  - CHAPTER 5 .................................................................................................................................................. 15  
  - CHAPTER 6 .................................................................................................................................................. 16  
**CHAPTER 2 - U.S. HEALTHCARE SYSTEM** ........................................................................................................... 17  
  - COORDINATION OF CARE .......................................................................................................................... 17  
  - ACCOUNTABLE CARE ORGANIZATION ....................................................................................................... 19  
  - HOSPITAL FOCUS ....................................................................................................................................... 22  
    - Solution shops ........................................................................................................................................ 24  
    - Value added processes ............................................................................................................................. 25  
    - Facilitated network business .................................................................................................................... 26
## Table of figures

Figure 1: National health expenditure, 2010 ................................................................. 11

Figure 2: Elements of an ACO .................................................................................... 19

Figure 3: Value flow in an ACO model ......................................................................... 19

Figure 4: Adaptation of care delivery value chain ....................................................... 21

Figure 5: Business model elements ............................................................................ 23

Figure 6: Interplay of innovation and dominant design ................................................ 30

Figure 7: Generic blood glucose meter ......................................................................... 32

Figure 8: Ames reflectance meter ................................................................................ 33

Figure 9: Closed loop glucose monitoring system ....................................................... 35

Figure 10: Vitadock glucometer ................................................................................... 36

Figure 11: Glucometer timeline, S curves and shift in dimensions of competition ....... 38

Figure 12: Mobile health industry landscape ................................................................ 43

Figure 13: Breakdown of professional mobile health applications .............................. 47

Figure 14: Consumer oriented mobile health applications ........................................ 52

Figure 15: Forecast for diabetes till year 2020 ............................................................. 55

Figure 16: Diabetes timeline ....................................................................................... 58
Figure 17: Elements of treatment regimen determination phase .............................................. 63

Figure 18: Breakup of reasons for visits ................................................................................................ 67

Figure 19: Types of glucose monitors and corresponding type of firms over time ....................... 70

Figure 20: Number of patents filed for non-invasive glucose monitors ........................................ 71

Figure 21: Number of patents filed for continuous glucose monitors ............................................. 71

Figure 22: Number of articles over time for continuous glucose monitors ........................................ 73

Figure 23: Number of articles over time for non-invasive glucose monitors .................................... 73

Figure 24: Stakeholder map with value chain analysis ..................................................................... 77

Figure 25: Consolidation of mobile health industry ......................................................................... 94

List of tables

Table 1: Potential uses of technology ................................................................................................. 21

Table 2: Healthcare expenditure attributable to diabetes ................................................................. 55

Table 3: Breakdown of costs associated with diabetes ..................................................................... 85
CHAPTER 1: INTRODUCTION

BACKGROUND

The U.S. healthcare industry is currently at cross roads. The pressure of escalating costs, higher insurance premiums, issues related to universal coverage, an aging population and a shift away from non-communicable diseases to chronic diseases are challenges that the industry faces today. Escalation in costs of healthcare and price of insurance premiums are two of the most highly cited issues plaguing the industry today. (Cutler)

The expenditure on the U.S. healthcare system was nearly $2.6 trillion in 2010 or about 16% of the country’s GDP. (U.S. healthcare costs) The U.S. healthcare system is a system that is primarily market driven, characterized by the participation of many private companies in all phases of healthcare delivery.

While there is universal acceptance of the fact that the biggest issue with the healthcare system is cost there is considerable debate on some of the major drivers of increasing healthcare costs. Some of the major reasons are listed below:

1. Fee-for-service model

The current reimbursement model is structured in such a way that the caregivers are rewarded by the number of times a patient is treated and not the quality of the care or the outcome (Fee-for-service model). Therefore the caregivers are incentivized to prescribe treatments and routines that could either be very costly or inefficient.
2. Medical technology

Some argue that the emphasis on innovative medical technology, including pharmaceuticals, has led to an increase in costs. In fact a 2008 McKinsey report (McKinsey Global Institute, 2008) claims that lack of patient price sensitivity, the role of physicians and lack of market levers contribute to the high costs of new medical technologies.

3. Administrative costs

Administration costs along account for roughly 7% of overall healthcare expenditure. This amounts to approximately $400 billion annually. (U.S. healthcare costs)

Below is a breakup of costs associated with healthcare delivery (Anne B.Martin, 2012).

![Figure 1: National health expenditure, 2010](image-url)
MOTIVATION

Estimates peg the number of global cellular subscribers to be about 6 billion in the year 2011. The reach of wireless services, global penetration of cell phone devices and the establishment of the smartphone application eco-system has led to a new category of healthcare solutions called Mobile Health or mhealth in short. These solutions utilize a combination of cell phones, software (both for smart phones and feature phones) and potentially some external devices to create solutions for consumers. Some examples of such solutions are blood pressure monitors, blood glucose meters and applications that track levels of physical activity. Such is the potential of mobile health that the United Nations observed in its report (World Health Organization, 2011) out of 114 member states surveyed 83% had at least one mobile health program with many offering four to six programs.

This thesis is aimed at shedding more light on how technology, specifically those leveraging mobile phones, can and are being used to lower the costs of providing healthcare. Furthermore the intent is to have a discussion on the evolution of the mobile health industry via some frameworks, notably that of Professors James Utterback and Clayton Christensen. The goal is to provide the reader with a solid understanding of what the mobile health industry structure is, latest emerging trends, various solution spaces currently occupied and possible trajectory of evolution into the future. More importantly the thesis demonstrates the applicability of mobile health solutions by highlighting various solutions that currently exist for the chronic condition of diabetes.
RESEARCH METHODOLOGY

To better understand the complexity associated with the U.S. healthcare system reports from various organizations such as the World Health Organization, Kaiser Family Foundation and OECD were reviewed. Articles written by business professors such as Prof. Michael Porter were also reviewed to gain an understanding of solutions proposed by the authors using latest management tools and techniques.

A major part of this thesis is based on books written by Professor Utterback titled "Mastering the dynamics of innovation" and by Professor Clayton Christensen titled "The innovator’s prescription". These books provided the frameworks through which analysis of the healthcare industry and the mobile health sector was performed.

One of the biggest sources for information related to mobile health has been the website http://www.mobihealthnews.com. This website tracks the latest news and trends emerging in the mobile health space. Reports published by this website were a major source of information on mobile health applications and categories. Furthermore I gained some huge insights by attend the mHealth summit that was held in Washington D.C in the Fall of 2011.
THESIS OUTLINE

CHAPTER 1

The first chapter would start off with a brief description of issues plaguing the current healthcare system in the U.S. Furthermore emphasis would given on highlighting some technological solutions, such as EHRs and remote patient monitoring systems, that are being adopted to address some of the problems in the healthcare sector.

The discussion on technology would then be expanded to include mobile health including what mobile health actually is, illustrated via examples of solutions existing in the market.

The literature review section would highlight some of the papers/books/market research reports read on healthcare system and mobile health.

CHAPTER 2

The first part of the second chapter would concentrate on the discussions distilled from various literature sources primarily by Clayton Christensen and Michael Porter.

The second part would contain detailed discussions on some of the solutions in different functional areas such as diagnosis and electronic records. The discussion would include the value proposition, architecture and business model.

CHAPTER 3

The first part of this chapter would start with discussions on what mobile health solutions are, what the value proposition is.
The next part of the chapter would then provide the reader with a snapshot of the industry landscape. The intent is to show a mapping between functional areas and solutions in each of the functional areas. The functional areas are obtained via generic value chain analysis of any chronic condition management.

The next part would be a summary of Jim Utterback's work with emphasis on his concept of dominant architecture. This part would then include an analysis of the solutions through the lens of the dominant architecture framework.

CHAPTER 4

The intent is to keep this chapter specific to diabetes. The initial part of the chapter would be on the condition specifics and identification of generally accepted treatment procedures.

The next part would detail current mobile health solutions in the market targeting diabetes specifically. A mapping would be performed categorizing the solutions into buckets corresponding to the different phases in the condition management/treatment.

The chapter would conclude by identifying gaps in current solutions and recommendations for future work.

CHAPTER 5

The contents of this chapter are centered on the prediction of emerging trends within the mobile health industry and in a couple of cases specific to solutions for the diabetes condition. The forecasts are based on insights gained from numerous articles, conversations with industry professionals and conferences.
CHAPTER 6

The entrepreneurship spirit is pretty infectious at MIT and this forms the basis for the last chapter. The contents are geared towards what some challenges I faced and insights I gained while dabbling in entrepreneurial ventures related to mobile health. This chapter could serve as guidance or reference for future entrepreneurs.
CHAPTER 2 – U.S. HEALTHCARE SYSTEM

COORDINATION OF CARE

Coordination of care can be defined as a set of activities that are integrated in order to meet the healthcare needs of individual (Massachusetts consortium for children with healthcare needs). The fundamental goals of care coordination are (Agency for healthcare research and quality):

1. Sharing of health information between the providers of healthcare to facilitate the correct set of activities and procedures for the patient. Information such as test results, medications, adherence information and symptom tracking are the types of information that are most commonly shared

2. Help in establishing a sense of responsibility among the providers of care. This aspect involves specifying the various roles that participants play and assumption of risks associated with treatment failure

Associated with the aspect of care coordination are core sets of activities that define the intended functionality of care coordination:

1. Determination of needs: this is a critical step in the care coordination framework as this involves identifying the needs and the healthcare goals for the patients. The assessment of these needs which is based on the medical and behavioral history of the patient needs to coordinated with healthcare providers, family members and the patient
2. Communication of information: determination of needs is not a static process. As the patient is moved along the health plan the needs and metrics change, which necessitates the exchange of accurate patient related information amongst the participants. Information needs to flow between patients and healthcare providers and between teams of healthcare providers.

3. Enabling transition of care: transition typically includes both accountability and information between various teams providing the care. Examples include transitions between home and hospital, between acute care and ambulatory care.

It can be clearly seen that not only is the repository of information important to deliver efficient healthcare targeted at the needs but the flow of information is extremely crucial to facilitate the continuation of proper treatment for the patient. Technology plays a vital role in the storage and dissemination of information. It can also help reduce medication errors, improve operational efficiency of healthcare providers, facilitate delivery of healthcare in remote areas, improve diagnosis of conditions and provide accurate and up-to-date information to healthcare providers (Geisler, 2008). However many studies believe that technology advances in the field of medicine are one of the major factors behind escalating healthcare costs. (Callahan) We shall now consider some proposed structural changes that have been recommended to improve the coordination of care and then proceed to understand the role that technologies are intended to play within those settings.

The first of these structures is what is known as an Accountable Care Organization (ACO) and another structure recommended by Professor Clayton Christensen in his seminal book *The Innovator's Prescription* (Clayton M. Christensen).
ACCOUNTABLE CARE ORGANIZATION

According to the Center for Medicare and Medicaid services (CMS) an accountable care organization is defined as a group of doctors, hospitals and other healthcare providers who come together voluntarily to give coordinated high quality care to patients (Center for Medicaid and Medicare Services). One of the main goals of the ACO is to reduce the costs of healthcare while maintaining, if not improving, the current quality of healthcare.

Figure 2: Elements of an ACO

Figure 3: Value flow in an ACO model
In the current structure CMS provides guidelines to organizations that wish to form or become part of an existing ACO. For example, one of the guidelines is that the ACOs would need to provide healthcare to a minimum of 5,000 Medicare patients for a period of three years. Participants of an ACO can set their own standards for healthcare depending on the needs of the patient. Critics argue that physicians are still reimbursed via the fee-for-service model. While this is true a provision for shared savings has been created to incentivize the participants to provide quality healthcare and reasonable costs. If the ACO is able to provide the healthcare needed at a lower cost relative to the threshold set by CMS, the difference is then shared with the participants in the ACO network apart from the fees that the participants would charge normally. The patient retains the choice for getting the care that is required from organizations/physicians outside the ACO network.

The creation of the ACO network requires a constant sharing of information not only between the providers but also between the patient and provider. The emergence of the patient centered medical home (National Committee for Quality Assurance), which can be viewed as an extension of the ACO model, further necessitates the accurate and on-time exchange of information.

To understand how technology can play a vital role in the ACO setup one needs to understand the various activities associated with the delivery of the care itself. A useful framework can be the Care Value Delivery Chain (CVDC) (Joseph Rhatigan). According to the paper: “The care delivery value chain (CDVC) is a framework that allows a systemic analysis of value creation across the myriad of activities that occur during the care of a patient for a specific medical condition”.

19
Figure 4: Adaptation of care delivery value chain

Assuming that the patient is beyond the prevention phase technologies can serve as tools in the hands of the healthcare providers for the next two phases. The table below highlights some ways in which existing technologies in all areas, not just IT, can be leveraged to provide some solutions:

<table>
<thead>
<tr>
<th>PHASE</th>
<th>TECHNOLOGIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing/screening</td>
<td>Remote decision support systems</td>
</tr>
<tr>
<td></td>
<td>Smartphone based retinal scanners</td>
</tr>
<tr>
<td>Disease management</td>
<td>Remote patient monitoring systems</td>
</tr>
<tr>
<td></td>
<td>Body sensors connected to smartphones</td>
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<tr>
<td></td>
<td>Electronic medical records – web based and smartphone based</td>
</tr>
<tr>
<td></td>
<td>Remote consultation</td>
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<tr>
<td></td>
<td>Imaging systems with file sharing capabilities</td>
</tr>
<tr>
<td></td>
<td>Electronic prescription services</td>
</tr>
</tbody>
</table>

Table 1: Potential uses of technology

As can be seen above, technology can have multiple applications in each stage of the care value delivery chain. The integration of these technologies with each other can create value that is greater than the sum of the values these technologies can add. This concept of systems thinking can be demonstrated by a couple of simple examples.

Let us assume in the first example assume that a patient moves from City A to City B. In City A the patient had a preferred physician and a clinic that he/she used to go to (let us assume that they are \( P_A \) and \( C_A \) respectively). Once the patient moves to City B then she enlists the
assistance of another physician $P_B$ and clinic $C_B$. The new physician would want to understand the previous medical history and would want access to all the medical files. Under the traditional mechanism the patient would have to obtain all copies of her previous medical history and provide it to the new patient. But technologies such as an electronic health record system would enable seamless transition of all the data without the need for the patient to assume responsibility. This mechanism, of course has its own caveats with one of the biggest issues being interoperability of the two EHR systems if different companies developed them.

In the next section we shall examine an academic theory on the structure of the healthcare industry put forth by Professor Clayton Christensen of the Harvard Business School.

**HOSPITAL FOCUS**

Any changes to the current structure of the U.S. healthcare industry need to be accompanied by a change in the business model. To understand how a business model can be changed we need to first understand the elements that make up a business model. The critical elements of a business model are (Pigneur, 2010):

1. Market segments: who exactly are the consumers of the product/service going to be?
2. Value proposition: what is the benefit that the product/service is going to provide to the consumers?
3. Channels: what are the ways in which the consumers can access the products/services being designed?
4. Revenue streams: how can the products/services generate monetary value within the industry structure?

5. Resources: what kind of assets would be required to deliver the products/services?

6. Cost structure: what are some of the costs (both direct and indirect) incurred in the provision of the product/service?

7. Activities: what are some of the key activities that need to be performed or should be performed in order to provide the product/service?

The above elements can be rearranged to form distinct categories as is shown in the figure below.

Figure 5: Business model elements

Professor Fjeldstad has developed a framework where business models can generally be attributed three separate business entities namely shops, chains and networks (Oystein D. Fjeldstad).
Solution shops

Under this framework solution shops can be likened to an entity whose value proposition is very unique and narrowly focused. For example, Starbucks is a solution shop whose value proposition is pleasing the customer's taste buds with good coffee, with the good part being debatable. Similarly a law firm is another solution shop where the value proposition is providing clients with legal advice.

Many of the activities that occur in a hospital can be theoretically spun off into solution shops. Diagnosis is one such task that can be practiced in a solution shop. The solution shop would be staffed by experts whose only job is to diagnose diseases and recommend the patients to specialist hospitals for treatment regimens in cases of complicated conditions. If the conditions are simple enough the solution shop or diagnostic clinics can themselves recommend treatments. This would be similar to going to Dunkin Donuts for coffee as compared to going to a fancy steakhouse for coffee. Since the clinics would specialize only in diagnostic services the costs would reduce (coffee in Dunkin Donuts or Starbucks for that matter is cheaper than in a steakhouse).

One of the newer emerging trends is decision support system that can hasten the formation of these diagnostic clinics. For example, SimuConsult is a firm that is developing software that services as a clinical decision support system. For simple diagnosis the patient would no longer have to go to a hospital and wait to see a doctor. Instead the patient can go to a nearest diagnostic clinic and get a quicker but yet accurate diagnosis for their condition. If the condition is complicated the patient can be then referred to a specialty hospital.
Value added processes

Value added processes are actions that are taken that create value for the consumers. Consider for example cooking. The chef gathers all the vegetables, meats and spices and uses his/her skill to transform the raw ingredients into meals that are consumed by customers. Another example is teaching. The teacher gathers all the tools such as online resources and textbooks and uses his/her skill to impart relevant education to the consumers who in this case are the children.

Activities carried out in the hospital can be classified as value added processes. The doctor reviews all the tools available to him such as medical references, patient history, diagnostic results, emerging health trends and provides a recommended course of action to help improve the patient's health. By concentrating on a core set of processes a hospital would be able to improve its operational efficiencies and thereby reduce its costs. A famous example of this type of operation is the Aravind Eye Care system (Aravind Eye Hospital). This system is fine tuned to provide surgeries only for eye care for the poor where hundreds of surgeries are performed in one day. In fact if the system provides free transportation and boarding for the duration of the care. The profits generated by providing care for patients who can afford it are put back into the system that provides care for the poor. By specializing in eye care the system has been able to trim excess costs thereby creating a highly efficient economic model. It's similar to an automotive vehicle production line where the only activity is manufacturing cars. The repetition of process over and over again enables the operators to keep fine-tuning the process for maximum efficiency and lower costs.
Facilitated network business

This is the third type of business model, which is essentially a platform that enables transactions between members of the platform. Online bulletin boards, websites such as Facebook and blogs are all examples of facilitated network business. This type of platform facilitates exchange of “products” in whatever shape or form between the participating members. For example a website dedicated to cooking might have a forum for discussion about recipes. The product here is the recipe. The network allows the participating members to exchange the recipes with one another, modify or improve each other’s recipe among other benefits.

Such facilitated networks are emerging in healthcare as well. The website, Patientslikeme.com (Patientslikeme), is a prime example of such a network. Patients with certain conditions can reach out to other patients with similar or same conditions and use the network to exchange notes on therapies, medications, experiences and physicians.

Another such facilitated network is Sermo (Sermo), which is a network of physicians for physicians. The physicians can exchange notes on latest medical practices and emerging trends in practice management for example.

The patient and his/her care remain at the core of transformation. Technology can be used to connect these entities to ensure accuracy, availability, access and safety of the information that is required by the operators within each of these entities to do their jobs.
In the following chapter we shall analyze some of these technologies and discuss their evolution through the framework of *dominant architecture* espoused by Professor James Utterback (Utterback).
CHAPTER 3 – DOMINANT ARCHITECTURE

DECENTRALIZATION

Innovations generally find receptive audiences where resources or processes enforce a constraint on the efficiency that can be achieved while performing a task. Generally innovative products have the following characteristics (Christensen):

(a) Simple
(b) Affordable
(c) Accessible

The innovations help in decentralizing the work that is very complex and can only be done at a large facility. Let us consider the example of the machine that I am using to write this document – the computer. The early age computers were huge devices that needed entire rooms for storage, required a large amount of power and needed specialized operators for running the machines. Then came the era of mini-computers. Although they were more portable and powerful most of the customers were large sized firms and research establishments. The reach of the computers had not yet stretched to the general population. The era of the minicomputers was replaced by the era of workstation, which could be utilized by smaller sized firms, was not very complicated to operate and training of personnel to use the systems was relatively easier. Finally came the era of the personal computer with companies such as HP and Apple making their foray into bringing the technology into the hands of the whole population. Of course today laptops, tablets and smartphones (which are becoming as powerful as computers nowadays). As can be seen from this example while the early computers were very complicated and required
specialized training to use them for tasks. But today the personal computers, laptops, tablets and smartphones have made it easier for almost anyone to write a program, create enviable graphic designs and develop applications. In a sense the advantages that computing power offers have been decentralized.

The healthcare industry has also been following a similar pattern. A physician’s clinic or the hospital were places one would visit to get some vital metrics such as blood pressure and blood glucose levels measured to keep track of one’s health. But the evolution of medical technology made it possible to have these devices at home. Today there are portable monitors that can be connected to a smartphone so your health information can be stored online and is with you wherever you go. Examples of such companies are Vitadock, myglucohealth, Withings. Additionally there are layers of sophistication being added on such as personal recommendations and behavior modification using incentives. In a sense the care is being de-centralized and is being *democratized*. We shall return to such examples and cover them in more detail later.

**DOMINANT ARCHITECTURE**

The questions of how technology evolves to its current state and what factors influence the evolution are at the forefront of understanding innovation. Tushman and Anderson (Michael Tushman) describe the evolution as cyclical periods of changes where eras of small incremental changes are disrupted by radical changes, which are followed by an era of experimentation where firms try to adapt to the radical innovation and architect products that integrate this innovation. It is during this era of experimentation that a *dominant design* arises.
Figure 6: Interplay of innovation and dominant design

According to Utterback (Utterback), "a dominant design in a product class is, by definition, the one that wins the allegiance of the market place, the one that competitors and innovators must adhere to if they hope to command significant market following". This concept can be illustrated via the example of the typewriter. In the late 1800s Remington was a dominant force in the industry whose position was being challenged by some upstart companies. The first decade of the 1900s witnessed entry by a large number of competitive firms that were, in part, assisted by the standard model of the typewriter. The Model 5 designed by the firm Underwood was introduced in the early 1900s and due to some architectural changes became the dominant design within the typewriter industry. This era also witnessed the exit of a large number of firms that could not complete the shift to the new design and by 1940 only very few firms remained. Post 1940 new firms started emerging, which copied the Model 5 architecture and once again the number of firms started to grow. However
they were disrupted by the emergence of the electronic typewrite, another architectural change. The electronic typewriter in turn was disrupted by personal computers, which although still prevalent, are being disrupted by tablets and smartphones.

One must not assume that a dominant architecture is the best possible combination of features and technologies. In fact it is far from it. Products that are dominant do not satisfy all the needs of a segment of the market but meet many requirements of the entire market. In other words they are not customized products. It can be considered to be a platform from which many variants to meet the different needs of the various segments can be launched.

**DOMINANT ARCHITECTURE – BLOOD GLUCOSE METER**

In this section the evolution of blood glucose meters shall be very briefly studied to highlight the application of the dominant design concept to the medical devices industry.

Blood glucose meters are instruments that are used by diabetics to measure the level of glucose in their bodies (Wikipedia). The patient pricks their skin to draw a few drops of blood and squeezes the drops onto a test strip. The test strip is then inserted into a device that measures the level of sugar in the blood and displays the readings, units being mg/dl or mmol/l, to the user. The patient can then adjust the level of insulin, diet and exercise regimen based on the readings. The frequency of readings depends on the severity of diabetes in the patient.
A blood sample is taken and put on test strip.

Strip is put into blood glucose meter.

Figure 7: Generic blood glucose meter

The earliest blood glucose indicator was called *Dextrostix*, which were strips of paper. A patient would have to apply drops of blood to the strip, which would cause the strip of paper to change color. The color change would indicate the amount of sugar. One of the major disadvantages of this solution was the extra work required in decoding the color as well as the accuracy of the results (M A Preece, 1977). It usually required a trained care provider to interpret the results.

The next radical innovation would come in the form of automatic reading display of bloody sugar level. The *Ames Reflectance Meter* invented in 1971 measured the light wavelength emitted by the colors of the Dextrostix and provided a numerical reading for the blood glucose level. This single innovation spawned a bunch of companies that tried to imitate the reflectance meter.
The invention of the Ames Reflectance Meter ushered in a new phase of glucose home monitoring that was quickly capitalized by companies such as Bayer which developed the first commercially available glucose home monitoring device. This enabled the patients to monitor their blood sugar at their convenience. Incremental innovation were made which then led to an increase in the number of companies manufacturing home glucose monitors. New regulations formulated by the FDA, CDC and American Diabetes Association provided a fillip to this nascent industry, which resulted in a number of firms producing home glucose monitors. There were a couple of noticeable differences in the products compared to earlier eras:

a. The new products did not use the Dextrostix. They firms developed their own proprietary test strips that worked with their devices
b. The products were becoming more accurate and most importantly were minimizing the inconvenience of drawing blood. These devices typically required just about a drop of blood for their analysis which required no more than a pin prick
The next era of radical innovation came in the form of continuous glucose monitoring and integration with insulin pumps. One of the earliest developers of the continuous glucose monitors (CGMs) was Minimed® which came out with their CGM around 1999. The firm was then bought by Medtronic® which integrated its product with their own line of insulin pumps to form the first closed loop diabetes monitoring system around the late 2000's (Medtronic). The product architecture of these devices is radically different from those of traditional glucose monitors. To form a closed loop system a sensor is implanted within a patient’s body, typically in the abdominal area. The monitor is connected to an insulin pump that regulates the dosage of insulin depending on the reading obtained from the glucose meter. Typically the sensor can be work for a few days after which it needs to be replaced. The monitor includes a memory chip that stores values of blood glucose levels for an extended period of time. These readings can then be provided to the physician for regulating the treatment regimen. A closed loop monitoring system offers a couple of distinct advantages over the traditional method of monitoring glucose levels and regulating the amount of insulin into the system (Terry G Farmer, 2008):

a. Multiple insertions would not be required thereby increasing the convenience to the patient

b. Changes to insulin levels can be made easily and fairly quickly. For example, a departure from the normal lunch routine can easily be compensated by the system
Smartphones have enabled the birth of an entire new ecosystem of products and services. The introduction of the Apple iPhone™ and Android smartphones led to the creation of the Apple Appstore and the Android Marketplace, online repository of various applications that can be used on smartphones. People are able to purchase, download and run applications such as games and business tools. Medical and fitness applications are increasingly becoming popular in these stores. This development represents the next wave of innovation for medical devices. Companies such as Medisana, (creators of the Vitadock® range of mobile health products), Mobisante (creators of MobiUS™ SP1 portable ultrasound system) and Withings (creators of mobile health products) have all created products that people are able to use in conjunction with their smartphones. While there are similarities in architecture between these products and their predecessors the most notable differences lie in their integration with smartphones and the ability for the patient to control the devices and obtain the readings using the smartphones.
As can be seen from earlier descriptions the humble blood glucose meter has undergone major transformations caused by changes in the fundamental architecture of the product. Every architecture change has only made it easier for patients to use the product rather than complicate them. Each architecture change has spawned an era of new competitors and demise of large incumbent firms with a few exceptions. Each architecture change has shifted the dimensions of competition for the products. But what are the dimensions of competition generally speaking?

To answer the above question we need to revisit the disruptive innovation theory put forth by Professor Christensen. A dimension of competition can be defined as the improvement in a product, which increases the adoption rate of the product. According to the theory when a product is relatively new customers tend to judge the product in terms of performance and quality. In the case of the glucometer the first product was the Destrostix that was not very accurate and required some kind of specialist training. The introduction of the Ames Reflectance Meter enabled accurate readings of the Dextrostix. The introduction of the Bayer glucometer, which was quickly followed by a host of other
competitors, all concentrated on improved readings. In short the dimension of competition was on performance and quality.

However once the products achieved sufficient accuracy, the people were unwilling to pay a premium for products that offered even more accuracy. The products then offered features such as portability and memory, which made it easier for the patients to use the products. This shift is what the model predicts when a product starts overshooting the needs of the customer base on the original dimension of competition. When a product overshoots the needs of the customer needs the market becomes more and more unwilling to pay for improvements along the same dimension of competition.

The introduction of the closed loop glucose monitoring system and then smartphone-based devices have only accelerated the process of the shift to the new dimensions of competition. The smartphone based device enable the people to use the devices in an easier manner and the connectivity offered by the smartphones enable the users to upload and share the readings with other patients and physicians. Therefore to summarize, radical changes in architecture has triggered a shift in dimensions of competition along the lines of the prediction of the disruptive innovation theory.

The figure below summarizes the evolution of technology, specific to glucose monitoring devices, and highlights how the each radical innovation has shifted the dimension of competition.
We can similarly extrapolate the framework and studies from above to other devices to understand the evolution of each of those devices. The results would indicate that gradually the products have had their architecture modified in such a way that they are now becoming increasing convenient to use.

Figure 11: Glucometer timeline, S curves and shift in dimensions of competition
DOMINANT ARCHITECTURE – MOBILITY

The interplay between dimensions of competition and product architecture is a very interesting dynamic. According to the theory of disruptive innovation as long as product performance does not meet the expectations of the market the customer will be willing to pay a premium for products that offer better quality. A product’s quality can be measured on different dimensions. For example, in the case of the glucometer quality could mean accuracy of the reading and portability of the product. When the product’s quality has met or exceeded the market’s demand then the basis for competition shifts to speed, responsiveness and convenience.

The introduction of the “mobile” aspect in glucometers, and in the future potentially to other such medical devices, is in response to the shift to convenience. In today’s interconnected world convenience includes the ease with which patients can access and disseminate information (Robert S H Istepanian). As we have studied in the previous chapter the healthcare system is on the verge of getting fragmented into individual “specialties” that will form partnerships to deliver care to a patient (ACO model). As has been mentioned before this sort of transformation will necessitate transfer of information with the patient at the center. A clear trend is emerging where the increasing mobility offered by different devices together with the mobility of smartphones is going to enable a patient centric healthcare delivery system that could potentially reduce costs. The impact has not been oblivious to organizations such as the World Health Organization, which in its report identified the intersection of healthcare and mobile phones, known as Mobile Health (mHealth), as the single force that has the potential to transform the delivery of healthcare.
across the world (World Health Organization). Considering all of the above we can only draw the conclusion that the current architecture, where devices are either connected or integrated into smartphones will remain dominant for the foreseeable future.

In the next section we shall discuss what mobile health is, what are some solutions available today and then proceed to paint a broad picture of the industry landscape.

WHAT IS MOBILE HEALTH?

Mobile health solutions are a specific category of healthcare products/services developed that leverage mobile technologies such as smartphones, tablets and cloud infrastructure. The range of solutions can range from simple text-messaging based services to complex remote patient monitoring systems. Mobile health can be broadly broken down into five different areas (Juniper Research):

1. Enterprise applications: this could include solutions in the electronic health record space
2. Data and voice based examples: includes solutions such as remote diagnostic tools such as MIT SANA, which provides support to healthcare workers in rural areas of developing economies
3. Patient monitoring devices: devices such as Agamatrix diabetes solutions, Runkeeper fitness solutions belong to this category
4. Educational: currently most educational solutions such as Epocrates cater to the medical professional section
5. Remote diagnostic support: solutions that integrate some basic level of decision support, telemedicine belong in this category

But why is the healthcare industry so excited about mobile health? There must be a genesis to this heady excitement and some real needs experienced by people within the healthcare delivery circle including patients. The answer lies in some statistics that help explain why there is so much excitement and energy associated with mobile health solutions. According to some research reports (Absolute Software) (Manhattan Research) (Quantia Communications) (PricewaterhouseCoopers):

a. 82% of physicians currently own smartphones
b. Close to 19% of physicians have integrated mobile devices into their practice
c. About 35% of physicians have expressed tremendous interest in employing mobile devices into day-to-day operations
d. 39% of Chief Medical Information Officers have already integrated mobile devices in their facilities
e. As high as 86% have indicated access to electronic health record information as a primary purpose of using mobile devices

How do these statistics compare to the adoption rates of EHR system? Here are some more numbers (Chun-Ju Hsiao):

a. Only 57% of physicians reported employing any type of EHR/EMR system including some that do not fit the “meaningful use” criteria
b. About 34% of physicians reported using an EHR/EMR system that met the very basic criteria for “meaningful use”
The increased adoption of EHR systems, the ubiquity of mobile devices and the transformation of the structure of the healthcare industry are some of the major factors driving the mobile health revolution. However the hospitals/physicians alone are not the only adopters of the mobile health technology. Today with devices such as Jawbone Up, Lark and Withings the patients also is becoming a larger consumer of mobile health technologies.

Countries all over the world have taken notice of the potential of mobile health technologies, especially when it comes to healthcare delivery in low resource settings. According to the WHO report (World Health Organization) about 83% of member states reportedly offered at least one mobile health solution with a significant number of countries offering multiple solutions. The most popular categories were:

a. Health call centers
b. Emergency toll-free telephone services
c. Disaster relief
d. Mobile telemedicine

As we can see from the above information mobile health solutions need not be dependent only on smartphones. There are a wide variety of services that can be offered on feature phones as well. Text4baby (Text4baby) is a free text based messaging service designed to promote maternal and child health. SANA (SANA) is another mobile health solution whose value proposition is remote diagnostic support for healthcare workers in low resource settings.

Some of the major drivers for mobile health solutions have been (Mobilestorm):
a. Healthcare reforms and the HITECH Act promulgated by the government

b. Rapid adoption of mobile devices (smartphones, tablets)

In the next section we shall study the mobile health industry landscape and identify some of the major categories that occupy the mobile health space. The intent is not to list every application or solution that exists as it would be beyond the scope of the thesis but to highlight some trends that should guide the user in understanding the landscape.

MOBILE HEALTH INDUSTRY LANDSCAPE

As was mentioned before there are a broad range of mobile health categories that constitute the market today. However while these categories are themselves distinct the solutions need not be. For example, there could be an enterprise level application, which offers a secure peer-to-peer text based messaging solution or information sharing solution.

![Figure 12: Mobile health industry landscape](image)
The figure above illustrates the industry landscape of mobile health application as of today. They range from personalized solutions that contain elements of social networking (such as health gaming applications) to enterprise level applications such as mobile EHRs, drug and disease reference tool for physicians. According to recent reports (MobiHealth News) at the end of 2010 approximately 63% of physicians were using some sort of enterprise application. In terms of absolute numbers the revenue from smartphone applications for healthcare professionals doubled from $49M in 2009 to about $84M in 2010. The following sections shed more light on the various applications that exist in the categories defined above.

**Enterprise oriented mobile health solutions**

Clinical consultation and reference/education applications are among the most widely sued types of applications by medical professionals in an enterprise atmosphere.

Clinical consultation applications are specifically used at the point of care whereas the reference/education applications are used in an asymmetric way. The clinical consultation applications also integrate some form of diagnostic support. An example is the *Eating Disorders* application that helps clinicians screen patients for anorexia and bulimia. Another example is the *iNeo Stroke* that is supposed to be a decision support tool for stroke diagnosis.

The reference/education applications are targeted at physicians as well medical students who need to look up information about specific treatments, drugs and dosage calculations. A good example of this type of application is the *Medscape* application that has information
about 8,000 generic and branded drugs available in the market today (Medscape). Another example is the Clinical Orthopedic Exam (CORE) application that helps diagnose musculoskeletal and orthopedic disorders. There are other types of reference applications such as the CPT E/M quick ref application (American Medical Association) that help in a quick look up of appropriate codes for billing activities. Patient engagement and the interaction between the physician and a patient are increasingly coming under the microscope. Dr. Emilie Johnson (Urologist at Children’s Hospital) maintains that there is a significant need to improve the communication between the patient and the physician. One of the biggest problems is the inability of the patient to understand certain phrases and abbreviations used by physicians. It is there that applications such as the Mosby’s Mobile Dictionary of Medicine (Elsevier) can be leveraged to provide patients and physicians alike the ability to de-mystify medical conversation to ensure complete understanding.

While workflow solutions do not form a major part of enterprise applications solutions such as Procura Mobile (Procura Mobile) help enterprises maintain operational efficiencies.

Then there are EMR applications such as Prime Mobile (Prime Mobile) that are developing mobile EMR/EHR applications for enterprises. These kinds of applications enable the healthcare provider to conveniently access all aspects of patient clinical information, from allergies to medications to latest radiology results, and issue orders in a convenient way. A subset of the EMR/EHR applications is the patient tracker suite, which helps caregivers the ability to track all aspects of their patients such as medications and patient activities.

Remote patient monitoring enables care givers to monitor their patients while they recover in a place that is separated from the hospital, for example their homes. According to a
Deloitte study in 2009 (Dolan), about 60% of healthcare consumers in the U.S. are interested in home monitoring technologies to manage their condition. This has prompted companies such as GE, Intel and May Clinic to invest resources to understand and address challenges in home health monitoring. The interest in remote monitoring has spawned products such as the Airstrip Patient Monitoring suite (Aistrip) that offer clinicians the ability to remotely monitor their patient’s vital signs.

To summarize the enterprise/professional mobile health solutions are mainly composed of consulting applications & reference/education applications while other types of applications such as EMR/EHR applications, workflow optimization applications and imaging applications form a minority portion of the available application space today. Below is a breakdown of the market share based on category.
Figure 13: Breakdown of professional mobile health applications
Consumer oriented mobile health solutions

One of the biggest reasons for the growth in consumer health applications has been the demand for applications not just provide information related to specific conditions but for the most part provide consumers an analytical summary of their health. According to a survey conducted by the consumer health information corporation (CHIC) (Lewis) about 60% of survey respondents wanted to manage a health issue via an application and about 50% wanted to track their own health via an application. With all this demand for personal health care applications the total revenue generated by digital health in 2010 was about $1.7B. The following paragraphs will highlight, with some examples, the different types of applications that constitute the individual mobile health application space.

One of the most popular categories in the individual mobile health space is the fitness/cardio category. Applications such as Basis (Basis) and Pedometer Ultimate GPS (Arawella Corporation) help an individual monitor metrics such as heart rate, activity level and calories burnt and provide feedback in terms of visual displays and charts. This is correlated to the findings of the CHIC survey where about 80% of the survey respondents expressed interest in using healthcare applications that provided them with feedback.

The fitness/cardio applications are followed by dietary/calorie counter applications in terms of popularity. These applications help people track their calorie intake, diets and food allergies. Many of these applications are used in conjunction with physical devices such as weight scales, for example Withings. Applications such as Honest Label (Honest Label)help consumers track nutrition information in products available in the supermarket.
by scanning the bar codes. Calorie tracking applications such as *Fast Food Calories* (Nanobit Software) contains calorie information of dishes in major restaurants and helps people track the amount of calories they consume.

Applications targeting chronic conditions such as diabetes and blood pressure are becoming increasingly popular. Diabetes is increasingly becoming a condition that affects the majority of the population with the WHO estimating that about 340 million people worldwide have diabetes (World Health Organization). The evolution of blood glucose monitors was explained in the previous sections where applications such as Vitadock and myglucohealth use mobile applications in conjunction with glucose monitors to help patients monitor their blood glucose level and regulate the insulin intake. Increasingly closed loop diabetes systems, such as the one being currently developed by *Pancreum* (Pancreum), are being investigated to understand the practical feasibility as well as effectiveness in helping patients achieve better control of their situation.

The use of mobile health applications to treat mental disorders is becoming increasingly popular. It is not surprising given that about 20% of children have faced debilitating mental disorders at some point and in a given year, approximately 25% of adults are diagnosed with some form of mental disorders (National Institute of Mental Health). Post Traumatic Stress Disorder is becoming quite a serious issue among active and inactive armed forces personnel. To combat the looming threat of mental illness many companies are developing applications to detect mental illness and help patients cope with their situation. For example, the Department of Veteran Affairs released a *PTSD Coach* (mHIMSS) application to help patients with resources and mental health information. The T2 Mood Tracker
(National Center for Telehealth and Technology) developed by the National Center for Telehealth and Technology helps users "self-monitor, track and reference their emotional experience over a period of time".

Applications such as Lark (Lark), which help monitor sleep patterns, are becoming increasingly popular. Then there are applications such as C-Mommy, which helps women recover from C-section deliveries that are specifically targeted at women. Strength training applications such as Dailyburn (Dailyburn), integrate the social gaming aspect into their applications for improving the health outcome of the consumers.

The social/gaming aspect of healthcare is picking up steam with applications such as Habitual (Kairos Labs) and Mindbloom Life (Mindbloom) focusing on behavior modification to improve health outcomes. There are also web-based games by companies such as the insurance provider Humana that are being developed to increase the quality of health of individuals. The increase in the number of applications that leverage gaming for behavior modification was noted in the article 'Interactive Games to Promote Behavior Change in Prevention and Treatment' where the authors claim that the increasing the engagement via a game could be a useful tool to deal with the challenges of motivation among patients (J. Leighton Read M. &., 2011). The power of social networks and gaming is being harnessed by companies such as Healthrageous (Healthrageous) and Keas (Keas) that are developing enterprise level wellness initiatives to improve the health and well being of employees. A report by Mobihealth News the authors of the book "Connected: the surprising power of social networks and how they shape our lives" suggest that utilizing social networks as a source of motivation can help individuals cross hurdles they would not be able to cross by
themselves (Mobihealth news). The report goes on to highlight the increasing interest in gaming of healthcare noting the increase in conferences centered on gaming in health, increase in journal articles about gaming of healthcare. But is there any future to gaming of healthcare or is it just a trend that will decline? According to the report the future is very bright for the concept of gaming in healthcare with big-name players such as Humana, Kaiser, Frog Design and research centers in UCLA all developing novel social and behavior mechanics to improve the wellness of people.

As a summary the various types of applications in the individual mobile health space are shown in the figure below.
Figure 14: Consumer oriented mobile health applications
CHAPTER 4 – DIABETES

DIABETES – AN OVERVIEW

Diabetes is a chronic condition that occurs when the amount of insulin generated by the pancreas is insufficient to break down the sugars absorbed by the human body in various forms from the food consumed (World Health Organization). It is estimated that about 346 million people have diabetes around the world and a major proportion of those cases are in the developing regions of the world. Diabetes is primarily of three types:

a. Type I
b. Type II
c. Gestational

Type I diabetes occurs when the pancreas does not produce insulin required to break down the sugars in the food consumed. This leads to accumulation of sugar in the body without being used for energy. The causes of Type 1 diabetes are currently unknown although it is not believed to be caused by excess consumption of sugary foods. Type 1 diabetes occur mostly in children and young adults and usual treatment regimen is insulin intake either orally or by injections (Canadian Diabetes Association).

Type II diabetes, also known as non-insulin-dependent-diabetes (NIDDM) is the most prevalent type of diabetes with estimates pegging the number of Type II cases to constitute approximately 90% of overall diabetes cases (World Health Organization). The causes of Type II diabetes can be classified as reversible and irreversible. Irreversible causes include
race, age, gender and hereditary factors. Some of the reversible causes of Type II diabetes are (Steyn NP, 2006):

  a. Obesity
  b. Physical inactivity
  c. Diet: consumption of fat, carbohydrates, alcohol

Gestational diabetes is the third type of diabetes, which affects pregnant women. This type of diabetes affects only a small segment of the population with estimates at 7% of all pregnant women at a given time (Agency for healthcare research and quality, 2009). When women are pregnant the pancreas produces excess levels of insulin to cope with the increased food intake. However when the insulin produced is not enough diabetes sets in but usually goes away after the pregnancy.

As was mentioned before Type II diabetes is the most common form of diabetes. The United States is facing one of the worst health crises with regards to diabetes. According to the national diabetes factsheet published by the Center for Disease Control and Prevention diabetes affects 25 million people in the United States alone, which is equal to 8.3% of the population (Centers for disease control and prevention). According to the same report between the years 2005-2008, based on glucose testing, approximately 35% of adults aged 20 and older had existing pre-diabetes condition. Additionally the report claims that diabetes is the seventh leading cause of death in the United States.

A report published by the United Health center for health reform and modernization (United Health center for health reform and modernization, 2010) estimates that by 2020 approximately 15% of adults would exhibit the disease. The economic impact is no less.
The same report estimates that the spending between 2011-2020 would total up to $1.3T in private spending, $2T in Medicare and $111B in Medicaid.

![Prevalence of Diabetes and Prediabetes in the Adult Population 2007–2020](image)

**Figure 15:** Forecast for diabetes till year 2020

(Source: United Health report)

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<thead>
<tr>
<th>LINE ITEM</th>
<th>2007</th>
<th>2010</th>
<th>2020</th>
</tr>
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<td>$34</td>
<td>$585</td>
</tr>
<tr>
<td>People with Type I diabetes</td>
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<td>$5</td>
<td>$73</td>
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<tr>
<td>People with Type II diabetes</td>
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<td>$140</td>
<td>$2,439</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$141</strong></td>
<td><strong>$179</strong></td>
<td><strong>$3,097</strong></td>
</tr>
</tbody>
</table>

**Table 2: Healthcare expenditure attributable to diabetes**

(Source: United Health report)

People suffering from diabetes often are very susceptible to the various complications such as hypertension, heart disease, stroke, kidney failure, nervous system failure and possible amputation of the limbs. While it is hard to treat Type I diabetes Type II diabetes can be prevented or managed by regulating the patient’s lifestyle including physical activity and
diets. According to a WHO report (WHO) the following are recommended for patients who are either diagnosed with or are highly susceptible to the condition:

a. Maintaining adequate body weight and BMI
b. Practicing a moderate level of physical activity
c. Reducing saturated fat intake
d. Increasing consumption of dietary fiber

All of the above activities, of course, need to be supplemented with periodic glucose monitoring and insulin intake as recommended by the doctor.

The contents of the following sections have been divided into three parts: one part contains information on disease lifecycle management, which demonstrate the various stages and activities included in detecting and managing a disease. This part also contains interviews with practicing physicians to get a perspective on the clinical/administrative aspects of condition management. The second part discusses the various diabetes applications that are available in the market and a brief explanation of the functionality that they accomplish. Contents for the third part are drawn from analyzing the gaps in the applications available in the market today with respect to the disease lifecycle management and hypothesis of some applications that could be useful in the near future.

**CHRONIC CARE TIMELINE**

The approach taken in this section is to construct a timeline of events for Type II diabetes in particular. By doing so we can understand the chain of events that gets triggered which ultimately leads to the patient having to comply with the treatment prescribed by the
physician. This also enables us to identify potential solutions that can be created to facilitate the care delivery to the patient. The content for this section was generated based on interviews conducted with medical students and practicing physicians. It must be mentioned that listing every possible solution is beyond the scope of this thesis.

At a very high level there are three steps in the management of any condition:

1. Detection of abnormality in body functionality
2. Analysis/diagnosis to identify condition and possible variants
3. Specification of treatment which is done by the primary care physician who is sometimes aided by specialists
4. Continuous follow up with the patient to ensure compliance with treatment regimen
The detection phase is the first phase of care delivery management. A diagnostic event is triggered when any of the following events occur:

1. A patient visits a primary care physician (PCP) for a routine check up
2. A patient visits a PCP when an abnormality in body functionality is detected
3. An emergency event occurs and the patient is taken to the emergency room (ER)

When any of the above events occur the PCP orders a battery of tests based on medical knowledge as well as patient’s history to determine the cause of the abnormal symptoms.
exhibited by the body. It is in this phase that samples taken from the patient (blood, urine, stool and tissue) are sent to the various laboratories for testing. Once the PCP receives all the results of the test the physician leverages his/her medical training and the results of the test to diagnose the cause of the symptoms – in our case Type II diabetes. An important aspect of the diagnosis is the information provided by the patient on previous conditions, family medical history and dietary habits. This phase is especially important to keep in mind because advances in technology can create a situation where the diagnosis part can be moved away from the purview of a PCP and can be handled by other healthcare workers such as nurses. Type II diabetes is a condition that has been well studied and the symptoms well documented which sifts the diagnosis from the realm of empirical medicine to the realm of precision medicine as explained by Professor Christensen.

The next phase involves the determination of appropriate treatment regimen for the patient based on the diagnosis performed by the PCP. For Type II diabetes, among others, there are two important elements that constitute the treatment regimen once a patient has been diagnosed with the condition:

a. Insulin intake
b. Dietary, lifestyle improvements

As was explained in the earlier sections inadequate production of insulin leads to the onset of insulin. Patients diagnosed with Type II diabetes, depending on the severity of the condition, are prescribed with a certain dosage of insulin that needs to be taken on a regular basis. Generally the patient monitors their blood sugar level using glucose monitors and then injects insulin into the body depending on the reading. The readings from the
glucose monitors have to be taken at frequent intervals during the day. Additionally the PCP also helps the patient with identifying required changes in their dietary habits and exercise regimen to help cope with the demands of the diabetic condition. Usually specialists such as a nutritionist are brought in to assist the patient understand and chart out the new requirements. This phase is generally very complex because it requires a lot of coordination between the PCP and other specialists. For example a patient could have anther pre-existing condition and the new treatment specified by the PCP could result in serious health complications due to conflict with existing condition and medication.

According to recent reports approximately 98,000 people die annually in the United States due to medical errors in hospitals. It is very critical, in this phase, for all stakeholders to have access to all the information about the patient in order to coordinate the development and execution of an optimum care plan.

The next phase in the care management timeline is related to ensuring that the patient is compliant with the care plan developed by the physician in conjunction with specialists. Typically the patient schedules regular visits with the PCP and the specialist. Specifically for diabetes the patient provides the PCP with data obtained from the glucose monitor and information about their activities. The PCP then reviews the data for any abnormalities and then recommends any changes if necessary. The patient then visits each of the specialists to review their current health, progress and changes in care plan.

In this section we shall analyze each phase of the lifeline and highlight existing categories of applications and features that they offer. The aim is to understand all the activities that transpire in each phase, understand what the current solutions and what problems they
address and finally hypothesize potential applications that can be developed for problems not currently addressed.

PRE-DIABETES PHASE

As was mentioned above in this phase the patient feels some abnormality in the way the body is functioning and depending on the situation either visits the ER or brings up the abnormality in an interaction with the physician.

Based on the interviews with Dr. Kelly, a M.D student at University of Texas and a master of public health student at Harvard School of Public Health, Dr. Maulik Majmudar who is a clinical cardiology fellow at Brigham and Women’s Hospital and Dr. Emilie Johnson, M.D and student at the Harvard School of Public Health maintain that in the course of their career one of the biggest reasons for the onset of diabetes is a lack of awareness of risk factors and failure to perceive deterioration in body metrics. Type II diabetes can also be caused by genetic factors and according to Dr. Kelly and Dr. Johnson most people are unaware of their family’s medical history.

There are many of the diabetes related health applications in the market today such as Diabetes Buddy, Glucodock and Track 3 - diabetes planner and carb counter. However these solutions are not particularly useful in the detection/pre-diabetes phase because:

a. The applications specific to diabetes available in the market today are targeted at the population segment that already has been diagnosed with the condition. They help patients track their glucose levels and exercise regimen.
b. The applications do not provide people with risk factor calculation based on their dietary habits, fitness regimen and genetics.
According to Dr. Johnson the biggest gap in the application market space today, specific to diabetes, is the failure to address pre-diabetic patients. Applications such as risk factor calculation can be hugely beneficial to people to not only become aware of the fact that their current lifestyle could lead to diabetes but also help them reverse their march to a diabetic condition. These applications can be then extended to provide a logbook to record family as well as personal medical history to help people track their risks of inheriting a chronic condition such as Type II diabetes.

**DIAGNOSIS PHASE**

The diagnosis phase is the next phase where the patient who has reported abnormalities is subjected to clinical tests. Specific to Type II diabetes tests such as baseline blood tests and cholesterol/lipid panel tests are run to detect the diabetic condition as well as establish the severity of the condition.

Since the tests are run in a clinical environment there is not much potential to develop smartphone based application solution for the general consumer. However from a physicians perspective it is very important to have access to the test results as quickly as possible. Applications that deliver the right content to the physician at the right time provide the maximum value proposition.

There are many mobile device based EMR solutions that provide the physician access to all the patient’s data. EMRs such as Allscript Remote+ and Physician Express afford the physicians the luxury of access to information from anywhere. However mobile EMRs constitute only about 2% of all professional medical applications. There is a huge potential to further develop such solutions in the future. The emergence of ambulatory EMR systems
has led to a fragmented industry where there are many disparate EMR systems that do not necessarily communicate with each other. Let us assume that a patient visits a doctor in Hospital A with pre-diabetic symptoms. If the patient is referred to Clinic B for some tests it is highly likely that record system used in Clinic B is incompatible with the record system in Hospital A. Therefore the physician would be unable to electronically access the test results leading to more paper based results. Generally speaking a frequent problem associated with EMR systems is interoperability (Brailer, 2005).

To obtain maximum benefit from mobile EMR systems the solutions need to be interoperable so that information from various sources can be aggregated in one place. This would enable the physician to make more accurate and time diagnosis to help the patient.

TREATMENT REGIMEN DETERMINATION PHASE

Once the diagnosis is over the physician, together with a nutritionist, puts together a care plan for the patient to follow for better condition management. This includes plans related to dietary needs, fitness regimen among other lifestyle factors. This phase can be broken down into multiple stages as shown in the figure below.

Figure 17: Elements of treatment regimen determination phase
The physician patient interaction is one of the most important elements for chronic condition management. Studies have highlighted the correlation between good patient-physician interaction and improved health outcomes as well as patient satisfaction (Science Daily). The article cites that doctors try to gauge the patients understanding of their instructions only about 2% of the time. While the average physician-patient interaction time has not changed advances in medicine have fostered a larger volume of information exchange. Due to this the patient is overloaded with information, which then tends to be less sticky.

The mobile health application space does not contain any application that optimizes the patient-physician interaction. Applications that help the patient transcribe physician’s instructions, help the patient send concerns ahead of time to the physicians are some examples of applications that can help improve the quality of patient-physician interaction. Applications that facilitate the communication between the patient and physician in an asynchronous fashion can be integrated with EMR systems to capture records of all communication as part of medical history.

When multiple stakeholders are involved in developing the care plan all stakeholders should have access to all the information. Imbalance of information results in errors in delivery of healthcare. According to a report by the Institute of Medicine (Institute of Medicine) majority of errors in healthcare delivery are caused by faulty processes, systems and conditions that foster incorrect actions by healthcare workers. Applications such as EMRs, that exists today, can address the problem of care coordination.
Patient compliance is the most complicated aspect of healthcare delivery and admittedly ripe for disruptive solutions to solve the challenge. According to Dr. Johnson, patients often find it difficult to accept the fact that they have been diagnosed with a condition such as diabetes. This situation is compounded by the change in lifestyle that is necessary to manage the condition. Dr. Kelly maintains that any resistance on part of the patients to change their lifestyle is due to the fact that the patients are unable to see the long-term benefits of a healthier lifestyle. The patients admittedly need a lot of help coping with the change in lifestyle required to maintain a stable health quotient after getting diagnosed with diabetes.

Discussing long-term patient engagement strategies to ensure compliance with treatment regimen is beyond the scope of this thesis. However mention must be made of a recent trend in mobile application - namely gaming. Gaming implies leveraging actions and rewards to affect patient behavior in a positive manner (Brian Edwards). Companies such as Humana which developed Humana Vitality, Livn.it and Mindbloom are all leveraging aspects of gaming to incentivize people to adopt a healthier behavior. One of the most famous examples is a study conducted on Packy & Marlon, a Nintendo game that led children control a character who had Type 1 diabetes by monitoring glucose levels and insulin intake. In the study that lasted 6 months the research team noticed a 77% reduction in emergency care visits attributed to diabetes amongst the participants (J. Leighton Read & Stephen M. Shortell). According to Dr. Yan Chow of the Kaiser Innovation Center game thinking is becoming important in healthcare because it gives people the freedom to fail.
The ability to leverage social networks to help in behavior modification is a growing area of interest. Family members, friends and people with similar condition can be powerful stakeholders in helping people cope with lifestyle changes required to manage the diabetic condition. Let us consider a possible solution where the patient can post their latest readings and historic trends of blood-sugar levels. If the family members and friends are then able to view and post messages that are encouraging in nature, the patient can be motivated to continue to lead healthier lifestyles. This offering can then be further enhanced by incentive based behavior modifications. The family members can perhaps offer a challenge, for example requiring the patient to maintain a blood sugar level at a predetermined level for an extended period of time, with a reward at the end for successfully completing the challenge. The family members need not necessarily post this challenge. If it is possible to bring the clinical representatives into the loop, the challenge can be issued by the physician/nurse. This incentive based behavior modification is just another example of gaming that was mentioned earlier.

SCHEDULED VISITS/FOLLOW UP PHASE

Once the physician and the specialist(s) have determined the treatment regimen the patient is provided with instructions on the next steps in term of altering the diet and exercise regimen. The physician's office and specialist's office then coordinates periodic visits/consultations to discuss progress made and changes to the recommendations based on the current state of patient's health.

The figure below shows the breakup of reasons for visit to a physician's office, a community health center and an outpatient department (National Center for Health Statistics, 2008).
Table. Selected services ordered or provided by primary care setting: United States, 2008

<table>
<thead>
<tr>
<th>Services ordered or provided</th>
<th>Physician offices</th>
<th>Community health centers</th>
<th>Outpatient departments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drug or immunization</td>
<td>80</td>
<td>83</td>
<td>81</td>
</tr>
<tr>
<td>Lab and other tests¹</td>
<td>50</td>
<td>49</td>
<td>52</td>
</tr>
<tr>
<td>Health education service²</td>
<td>39</td>
<td>40</td>
<td>46</td>
</tr>
<tr>
<td>Any imaging²</td>
<td>14</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>Nonmedication treatment³</td>
<td>10</td>
<td>10</td>
<td>16</td>
</tr>
</tbody>
</table>

¹Lab and other tests include scope procedures, biopsy, EKG/ECG, spirometry/pulmonary function test, and other services.
²Health education services include education about asthma, diet and nutrition, exercise, growth and development, injury prevention, stress management, tobacco use and exposure, weight reduction, and other education.
³Non-medicadon treatment includes complementary and alternative medicine, durable medical equipment, home health care, hospice care, physical therapy, radiation therapy, speech and occupational therapy, psychotherapy, other mental health counseling, excision of tissue, orthopedic care, wound care, other nonsurgical procedures, and other surgical procedures.
⁴Difference between outpatient department and other settings is statistically significant.

NOTES: Community health center (CHC) and outpatient department (OPD) visits were age-adjusted to physician office distribution. In physician offices, the percentage of visits by patients 65 years and older was higher and the percentage of visits by patients aged 18-44 years was lower than comparable percentages in CHCs and OPDs.

SOURCES: CDCNCHS, National Ambulatory Medical Care Survey and National Hospital Ambulatory Medical Care Survey.

Figure 18: Breakup of reasons for visits
(Source: Center for Disease Control & Prevention)

As can be seen the drug/medication reasons constitute approximately 80% of all physician visits. These visits require taking time off from work, re-organization of schedules/meetings at the work place and possibly driving through traffic. For people gainfully employed these visits cause a drop in productivity. E-prescription services can offer a huge value proposition to address this problem. Very few companies such as OnCall and RiteAid are rolling out e-prescription applications to address this burgeoning market space.

Another reason for the scheduled visit is for the patient to provide the glucose level readings from the glucose monitor to the physician as well as various other vital body metrics to the nutritionist. Mobile applications with attached devices that can monitor the body metrics can be leveraged to transmit the required information to the relevant healthcare workers without the patients actually having to go physically to the
physician's/nutritionist's office. Applications such as Withings and Glucodock have already entered this particular market space with solutions that include hardware devices to measure vital metrics and software to record, store and display readings.

Remote patient consultation that leverages advancements in networking technologies is becoming extremely important to provide care to people who are often face problems related to access. Only a very few companies offer telemedicine solution with one of the leading companies being American Well. According to the Center for Disease Control telemedicine technologies can help sustain the overall public health infrastructure (Amanda K. Hall, Michael Stellefson, & Jay M. Bernhardt, 2012).

To summarize, each of the phases in the diabetes lifecycle offer potential for innovative solutions with some phases being more crowded than others owing to factors such as potential for simple solutions, complexity due to content sourcing and management, security concerns and privacy concerns.
CHAPTER 5 – TRENDS

In this chapter we will leverage the key findings and insights of the previous chapters to draw conclusions about emerging trends in mobile health related to diabetes management.

CONCLUSION 1 – diabetes monitors

Based on the data collected and presented in chapter 3 there are some clear trends emerging in the space of glucose monitors:

Trend 1

The glucose monitor market is going to be predominantly composed of personal glucose monitors, which can be seen from Figure 19. The emergence of smartphone and application market is going to increase the pace of development of glucose monitors that can sync with the smartphones for purposes of display, sharing and tracking. Glucose monitors can also be integrated with other devices such as blood pressure monitors and weight scales in the form of a remote patient monitoring system. These monitors can be used to address the burgeoning needs of emerging medical home market. Remote patient monitoring enables care givers to monitor a patients' vital signs from a distance using a combination of hardware and software elements. It could be considered to be a subset of telemedicine technologies.

One of the biggest barriers to the development of remote patient monitoring systems is the reimbursement scheme despite the fact that in a recent study for telehealth services there was almost a 20% reduction in hospital admissions. (Frost and Sullivan, 12/2011). While
bills such as the Medicare Remote Monitoring Access Act of 2008 have been drafted to spur the deployment of remote monitoring systems it is expected that more states would move toward a direct reimbursement scheme. This would enable the development and deployment of remote monitoring systems, part of which is the glucose monitor.

Figure 19: Types of glucose monitors and corresponding type of firms over time  
(Data source: Medical Device Registers from Grey House Publishing)

Trend 2
In order to understand the future evolution of the glucose monitor a patent search was performed using Google patents, PatentSnap and Free Patents Online. Additionally a search was performed was articles written on the two topics. The number of patents filed and articles published are used as indicators of industry activity. Glucose monitors generally consist of three categories: invasive, non-invasive and minimally invasive. Since there has been considerable debate on whether invasive or non-invasive technologies are the most effective patent search was done using the key words: non-invasive glucose monitors and continuous glucose monitors which is becoming a popular type of glucose monitor (Frost
and Sullivan, 3/2012). The results of the patent search are shown below. It is important to point out that

![Non invasive glucose monitor patents](chart1)

**Figure 20: Number of patents filed for non-invasive glucose monitors**

![Continuous glucose monitor](chart2)

**Figure 21: Number of patents filed for continuous glucose monitors**

As can be seen from the above charts the last few years have seen a rise in the quantity of patents filed related to continuous glucose monitors. A point to be noted here is there was
no data available for 2012 yet which is why the number of patents in both cases is shown as zero. In fact the American Diabetes Associated recommends patients to adopt continuous glucose monitors to manage their diabetic condition (Mark R. Burge, Stephen Mitchell, Alison Sawyer, & and David S. Schade, 2012). A big advantage of the continuous glucose monitor is that it can be used as part of an overall artificial pancreas system where there is a closed loop feedback between the human body, the continuous glucose monitor and an insulin pump that delivers insulin dosage based on an algorithm. There has been a significant progress in the development of continuous glucose monitors with firms such as Medtronic, Dexcom and Abbott Laboratories offering such solutions (IBIS World, 2011). However the major drawback of the continuous glucose monitor is the cost which can run into a couple of thousand dollars and with shrinking reimbursement this could lead to a much slower adoption rate. While there were a few firms offering non-invasive glucose monitors in the mid-2000s none of those firms are still functioning in 2012 with data suggesting that non-invasive glucose monitors disappeared from the market in or before 2008. Overall in the present times there are more firms offering continuous glucose monitors when compared to zero firms offering non-invasive glucose monitors.

This conclusion is further strengthened by compiling results of a search done for articles based on the keywords. The results are shown below:
Figure 22: Number of articles over time for continuous glucose monitors

Figure 23: Number of articles over time for non-invasive glucose monitors
Figure 22 and Figure 23 highlight the fact that there have been more publications over the past two decades on continuous glucose monitor as compared to non-invasive glucose monitor. This indicates the focus of the industry in developing the continuous glucose monitoring technology, which supports our hypothesis that the future glucose monitors would be of the continuous type rather than the non-invasive type.

With so many firms now starting to invest and product continuous glucose monitors is non-invasive glucose monitoring no longer a viable pursuit? Is, what some people in the glucose monitoring industry consider to be the Holy Grail, no longer attainable? We cannot answer these questions with absolute certainty but understanding the reasons why this technology has not matured may provide us with some clues. Non-invasive blood glucose monitoring can be defined as a technology that does not require any blood to be drawn, skin to be pierced or tissue to be damaged. This should not be confused with minimally invasive glucose monitoring technologies that require sensors to be embedded beneath the surface of the skin. Without going into too much detail some of the most researched techniques are highlighted below along with a brief summary of why those attempts have failed (Smith, 2011).

Spectroscopic techniques are one of the most explored techniques for non-invasive glucose monitoring. These techniques, which consist of some form of light measurement, can actually determine the concentration level of certain compounds depending on the way they interact with incident light waveforms. The incident light could lie in different spectrums such as infrared or have characteristics such as polarization. Depending on the technique used the incident light could have different characteristics. For example, one of
the techniques uses near infrared spectrum light to penetrate tissue and the reflected light is measured to obtain the concentration of blood glucose. However as with such techniques the major problems are with the quality of reflected light, which is very weak. Therefore models have to be developed that can fully explain the correlation between the observed results and the actual results. If the testing environment varies the results also varies by a significant amount thereby invalidating the model built. Furthermore the human body consists of various compounds, many of which exhibit similar spectral characteristics to glucose. Therefore the errors in the measured signal could be pretty high. These issues are common to any technique, which is related to spectroscopy.

Glucose molecules have the ability to rotate polarized light. This fact has been exploited by techniques, which pass polarized light through the cornea in the eye and measure the amount of rotation by glucose molecules present in the fluid that exists in the anterior chamber of the eye. The problem with this technique has been that the level of glucose changes very slowly in the eye (almost 1/100th), which means significant delays in measuring the real value of blood sugar level. This is simply unacceptable as this can mean the difference between life and death for diabetic patients.

Another popular technique explored revolved around trying to estimate the blood sugar level by analyzing the breath of the patient. The premise is that elevated levels of blood sugar can trigger the presence of certain compounds known as acetone in the breath of the patient. While measuring the level of acetone in the breath of an individual can help detect the presence of excess blood sugar, normal or low levels of blood sugar cannot be detected.
It is beyond the scope of this thesis to analyze every possible mechanism of non-invasive blood glucose measurement but from the literature available it is clear that every technique has been fraught with errors that could invalidate the measurement. Why have there been no commercially viable non-invasive glucose monitors in the past decade? In fact records (Medical Device Register) indicate that there were firms as recent as in 2004 manufacturing non-invasive glucose monitors. At least part of the answer lies in a study that was done comparing the performance of invasive glucose monitors with non-invasive glucose monitors manufactured by the firm Cygnus (Janet A. Tamada, et al., 1999). According to the clinical results while the accuracies of both types of monitors were very similar the issues with the non-invasive monitors were the following:

a. A time lag between the non invasive glucose monitor reading and the corresponding blood sugar value

b. Irritation of the skin caused by the sensors.

However research in this field has continued with the latest news coming from C8Medisensors, a company in San Jose that claims to have prototyped a non-invasive glucose monitor that measures the concentration of blood glucose from interstitial fluids using spectroscopic techniques. It must be mentioned that this device has not received any regulatory certificate either in the U.S. or in Europe.

**CONCLUSION 2 – STAKEHOLDER SOLUTIONS**

An analysis of the trends in the mobile health industry, specific to diabetes, and in general would be incomplete without understanding the trends exhibited by the various
stakeholders within this industry. In order to facilitate this understanding the framework of value chain analysis is used and then adopted to the mobile health industry, and specifically to diabetes.

The term value chain was made popular by Professor Michael Porter in his book “Competitive Advantage” (Porter). The definition of value chain in the context of a firm is a set of activities that are performed to design, develop, market, deliver and support its products/services. While I completely agree with his viewpoint for the purpose of this section I will use in the context of an industry and not at the single firm. Therefore the value chain in this context becomes a set of stakeholders that perform certain activities required to develop, launch and maintain a product/services. Using this definition the value chain for the mobile health related to diabetes can be visualized as below.

![Stakeholder map with value chain analysis](image)

**Figure 24: Stakeholder map with value chain analysis**

The categories on the horizontal activities constitute a set of stakeholders that perform activities required to fully develop and deploy a mobile health solution. It must be
mentioned that the companies listed in the above figure are only representative and by no means constitute the entire set of companies. The intent is to provide the reader with an understanding of the layout of the industry.

The stakeholders with developing a mobile health solution can be categorized as:

a. **Device developers**: firms belonging to this stakeholder group develop blood glucose monitors that work in conjunction with smartphones. There are other manufacturers of glucose monitors that are of standalone type but have not been considered for this study because the study is related to mobile health. Examples of such firms are Airstrip, Myglucohealth and Welldoc that manufacture glucose monitors and applications.

b. **Software developers**: a software development firm in this context refers to firms that obtain revenue by developing mobile applications for diabetes patients. Examples of such firms are *MyGlucose Buddy* and *Track 3* that help diabetes patients keep track of their glucose levels and meals consumed.

c. **Appstores**: while appstores are repositories for different applications they are not themselves involved in the development of mobile health solutions. However since they have facilitated the deployment of various solutions they have been included in this study. The two major appstores in today's world are Apple's iTunes store and Google's Android Marketplace.

d. **Insurance providers**: insurance providers have a major role to play in the adoption of mobile health solutions due to their control over reimbursements. However as shall be explained below there are some health insurance companies such as Aetna
and United Health Group are developing mobile applications to assist their customers

e. **Communication network providers:** these stakeholders provide the critical element of connectivity which is required by mobile solutions that transmit readings from the consumer end to the clinician end

f. **Enterprise solution architects:** developing solutions for a chronic condition such as diabetes involves complexity especially when enterprises such as hospitals or self-insured companies are involved. This is because features such as analytics on a population level data set are required. Integration into existing EHR/EMR systems is another dimension of complexity that solution architects of enterprise solutions have to grapple. These solutions require massive infrastructure support such as storage that can be offered only by big firms. Examples of such firms are IBM which offers solutions such as storage, analytics and Qualcomm whose 2Net™ platform enables wireless transmission of data between two points.

As can be seen from the figure above the industry landscape currently is very fragmented with firms belonging to different stakeholder groups developing solutions for different parts of the value chain. To understand how this could landscape could evolve we first need to understand the market drivers. The key market drivers for the mobile health industry specific to diabetes are (Frost & Sullivan, 12/2011):

   a. **Prevalence of the chronic condition:** diabetes, especially Type II is a condition that will continue to affect a large proportion of the world’s population. Due to this
market size one could expect a lot of interest in the development of solutions to help people better manage and prevent the onset of this condition

b. **Adoption of mobile phones:** according to some statistics in 2009 approximately 90% of Americans have mobile phones out of which about 20% own smartphones (Mobihealthnews, 2009) with some estimates pegging the actual number to about 72.5 M smartphone users in the year 2011. The trend points to increase in adoption of smartphones, which will then lead to an increase in consumption of information.

c. **Shift in architecture of healthcare delivery:** the movement towards a coordinated healthcare model is going to strengthen the need for information sharing irrespective of geographic constraints. Given the ubiquitous nature of mobile devices the case for the development of mobile solutions for healthcare is only getting stronger.

d. **Seamless connectivity:** smartphone applications enable the user to remain engaged with their health at all times irrespective of location, as long as a wireless signal is available. Combined with a web-platform, a smartphone application enables a seamless user-interface. Coupled with development of technologies such as HTML5, which enable the developers to easily manage the development of solutions mobile applications are the forefront of solving problems for the consumer.

e. **Cost of healthcare:** with healthcare expenditure pegged at 17% of GDP and rising, the employee contribution towards healthcare expenditure over the past few years has remained relatively constant at about 20%-25%. This represents a huge burden on the employees and employers alike (Kaiser Family Foundation). The ability to leverage mobile applications to help people manage their health as well as prevent
the onset of conditions is going to be a huge driver in the development of mobile health solutions.

Trend

One trend that could define the mobile health industry is that there is going to be a shift away from purely consumer-oriented solutions to integrated solutions that will integrate features targeted specifically at consumers. The primary reasons for this are the shift in healthcare delivery architecture and the incentives of the insurance payers to reduce costs.

The concept of coordinated care, which carries with it the need to integrate data that exists in silos, requires huge resources to address the complexity associated with integration. Further, larger firms easily support the emerging relevance of analytics in healthcare since services such as storage, secure access, archiving and virtualization can be either be bundled in with the analytics package or offered separately. This could lead to alliances between various service providers to provide an integrated offering.

One example of such a trend is the recent partnership between AT&T, a major telecommunication provider, and Welldoc that is a leading provider of chronic condition management solutions such as diabetes (Mobihealthnews, 2010). According to the report by Frost and Sullivan, AT&T is focused on diabetes management as one three areas for work on remote patient monitoring technologies. According to Dr. Jasinski, IBM Smarter Healthcare and Lifesciences, (Jasinski, 2012)IBM is leveraging its analytics engine to help organizations study diabetes patient information, plans and outcomes to help determine optimal treatment plans, medications (IBM). They are also working with payers to perform risk assessments on patient population to predict the likelihood of onset of diabetes in.
certain patients. Another huge impact that IBM is trying to make is in the area of integrated delivery network (IDN). An IDN is a collective of healthcare providers who via formal agreements perform the task of aligning healthcare resources required for the treatment. IBM plans on leveraging its analytics horsepower to analyze the success rate of doctors in helping their patients better manage their disease.

**CONCLUSION 3 – BUSINESS MODEL**

One of the major areas of change with respect to diabetes mobile health solutions is going to be the business model of applications. For the current study we are considering only consumer oriented mobile health applications. There are mobile health applications targeting medical professionals but since most of them are educational in nature those applications will not be considered.

The biggest factor affecting the future of the business model is the reimbursement scheme. Who is going to actually going to pay for the mobile health application is unclear right now according to John Horn, Director of machine-to-machine sales of T-Mobile USA (Fierce Wireless). The Center for Medicare and Medicaid services recently has been taking small steps in establishing reimbursement guidelines for mobile health solutions. Only last year they set national reimbursement rates for Cardionet, a product that uses wireless technologies for cardiac arrhythmia diagnosis and monitoring (Mobihealthnews).

**Trend**

Currently Medicare covers only a part of the overall cost of a glucose meter (GlucocardUSA). Glucose monitors that are of the continuous type and smartphone based glucose monitors
are currently not covered under reimbursement scheme. It is very likely that the consumer would have to cover the entire cost of those types of glucose monitors.

What we may see unfolding in the near future is a model where a significant source of revenue is not going to be the one time purchase of the application. Given the downward pressure on prices of individual applications newer business models that will integrate in-application advertising, in-application purchases will emerge to make up for decreasing revenue stream from just application sales.

As was discussed above the trend is definitely shifting to more of an integrated offering where the solution is tightly coupled with existing enterprise solutions in the care provider setting. The provider organization then will be in a position to subsidize the cost of the application to the patients within their network. Therefore what we could see in the future is an integrated offering that lets patients schedule appointments, communicate with their physician and view lab results being offered free of cost to the patients. This would put enormous pressure on standalone solutions being developed with a possible effect being migration of patients from these standalone solutions to the integrated solutions being offered either by healthcare provider organizations or by insurance companies.

CONCLUSION 4 – WELLNESS PROGRAMS

As was noted in previous chapters there is a considerable gap in diabetes applications that prevent pre-diabetic patients from the onset of the full diabetic condition. Due to soaring healthcare costs there has been a growing interest in chronic condition prevention and wellness programs. One of the biggest questions about these programs is the actual impact
of these programs in improving the health outcome of the participants as well reducing healthcare costs.

Trend

According to a recent study done on the savings impact of these wellness programs (Baicker, Cutler, & Song, 2010) it was estimated that for every dollar spent on wellness programs medical costs reduce by about $3. These programs can be very helpful in helping people lead a healthier life as well as offer powerful motivational factors such as peer performance and incentives. Companies such as Healthrageous (Healthrageous), Red Brick Health (Red Brick Health) and Keas (Keas) are working with self-insured companies in developing wellness programs that help prevent the onset of chronic conditions such as diabetes.

Many of the wellness programs integrate a gaming aspect where improvements in health outcomes are rewarded. Over the next few years mobile applications are expected to integrate the social/gaming aspect to their solutions. In fact estimates peg the revenues from mobile social/gaming applications to reach about $17B in 2014 (Mobihealthnews). Holistic solutions that will integrate social engagement and behavior change models will be one of the more popular health and wellness solutions adopted by self-insured employers in the near future.

CONCLUSION 5 – IMPACT OF MOBILE HEALTH IN COST REDUCTION

The most recent estimate for direct diabetes related healthcare costs came in 2007 when it was suggested that these costs amount to about $174B in 2007 (American Diabetes...
Association, 2008). This number included a total of $116B in excess medical expenditure and about $58B in reduced productivity. Some of the biggest contributing factors according to the study were:

- Hospital inpatient care which accounted for approximately 50% of total costs
- Retail prescriptions which accounted for about 11% of costs
- Physician visits which accounted for about 6% of costs

These cost estimations do not even include indirect costs associated with the condition such as absenteeism and impact on reduced productivity of family members. The table below provides a breakdown of health expenditures attributed to the diabetes condition.

<table>
<thead>
<tr>
<th>COST COMPONENT</th>
<th>Attributed to diabetes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dollars (in millions)</td>
</tr>
<tr>
<td>Institutional care</td>
<td></td>
</tr>
<tr>
<td>Hospital inpatient</td>
<td>$58,344</td>
</tr>
<tr>
<td>Nursing/residential facility</td>
<td>$7,486</td>
</tr>
<tr>
<td>Outpatient care</td>
<td></td>
</tr>
<tr>
<td>Physician’s office</td>
<td>$9,897</td>
</tr>
<tr>
<td>Emergency department</td>
<td>$3,870</td>
</tr>
<tr>
<td>Ambulance services</td>
<td>$103</td>
</tr>
<tr>
<td>Hospital outpatient</td>
<td>$2,985</td>
</tr>
<tr>
<td>Home health</td>
<td>$5,586</td>
</tr>
<tr>
<td>Hospice</td>
<td>$28</td>
</tr>
<tr>
<td>Podiatry</td>
<td>$273</td>
</tr>
<tr>
<td>Outpatient medications and supplies</td>
<td>$3,733</td>
</tr>
<tr>
<td>Diabetic supplies</td>
<td>$1,783</td>
</tr>
<tr>
<td>Oral agents</td>
<td>$8,586</td>
</tr>
<tr>
<td>Retail prescriptions</td>
<td>$12,692</td>
</tr>
<tr>
<td>Other equipment and supplies</td>
<td>$890</td>
</tr>
</tbody>
</table>

Table 3: Breakdown of costs associated with diabetes
As can be seen from the table above the total cost of ER visits and outpatient services alone amount to about $7B. Can mobile technologies be leveraged to reduce these costs? Let us
consider a hypothetical situation where a patient has been diagnosed with Type II diabetes. There are solutions such as Vitadock that can be used to help the patient monitor his/her blood glucose level. If these solutions are linked to the hospital/clinic EHR system a trained professional, either a physician or a nurse, would be able to check the blood sugar level of the patient on a regular basis. If there are deviations from recommended levels the physician/nurse would be able to get in touch with patient to help the patient get back on track. Of course the smartphone application can be algorithmically programmed to provide real time recommendations to the patient based on current and past patterns of blood sugar levels. With these kinds of support tools the patient can avoid visits to the physician's office, hospital outpatient rooms and ERs due to any complications. The immediate impact is on reducing costs associated with these visits. There are other indirect advantages as well. The patient would not have to take time off from work, wait in the physician's clinic or hospital room and drive through possible traffic.

Welldoc (Welldoc) is a company that has developed a solution very similar to the above. The solution that Welldoc has developed is a platform that integrates the clinical EMR system with a smartphone application that a patient can use. The smartphone application delivers personalized coaching, medication reminders and blood sugar readings. This system is supported by analytics and evidence based algorithms. The data gathered can be used by the clinics to measure performance and trends to gain deeper insights into new chronic condition management techniques. According to a recent study the Welldoc platform has been able to reduce ER visits and hospital stays by 58% (Mobile marketing watch). Even if this tool is used by a small percentage of the overall diabetic population the savings could run into billions of dollars on an annual basis.
Trend

My hypothesis is that in the near term the costs are going to escalate without the possibility of technology solutions coming into play to reduce costs. The adoption of such technologies is going to be very slow because of factors related to regulation, training and return-on-investment measurements.

Once the diffusion of such solutions is sufficiently high the potential of savings is enormous. With the implementation of remote patient consultation in conjunction with remote patient monitoring technologies, the need to visit a physician’s office becomes redundant. Theoretically, it is possible to entirely eliminate the 6% of cost, which amounts to $9B. Improvement in the management of the condition could lead to reduced comorbidities, which can further help reduce costs. Out of the $430B estimated for national expenditure for hospital inpatient care general medical conditions contribute to 76% of those costs out of which approximately 7% can be directly attributed to diabetes. Even a 20% reduction in these costs can save approximately $5B. There is also a potential to save a certain percentage of costs associated with lost productivity. Even if there is only a 10% savings, based on the 2007 numbers the potential savings could be as high as about $6B. We are already able to realize the tremendous impact of such solutions on the health and well being of individuals as well as on costs associated with delivery healthcare.

SUMMARY

In a report published by the Massachusetts Technology Council (Massachusetts Technology Council; New England Healthcare Institute, 2003) there were seven technologies identified
that, if implemented, had the potential to save the state $2.5B in healthcare costs. The seven technologies are:

a. Electronic patient-physician communication
b. E-prescribing
c. Ambulatory computerized physician order entry
d. Inpatient computerized physician order entry
e. Disease Management
f. Regional data sharing
g. E-ICU

The disease management portion alone is expected to have an annual benefit of $710M assuming a 75% adoption rate according to the report. Furthermore, the report specifically mentions the ability of disease management tools to increase patient involvement and quality of care when integrated with the clinical tools on the physician’s side.

Mobile health applications for diabetes belong to this category of disease management tools. Given the trend of consolidation among the various stakeholders in the mobile health space, these mobile health solutions have the potential to not only save costs but also increase the quality of care delivered to the patient.
CHAPTER 6 – PERSPECTIVES

The development of mobile health solutions has tremendous implications for all the stakeholders in the system – from the patient to the healthcare provider. In this chapter I shall try to extract the key impacts of this technology.

From an entrepreneur’s perspective, the healthcare industry offers challenges that are somewhat unique. Entrepreneurs need to satisfy extremely stringent criteria if they were to develop a successful offering for the healthcare market today. Factors such as barriers to entry, reimbursement schemes, and consolidation among others contribute to a typical entrepreneur’s dilemma.

IMPACT FOR ENTREPRENEURS – A US PERSPECTIVE

BARRIERS TO ENTRY

One of the factors that entrepreneurs consider before entering a particular segment is the barriers to entry factor made popular by Professor Porter. The barriers to entry can be decomposed into several contributory elements:

a. Government policies
b. Access to distribution channels
c. Switching costs
d. Capital structure
e. Economies of scale
By and large one of the biggest policies the government has implemented has been the HITECH Act (U.S. department of health and human services). This act is aimed at improving the quality and potentially the profitability of healthcare delivery by leveraging advances in information technology such as electronic health records (EHR). The benefits of EHR have been widely documented but the intention of the HITECH act is not adoption but "meaningful use" – a phrase that has generated considerable debate in its actual definition (David Blumenthal, 2010). There have been guidelines issued to address this very issue but they have kept changing through the years. Recently there has been tremendous push to factor in the dimension of mobility into the definition of meaningful use. The argument is that a physician is incapable of delivering the best care if they remain tethered to a terminal and is not free to take advantage of the mobility offered by devices such as tablets and smartphones (Versel).

Regulatory bodies such as the FCC and FDA have a huge role to play in the approval of applications and devices developed by different vendors. The current degree of uncertainty that exists is prohibiting the widespread adoption and development of such solutions, a fact that has not been lost on the lawmakers. In a recent letter sent by six Republicans in the U.S. House of Representatives the attention was drawn to the inconsistent regulatory environment governing mobile health devices and applications with calls for collaboration between the FDA and FCC (Dolan, Republicans put pressure on wireless health regulators).

What are the implications of the changing regulatory environment on the various stakeholders? From an entrepreneurs perspective the current regulatory environment does provide an opportunity to create solutions without going through a strict regulatory
control test. However as we shall soon see this alone is not enough to encourage development of more solutions. Privacy and security are of paramount importance to both solution providers and healthcare providers. Some of the major concerns related to implementation of mobile health solutions are:

a. Device management  
b. Device and data security  
c. Balance between professional and personal use

Device management requires a huge amount of IT support to manage the integration of mobile devices into the workflow of the organization, an aspect that is sometimes forgotten when developing solutions. As far as data security is concerned acts such as the Health Insurance Portability and Accountability Act (HIPAA) have been instituted to make sure that the personal data of patients is protected. All these factors require substantial expertise and knowledge, which is a hurdle for entrepreneurs.

Clinical patient data currently exists in silos within each healthcare provider setting. As was pointed out in the earlier chapters healthcare delivery and management is forecasted to evolve to a coordinated model that will require participation from many players. From a technology perspective one of the biggest factors that will affect the quality of care in such a model is going to be the consumption of data that currently exists in silos. The Healthcare Information Exchange (U.S. department for health and human services) has been created to enable seamless flow of data from one organization to another. Given these developments it is highly unlikely that the enterprises are going to switch to any new provider of solutions given the high switching costs associated with the transition.
Incumbents also have an advantage in terms of alliances, partnerships and distribution channels. EMR providers such as Epic already have an established client base and are leveraging their existing relationships to not only grow their current customer base but also expand their coverage to include individual patients. For example, Epic's MyPHR is an integrated PHR that helps patients manage aspects of healthcare such as access to records, refill requests and billing among other features. Another example is Boston Children's Hospital developing an application to access medical records and schedule appointments.

**INDUSTRY CONSOLIDATION**

A big factor that is also going to affect the potential for entrepreneurship is the consolidation of the industry participants as was demonstrated by some examples above. Chapter 5 demonstrated how the different stakeholders have already started integrating across the value chain in the various business segments. This could imply very few opportunities for entrepreneurs to develop solutions for this market.

An important conclusion that can be drawn is that incumbents definitely have more leverage in creating solutions that can gain widespread adoption. Developing solutions for enterprises such as hospitals requires firms to navigate the treacherous terrain of regulations, systems integration and entrenched partnerships — a tough code to crack for entrepreneurial firms. The implication of such a situation is that the industry is well on its way to becoming a tiered structured industry akin to the automotive industry where Tier 2 firms sell their products to Tier 1 firms who then integrate the various components from Tier 2 firms and sell the whole system to original equipment manufacturers.
The consumer/professional segment is perhaps a more viable market for initial mobile health solutions from an entrepreneur’s perspective. Applications targeting the professional segment are the types of applications that deliver educational and reference material, dosage calculators and radiography imaging solutions. The previous chapters highlighted existing solutions and potentially new solutions that can be developed. The biggest challenge to developing solutions for the consumer segment is the business model. While the drop in prices of mobile health applications in the consumer space has not been substantial, future competition is most probably going to drive the prices of individual applications down. This could create an unsustainable environment where revenue streams may not match the amount of money required for product development. *Freemium* models, where users only pay for premium features if they feel the need for it, could be successful in such instances.

**WORKPLACE WELLNESS INITIATIVES**

With approximately 60%-70% Americans obtaining health insurance through the employers programs benefiting self-insured companies offer a high growth potential. Work-place interventions not only help people with chronic conditions manage their disease better but these programs can also act as catalysts in preventing the onset of any chronic conditions. Based on preliminary interviews conducted with different self-insured firms the clear benefits of such programs lie in reducing the healthcare costs of self-insured companies and promoting teamwork and morale. According to statistics, people spend approximately 7.5 hours of a day on work with about 83% of all surveyed people getting most or all of their work done at the workplace (Bureau of labor statistics). Places of
employment offer a fertile ground to engage employees, and possibly their family members, in leading healthy lifestyle. As was mentioned before companies such as Red Brick, Healthrageous and Keas are doing this exactly. However there is a huge potential to actually extend this concept beyond just wellness. For example all these programs integrate biometric data into their solution. Building on this the program can be extended to integrate telehealth applications such as remote patient consultation, e-prescription services and patient knowledge portal. Such a suite of comprehensive solutions can be achieved with the help of health kiosks. Companies such as Solo Health and Health Spot are manufacturing kiosks that can facilitate such programs.

Figure 25: Consolidation of mobile health industry
The figure above highlights the future of the mobile health industry. It must be kept in mind that the solutions in the diagram above, such as remote patient monitoring or wellness initiatives, are not unique mobile solutions. Rather those solutions will have a mobile component associated with them taking advantage of technologies such as video calls and SMS services. Imagine a doctor consulting the patient with a technology similar to Face Time™ technology that exists in the Apple iPhones today.

The future of mobile health solutions will trend towards an integrated solution that will span both the patient and enterprise segments. What exactly do I mean by integrated? It does not mean one firm developing all these solutions by itself. There could well be firms developing individual solutions such as American Wells that is developing telehealth solutions. The maximum value can be captured if all of these different solutions are packaged or integrated together. Of course this does not necessarily mean that the different solutions have to be packaged as one. The point is that these solutions would combine patient data with the clinical solutions at the side of the healthcare provider. This situation would foster a collaborative environment for interactions between the patient and healthcare provider. The healthcare provider would have access to up-to-date information about the patient and can use that information to provide feedback to the patient in real time. Additionally these kind of integrated solutions will make it easier for distribution purposes. It can be expected that the integrated solutions will be distributed by the healthcare providers themselves. The question remains about the payment. Who is going to pay for this? Given the current situation the thought is that the healthcare providers would themselves pay for these integrated solutions, as they would be able to realize the potential savings.
SOCIAL MEDIA IN HEALTHCARE

The past few years have witnessed a significant upheaval in how people communicate with each other. Social media tools such as blogs, Facebook and Twitter have enabled people to share information in real time with a broad audience with minimal effort. Health 2.0 (Wikipedia) technologies create an environment in which people can share and digest information relevant to them. Online communities such as PatientsLikeMe provide patients an ability to connect with patients with same or similar conditions and discuss treatment options and medication regimen. Even healthcare professionals have access to social media tools at their work place. While these tools do have the power to improve the way patients and care givers interact especially with the rapid adoption of healthcare IT, the question of actual adoption rate of social media as a communication mechanism remains given the concerns around security, privacy, accuracy and legal implications. Given these constraints can social media tools be leveraged to improve the quality of healthcare delivered and improve the patient outcome?

As was mentioned before social media is used by both patients and providers unlike but seldom as a tool to communicate with each other. According to a recent survey of 1060 adults in the U.S. (PWC, 2012) approximately 33% of adults use social media for healthcare related discussions. In another survey approximately 75% of healthcare workers reported to using social media within their institutions (Frost and Sullivant, 2011). The top three reasons provided were connecting with peers, coworkers and patients.

Given the consolidation of the mobile health industry it is very easy to imagine a scenario where social media tools are integrated into the packaged solution set developed by
incumbent firms. Let us consider a hypothetical example to understand how the situation could unfold. Suppose a patient goes to the doctor when he/she is not feeling well. But before the patient goes to the doctor he/she uses social media to scout for the best doctors and healthcare institutes. After a routine diagnosis the doctor prescribes some medication to the patient, fills out an e-prescription. The patient is also provided with instructions to create a login to a secure portal that is connected to the clinical EHR systems as well as any other communication mechanism the clinic may have instituted. The patient then goes to the pharmacy, gets the medications and starts the treatment regimen. The patient then notes the daily progress using the portal. The patient also answers some questions designed by the clinicians to understand any side effects of the medication and symptom abatement. The doctor reviews these notes and provides real time feedback, which can be viewed by the patient through the portal. The patient would also be able to post questions regarding his/her health via the portal, which can be answered directly by either the doctor or the nurse. Quite possibly, if given the option, the patient can then connect with other patients with same or similar conditions to discuss issues such as condition management. A smartphone application that integrates the above features not only helps increase the convenience of the patient but also has the capacity to reduce the latency in communication between the patient and a physician or a nurse.

Furthermore social media tools can also act as collaborative tools that practitioners can use to disseminate knowledge and share best practices. Enterprise level online collaboration tools such as Yammer and Tibbr provide employees with an opportunity to connect with each other learn and teach.
The move away from the fee-for-service based reimbursement mechanism to a fee-for-outcome based system provides an opportunity for healthcare institutions to exploit these social media tools. For example, they could have a questionnaire posted related to the quality of service received by the patient and rating for the medical staff. These ratings can then be used to determine the appropriate level of reimbursement to be provided. The healthcare institute can then use aggregate ratings obtained from the whole population of patients to look for operational improvement opportunities. This would have a big impact on their overall quality of outcomes and hence the reimbursement amount and bonus. Pharmaceutical companies as of today do not have a direct way of reaching out to consumers to understand the usage and side effects. These social media tools, at an aggregate level, contain a treasure trove of information that can be sold to the pharmaceutical companies.

The above example is a very simple one that offers on the glimpse about the possibilities offered by social media to usher in an era of transparency into the healthcare segment. Not only can social media be used by healthcare institutes, the potential to leverage these technologies by business firms is also very high. The previous section alluded to wellness initiatives in work places that can potentially save millions of dollars in healthcare costs to the employers. These initiatives can integrate a social media component, such as posting of challenges, display of progress and peer-to-peer messaging that can be vital to help employees adopt a healthier lifestyle.

The two big issues that need to be grappled with are whether or not to develop an internal social media tool and deciding on appropriate metrics to measure the ROI of such an
initiative. Where healthcare is concerned data privacy and security are amongst the biggest concerns that patients and caregivers share. In this case building internal tools that conform to regulatory guidelines is probably a better option. Companies such as Facebook and Google maybe able to offer special features specific to the health segment sometime in the future but until then one can guess that tools such as Yammer are going to be very popular. The advantages that these tools can provide over generic social media tools such as Facebook are:

a. A high level of customization which means that the tools can be configured to align with the organization's internal processes

b. Security of data and privacy which means that personal information does not become public

The issue of ROI metrics is an important one but one that has no true answer. The best way to answer this important question is an answer I have frequently heard in school: “it depends”. The reason I bring this up is because different organizations have different objectives. For one organization gaining foot traffic might be the most important objective, for another it may be gaining additional revenue and for yet another it maybe increasing collaboration between co-workers in the case of a healthcare organization. Arriving at the metrics is beyond the scope of this thesis but it is a very important factor that needs to be considered when implementing such tools. As is commonly known “one cannot manage something can cannot be measured".
SUMMARY

In this chapter we looked at some challenges and opportunities that an entrepreneur faces in the rapidly changing world of healthcare. While some of the concepts, such as social media, may not strike as being a mobile health solution the number of firms today that have developed a smartphone application that leverage a patient’s social network for positive behavior modification stand testament to the opportunities that lie ahead. Opportunities discussed above can easily be ported over the smartphones, which can improve patient engagement and have the potential to improve the quality of health outcome.
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