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Information Technology Resources for Precision Medicine

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This is to certify that the doctoral dissertation by

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Abstract

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Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

Healthcare delivery organizations have an opportunity to use insights from the emerging field of precision medicine to improve the quality of patient care; however, information technology resources to fully enable precision medicine are lacking. The specific problem was that people have limited information to use when making decisions regarding information technology resources for precision medicine in healthcare delivery organizations given the emerging state of precision medicine. The purpose of this Delphi study was to determine how a panel of precision medicine information technology experts view information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. The research question asked how does a panel of precision medicine information technology experts view information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. The resource-based view of the firm served as the conceptual framework. Data were collected in three consecutive rounds of questionnaires. Thematic analysis was performed to develop a list of information technology resources that were rated by participants in terms of importance and feasibility, which were analyzed to assess if there was consensus among the participants. Of the 159 information technology resources that were rated, 77 information technology resources were considered important and feasible. The study results could lead to positive social change at individual, organizational, and societal levels. At a societal level, the study results could give rise to positive social change by creating a shared vision of what is needed to fulfill information technology resource requirements for precision medicine in healthcare delivery organizations and enable progress toward improved healthcare quality.

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Dedication

I dedicate this work to my family with gratitude. My family has provided encouragement and inspiration throughout my academic endeavors. I would not be where I am without my family’s love and support.

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I thank the members of my dissertation committee for overseeing my work. More specifically, I thank Dr. Howard Schechter, Dr. Jean Gordon, and Dr. David Gould. The committee provided valuable comments that led to a stronger dissertation.

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Chapter 1: Introduction to the Study

In this study, I focused on information technology resources that could enable healthcare delivery organizations to improve the quality of patient care using precision medicine. Fulfilling information technology resource requirements for precision medicine in healthcare delivery organizations requires careful and deliberate planning. To make sound decisions about information technology resources for precision medicine in healthcare delivery organizations people should have information about resource importance and feasibility. The results of this study may provide information to aid people in making well-informed information technology resource decisions for precision medicine in healthcare delivery organizations.

The need for this study stems from the fact that people have limited information to use when making information technology resource decisions for precision medicine in healthcare delivery organizations. The requirements for information technology resources for precision medicine in healthcare delivery organizations are uncertain given that precision medicine is an evolving field. Precision medicine is a field of diverse applications with an abundance of new discoveries. People need additional information to make sensible decisions about information technology resources for precision medicine in healthcare delivery organizations.

This study could give rise to positive social change beyond potentially improving information technology resource decisions for precision medicine in healthcare delivery organizations. This study included determining a consensus of information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. A consensus of information technology resource importance and feasibility could lead to the creation of a shared vision to meet the resource requirements for precision medicine in healthcare delivery organizations. Meeting the information technology resource requirements for precision medicine could enable healthcare delivery organizations enhance the quality of patient care. This study may lead to positive social change.

This chapter begins with the background of the study followed by the problem statement, purpose of the study, research questions, conceptual framework, and nature of the study. Chapter 1 also includes the definitions, assumptions, scope, delimitations, and limitations of the study. This chapter concludes with the significance of the study and a summary.

Background of the Study

Healthcare delivery organizations have a tremendous opportunity to use insights from the emerging field of precision medicine to improve the quality of patient care (Starkweather et al., 2018; Weinshilboum & Wang, 2017). Precision medicine is applicable to practically every medical specialty (Weinshilboum & Wang, 2017). The field of oncology provides an example in which there are promising precision medicine advances for the prevention, diagnosis, prognosis, and treatment of cancer (Warner, Jain, et al., 2016). The potential improvement of patient care in healthcare delivery organizations using precision medicine is wide ranging.

Achieving the potential benefits of precision medicine entails utilizing diverse and complex types of healthcare data with the aid of information technology (Gligorijević et al., 2016; Gómez-López et al., 2019). Precision medicine is transdisciplinary and involves integrating data from multiple areas such as the clinical, molecular, environmental, social, and behavioral domains (Beckmann & Lew, 2016; Prosperi et al., 2018). The use of varied types of data is consistent with the precision medicine concept that healthcare delivery improves as more health factors are measured (Vegter, 2018). As for the need of information technology, Levy et al. (2019) explained that an important driver of sustained precision medicine is information technology infrastructure including electronic health record systems and clinical decision support. Information technology aids in the use of increasing amounts of complex health data for precision medicine.

Healthcare delivery organizations are ill equipped to tackle numerous challenges associated with using information technology for precision medicine. The information technology challenges related to precision medicine are varied and include hardware, software, interoperability, integration, implementation, standardization, and human resource issues (Hulsen et al., 2019; Klein et al., 2017). Storing, processing, and interpreting large amounts of diverse precision medicine data requires considerable computational infrastructures that are typically not found in healthcare delivery organizations (Gómez-López et al., 2019; Pritchard et al., 2017). Information specialists need skills that span multiple disciplines and reports indicate that there is a shortage of workers with the skills necessary to implement precision medicine (Gómez-López et al., 2019; Hulsen et al., 2019). Healthcare delivery organizations have many information technology obstacles to overcome regarding precision medicine.

In this study, I addressed a gap in the literature of which there is not a consensus of information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. It is unsurprising that the literature does not contain an established consensus given that the field of precision medicine is evolving. Information technology resource importance and feasibility for precision medicine in healthcare delivery organizations is still open for debate in the literature. My intention with this study was to add to the debate by providing a new viewpoint.

The need for this study extends beyond there being a gap in the literature. An important reason I conducted this study is that people have incomplete information to use when making decisions regarding information technology resources for precision medicine in healthcare delivery organizations. Information technology resource requirements for precision medicine in healthcare delivery organizations are undetermined considering that the field of precision medicine is emerging. There are a wealth of new discoveries and a variety of applications in the field of precision medicine. The need for this study stems from the fact that people have limited information to use when making information technology resource decisions for precision medicine in healthcare delivery organizations, which is evident by there being a gap in the literature.

Problem Statement

Millions of opportunities are missed each year to use precision medicine to prevent patient harm (Caraballo, Bielinski, et al., 2017). The drug warfarin provides an example of evidence indicating that it is possible to prevent patient harm using precision medicine (Chan et al., 2016). Warfarin is a noteworthy example considering that in 1 year at least 2,000,000 people in the United States begin warfarin treatment and up to 20% of them may be hospitalized due to patient harm (Alessandrini et al., 2016). The general management problem was that healthcare delivery organizations underutilize information technology resources for precision medicine which can lead to adverse effects on the quality of patient care (Caraballo, Bielinski, et al., 2017). Information technology resources lacking vital characteristics may exacerbate the problem. For instance, several reports suggest that commercially available information technology products are not mature in terms of meeting the requirements for precision medicine in healthcare delivery organizations (Hoffman et al., 2016; Warner, Rioth, et al., 2016). Additionally, reports indicate there is a shortage of information specialists with the skills necessary to implement precision medicine (Gómez-López et al., 2019; Hulsen et al., 2019).

Billions of dollars are being invested in precision medicine globally (Feero, 2017; Ginsburg & Phillips, 2018). Healthcare delivery organizations require the appropriate information technology resources to take full advantage of the substantial investments in precision medicine. The specific management problem was that people have limited information to use when making decisions regarding information technology resources for precision medicine in healthcare delivery organizations given the emerging state of precision medicine. Support for there being limited information is that the literature does not contain a consensus of information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. In addition to a gap in the literature, reports suggest that healthcare delivery organizations have made ill-informed decisions regarding potential information technology resource requirements for precision medicine. For instance, Caraballo, Hodge, et al. (2017) explained that the longevity of early precision medicine information technology implementations is questionable due to scalability concerns. Additionally, several reports indicate that data storage approaches used in early precision medicine implementations may be insufficient for the long term (Danahey et al., 2017; Hicks, Dunnenberger, et al., 2016).

Literature Gap

A noteworthy gap in knowledge exists in that the literature does not contain a consensus of information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. The lack of agreement is apparent when considering multiple views present in the literature. For example, Gómez-López et al. (2019) discussed that a type of information specialist known as a clinical bioinformatician is required to effectively implement precision medicine in healthcare delivery organizations, but clinical bioinformaticians are rare. Caraballo, Hodge, et al. (2017) explained that commercial electronic health record systems and clinical decision support are essential to implement a type of precision medicine in a clinical setting, but the systems may not handle near future increases in data. Danahey et al. (2017) discussed that having the capability to integrate multiple data sources was essential to implement a form precision medicine at a university affiliated healthcare delivery organization, but the implementation involved custom building a sophisticated software system using several specialty resources. The literature does not contain a consensus of information technology resource importance and feasibility for precision medicine in healthcare delivery organizations.

Purpose of the Study

The purpose of this classical Delphi study was to determine how a panel of precision medicine information technology experts view information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. Determining a consensus of information technology resource importance and feasibility may help address the problem of people having limited information when making information technology resource decisions for precision medicine in healthcare delivery organizations. The information gathered from the participants could help make future information technology resource requirements less unclear. This Delphi study could provide information that aids people in making sound information technology resource decisions for precision medicine in healthcare delivery organizations.

Research Questions

Overarching research question: How does a panel of precision medicine information technology experts view information technology resource importance and feasibility for precision medicine in healthcare delivery organizations?

Subquestion 1: How does a panel of precision medicine information technology experts view information technology resource importance for precision medicine in healthcare delivery organizations?

Subquestion 2: How does a panel of precision medicine information technology experts view information technology resource feasibility for precision medicine in healthcare delivery organizations?

Conceptual Framework

I used the resource-based view of the firm as the conceptual lens for this study and is further described in Chapter 2. According to Lockett et al. (2008), the work of Wernerfelt (1984) is the seminal article regarding the resource-based view of the firm. Wernerfelt (1984) explained that a central concept in a resource-based view is company resources, which include any tangible or intangible company assets. Resources can be classified as physical resources, human resources, or organizational resources (Barney, 1991). I included each of the three resource categories in this study. Equipment, a person's intelligence, and a company's reporting structure are examples of a physical resource, human resource, and organizational resource, respectively (Barney, 1991). I centered this study around the concept of company resources.

In a resource-based view, the concept of an organizational capability is a special type of organizational resource that has distinctive features (Grant, 1991; Makadok, 2001). The main purpose of an organizational capability is to make other resources more productive (Amit & Schoemaker, 1993; Makadok, 2001). An organizational capability is built internally and embedded within a company (Amit & Schoemaker, 1993; Grant, 1991). I distinguish organizational capabilities from other types of resources in this study. According to Makadok (2001), an example of an organizational capability is the internal development of Walmart's logistics system which improves the productivity of other resources including real estate, trucks, personnel, and technology. The features of an organizational capability distinguish it from other types of resources.

Organizational capabilities and other types of resources are often discussed in the literature as being associated with the concept of economic rents (Grant, 1991; Makadok, 2001). The concept of economic rents refers to potential above normal earnings that are sustained (Conner, 1991). In a resource-based view, the term economic rents is used interchangeably with the term competitive advantage (Barney, 2001). This study included assessing information technology resource importance as a proxy for the concept of economic rents.

In theory, certain resource characteristics are more likely than others to result in economic rents (Amit & Schoemaker, 1993; Conner, 1991). Ideal resources have the characteristics of being valuable and rare, and cannot be perfectly imitated or substituted (Barney, 1991). This study included assessing information technology resource importance as a substitute for the resource characteristic of being valuable. In addition, this study involved assessing information technology resource feasibility which represents the inverse of three resource characteristics that are being rare, imperfectly imitable, and nonsubstitutable. Information technology resource importance and feasibility are key features of the research questions. This study entailed assessing information technology resource importance and feasibility to represent resource characteristics associated with economic rents.

Nature of the Study

I selected the qualitative research method for this study based on its being well suited to address the research questions. According to Williams (2007), a researcher selects the research method according to the type of data most appropriate for responding to the research questions. Williams (2007) also mentioned that researchers can use a qualitative method to understand details in situations that are complex. Similarly, Ravitch and Carl (2016) explained that qualitative research is descriptive and fitting when pursuing complexity. Additionally, Woods et al. (2016) discussed that qualitative research combines knowledge and understanding to make judgements regarding circumstances. Addressing the research questions involved gathering assessment information from knowledgeable people regarding a complex topic, which made a qualitative method suitable for this study.

When considering the literature, a Delphi design was appropriate for this study given that addressing the research questions involved assessing importance and feasibility information regarding a complex topic that is evolving and has many unknowns. According to Rikkonen and Tapio (2009), a Delphi design is appropriate for topics in which changes in trends are probable. Additionally, Delbecq et al. (1975) and Linstone and Turoff (2002) concurred that a Delphi design is fitting when there is incomplete information regarding a situation. Furthermore, Linstone and Turoff (2002) offered the view that a Delphi design allows a group of people to jointly address a complex problem and is useful to assess the importance and feasibility of options. Linstone and Turoff (2002) also explained that the need for a Delphi design can result from certain characteristics, including when exact analytics are not suitable for working on a problem or when the participants needed to examine a complex problem have not had prior communication. In addition, Delbecq et al. (1975) discussed that a Delphi design can be useful for planning activities regarding information technology. A Delphi design was well suited for this study in that addressing the research questions involved assessing importance and feasibility information regarding a complex topic that is evolving and has many unknowns.

I used nonprobability purposive sampling and supplemented it with snowball sampling to form a sample. The criteria to participate in the study were that an individual: (a) could describe cases illustrating good versus poor decisions regarding information technology resources for precision medicine in healthcare delivery organizations, (b) had a minimum of 3 years of professional experience dealing with information technology for precision medicine in healthcare delivery, (c) could write fluently in English, (d) did not have a personal or professional relationship with me, and (e) was at least 18 years old. Sampling provided the means to identify a group of specialists that met certain criteria.

I performed data collection and analysis in three consecutive rounds. I used open-ended questions to make the Round 1 questionnaire. I analyzed text data collected during Round 1 using thematic analysis. I structured the Round 2 questionnaire so that participants could rate the importance and feasibility of information technology resources identified in Round 1 as well as optionally provide additional information technology resources. I analyzed importance and feasibility ratings collected during Round 2 to assess the level of agreement among the participants. I performed thematic analysis on any additional information technology resources collected during Round 2. The structure of the Round 3 questionnaire allowed participants to rate the importance and feasibility of additional information technology resources identified during Round 2 as well as rerate the importance and feasibility of information technology resources from Round 2 that did not have consensus of importance, feasibility, or both. Similar to the data analysis for Round 2, I analyzed importance and feasibility ratings collected during Round 3 to assess the level of agreement among the participants. I performed three consecutive rounds of data collection and analysis.

Definitions

Big data: A large amount of diverse information (Auffray et al., 2016).

Clinical decision support: Computer software aimed at affecting the decisions clinicians make about patients (Miller et al., 2015).

Electronic health record system: A computerized information resource for healthcare workers regarding patients (Smolij & Dun, 2006).

Information technology: The use of computers to store, transfer, and process data (Ekwonwune et al., 2017).

Precision medicine: The use of assorted data to enhance the accuracy of healthcare (König et al., 2017).

Assumptions

I made several assumptions for this study that are attributable to the qualitative Delphi study design and extensive use of literature. The first assumption was that I would address the research questions in an objective manner by identifying concepts in the collected data and by assessing the concepts according to the level of agreement among the participants. The second assumption was that the data collected from the sample participants represent the views of the larger population of experts knowledgeable about information technology resources for precision medicine in healthcare delivery organizations. The third assumption was that participant responses to the questionnaires represent reality. The fourth assumption was that participants could clearly articulate their views in writing when completing questionnaires. The fifth assumption was that information found in the literature was accurate. The assumptions that I made for this study were necessary given the qualitative Delphi study design and reliance on the literature.

Scope

In this study, I addressed the problem of people having limited information to use when making decisions regarding information technology resources for precision medicine in healthcare delivery organizations given the emerging state of precision medicine. More specifically, the purpose of this classical Delphi study was to determine how a panel of precision medicine information technology experts view information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. I chose the specific focus based on how the study could enhance practice, theory, and positive social change as discussed below.

Delimitations

The delimitations should be taken into account when considering transferability of the study to other contexts. One delimitation was that the sample only included individuals that could write fluently in English. Therefore, I excluded people not able to write fluently in English. Another delimitation was that the resource-based view of the firm served as the conceptual framework. Hence, I centered the study around the concept of company resources. I reviewed but did not select other conceptual frameworks because the other frameworks were not well aligned with the purpose of this study. For instance, I considered but did not select the strategic alignment model described by Henderson and Venkatraman (1999) due to poor alignment with the study purpose. The boundaries of the study should be considered when assessing the transferability of this study to other contexts.

Limitations

A limitation was that this study was subject to self-selection bias in that the sample was composed of specialists who chose to participate. Knowledgeable experts may have opted not to participate in the study due to time constraints, indifference to the study, or insufficient compensation. In addition to offering a modest monetary gift, I partially addressed the first limitation by using questionnaires that did not require a substantial amount of time to complete.

Another limitation was that I used a cross-sectional design rather than a longitudinal design. A cross-sectional investigation is useful to analyze data for a specific point in time (Babbie, 2017) and does not provide information on how time may be an influence (Caruana et al., 2015). An example of the cross-sectional design limitation is that, according to McCoy (2017) and Vogl et al. (2018), research participants' perspectives may change over time. I partially addressed the second limitation by using a process to form consensus among the study participants. A consensus approach may have created a balanced perspective and incorporated persisting elements regarding the research questions.

A third limitation was that most participants stated they reside in the United States. There are many differences in healthcare systems of other countries when compared to healthcare in the United States. (Toth, 2016). The generalizability of the study to countries not represented in the sample is unknown. Considering differences in healthcare systems across different countries was beyond the scope of this study.

Significance of the Study

This study could contribute to practice, theory, and positive social change. Possible benefits of this study could advance practice in terms of strategic planning, prioritizing investment options, and assessing opportunities regarding information technology resources for precision medicine in healthcare delivery organizations. This study could lead to developments in theory regarding concepts of information technology resource planning, conceptual models regarding the evolution of information technology resources, and how the dynamics of information technology resources affect society. The study results could lead to positive social change in terms of enabling progress toward improved healthcare quality, informing information technology resource decisions, and advancing the intellect of people. This study could lead to advances in practice, theory, and positive social change.

Significance to Practice

The study results could contribute to improvements in practice. The results could aid people in making strategic planning decisions regarding information technology resources for precision medicine in healthcare delivery organizations. Additionally, the study results could be insightful to people when prioritizing resource investment options.

Furthermore, the results could be useful to people when assessing opportunities to create new information technology resources for precision medicine in healthcare delivery organizations. This study could lead to improvements in practice in multiple ways.

The study results could enable practitioners to be more efficient. Practitioners could save time by using the list of information technology resources as a checklist of resources to consider when making decisions regarding precision medicine in healthcare delivery organizations. Additionally, the list of information technology resources could be used by practitioners to consider information technology resources in an organized and more complete way. Furthermore, the list of information technology resources could be used by practitioners as a delegation aid when assigning tasks. There are multiple ways in which the study results could enable practitioners to be more efficient.

Significance to Theory

The study results could accelerate developments in theory. Given the emerging state of the field of precision medicine, the results could provide a new perspective to advance concepts associated with information technology resource planning when future circumstances are unclear. Additionally, having determined information technology resource importance and feasibility, the study results could inform conceptual models concerning the evolution of information technology resources for precision medicine. Furthermore, the results could lead to a better understanding of how the dynamics of information technology resources for precision medicine influence society. The study results could contribute to different types of advancements in theory.

Significance to Social Change

At a societal level, the study results could give rise to positive social change by enabling progress toward improved healthcare quality using information technology resources for precision medicine in healthcare delivery organizations. Information technology resources for precision medicine are underutilized, which can lead to adverse effects on the quality of healthcare (Caraballo, Bielinski, et al., 2017). Having created a list of information technology resources considered important and feasible, the study results could create a shared vision of what is needed to fulfill information technology resource requirements for precision medicine in healthcare delivery organizations. Creating a shared vision could lead to improved utilization of information technology resources for precision medicine in healthcare delivery organizations as well as improved healthcare quality. The study results could prompt positive social change at a societal level by enabling progress toward improved healthcare quality.

In addition to positive social change at a societal level, the study results could lead to positive social change at an organizational level by informing information technology resource decisions for precision medicine in healthcare delivery organizations. For instance, reports indicate there is a shortage of information specialists with the skills necessary to implement precision medicine (Gómez-López et al., 2019; Hulsen et al., 2019). Positive social change could result by educational organizations considering the study results when making decisions about enhanced curricula targeted at people who function as human information technology resources for precision medicine in healthcare delivery organizations. Enhanced curricula may help alleviate the shortage of information specialists. As another example, multiple reports suggest that commercially available information technology products are not mature in terms of meeting the requirements for precision medicine in healthcare delivery organizations (Hoffman et al., 2016; Warner, Rioth, et al., 2016). Positive social change could result by commercial vendors considering the study results when making decisions about the creation of new physical information technology resources that would meet the requirements for precision medicine in healthcare delivery organizations. As a third example, reports indicate that data storage approaches used in early precision medicine implementations may be insufficient for the long term (Danahey et al., 2017; Hicks, Dunnenberger, et al., 2016). Positive social change could result by healthcare delivery organizations considering the study results when making decisions about the creation of adaptable data storage solutions for precision medicine. Adaptability could help increase the longevity of data storage solutions. The study results could lead to positive social change by informing decisions made by organizations regarding information technology resources for precision medicine in healthcare delivery organizations.

Besides positive social change at organizational and societal levels, the study results may lead to positive social change at an individual level by advancing the intellect of people. I conducted this study in part because the literature did not contain a consensus of information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. Given that this study addresses a literature gap, individuals that read this dissertation may benefit intellectually. The study results may lead to positive social level change at an individual level.

Summary and Transition

In sum, this study focused on information technology resources for precision medicine in healthcare delivery organizations. Information technology resources are a vital component for precision medicine in healthcare delivery organizations. Given that precision medicine is an evolving field, information technology resource requirements are undetermined for precision medicine in healthcare delivery organizations. People have incomplete information to use when making decisions regarding information technology resources for precision medicine in healthcare delivery organizations. This study could provide information that aids people in making sound information technology resource decisions for precision medicine in healthcare delivery organizations. This study could advance practice in multiple ways. In addition, this study could accelerate different types of theoretical advancements. Focusing on information technology resources for precision medicine in healthcare delivery organizations could benefit society.

Knowledge is advanced by building upon what is already known (Xiao & Watson, 2019). Chapter 2 contains a synthesis of literature relevant to this study. The discussion presented in Chapter 2 provides a foundation of knowledge for this study to build upon.

Chapter 2: Literature Review

The general management problem addressed in this study was that healthcare delivery organizations underutilize information technology resources for precision medicine which can lead to adverse effects on the quality of patient care (Caraballo, Bielinski, et al., 2017). The specific management problem addressed was that people have limited information to use when making decisions regarding information technology resources for precision medicine in healthcare delivery organizations given the emerging state of precision medicine. Support for there being limited information is that the literature does not contain a consensus of information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. The purpose of this classical Delphi study was to determine how a panel of precision medicine information technology experts view information technology resource importance and feasibility for precision medicine in healthcare delivery organizations.

The synthesis of literature presented in Chapter 2 provides a base of knowledge for this study to build upon. I performed a thorough literature search and described the method used in the literature search strategy section of this chapter. The conceptual framework section includes a detailed review of the resource-based view of the firm as it applies to this study. The literature review section includes an extensive review of numerous topics relevant to this study beginning with a conceptual discussion of precision medicine. The summary and conclusions section includes a synopsis of the literature reviewed.

Literature Search Strategy

I completed the literature search in an iterative manner. I performed initial searches using broad keyword search terms, which I subsequently refined to focus on more specific topics. I applied date filters to concentrate on contemporary literature. I considered peer reviewed journal articles published within the past 5 years as a desirable category of literature. I assessed the titles of literature returned in search results to determine if the literature may be applicable to this study. I examined the full text of literature in cases where I deemed the titles to be relevant to this study. I reviewed the reference sections of literature relevant to this study to identify additional sources that may not have appeared in search results. I used an iterative approach to search the literature.

I performed the literature search using several online resources and keyword search terms. I searched the literature using Google Scholar and several online databases available through the Walden University library. The online databases included ABI/INFORM Collection, Academic Search Complete, Business Source Complete, Computers and Applied Sciences Complete, Emerald Insight, IEEE Xplore, ProQuest, PubMed, SAGE Journals, and ScienceDirect. The keyword search terms included: *big data analytics capability, big data analytics healthcare, big data analytics value, clinical decision support*, *Delphi*, *genomics clinical decision support*, *genomics electronic health record*, *genomics technology*, *information technology Delphi*, *information technology resources, personalized medicine*, *pharmacogenetics clinical decision support*, *pharmacogenetics electronic health record*, *pharmacogenetics technology*, *pharmacogenomics clinical decision support*, *pharmacogenomics electronic health record*, *pharmacogenomics technology*, *precision medicine*, *precision medicine adverse drug reactions*, *precision medicine big data*, *precision medicine clinical decision support*, *precision medicine electronic health record*, *precision medicine genomics*, *precision medicine omics*, *precision medicine quality*, *precision medicine safety*, *precision medicine technology*, *resource based view*, *resource based view Delphi*, *resource based view technology*, and *stratified medicine*. I used several online resources and keyword search terms to complete the literature search.

Conceptual Framework

The resource-based view of the firm grounds this study conceptually. A resource-based view focuses on internal company characteristics as opposed to external industry factors (Amit & Schoemaker, 1993; Barney, 1991). Company resources are a central concept in a resource-based view of the firm and include any tangible or intangible company assets (Wernerfelt, 1984). In a resource-based view, a company can be considered as a bundle of resources (Conner, 1991; Wernerfelt, 1984). In theory, the way a company combines resources affects the company performance (Amit & Schoemaker, 1993; Conner, 1991). Managers are tasked with renewing resources and relationships among resources (Conner, 1991). I have centered this study around the concept of company resources.

Differentiating types of resources helps bring clarity to the wide array of resources companies have. Resources can be categorized as physical resources, human resources, or organizational resources (Barney, 1991). In the context of information technology, physical resources are things used as part of an overall information technology infrastructure (Bharadwaj, 2000). Examples of physical information technology resources include computers, digital networks, software, and electronic data (Aral & Weill, 2007; Bharadwaj, 2000). Human resources, in the context of information technology, are the technical and managerial skills and knowledge of people (Bharadwaj, 2000). Examples of human information technology resources include technical and managerial competencies in information systems analysis and design, software programming, and emerging technology (Bharadwaj, 2000). Organizational resources are managerial focused and used to affect how people interact (Diin et al., 2018). Examples of organizational resources include methods of reporting, planning, coordinating, and controlling (Barney, 1991). This study included distinguishing resource categories to help bring clarity to the assortment of information technology resources for precision medicine in healthcare delivery organizations.

A special type of organizational resource is an organizational capability (Makadok, 2001). The concept of an organizational capability is the ability to perform an activity using multiple resources (Grant, 1991). The main purpose of an organizational capability is to make other resources more productive (Makadok, 2001). An organizational capability is built internally and embedded within a company (Grant, 1991; Makadok, 2001). The development of an organizational capability occurs gradually through experience and typically involves information-based processes (Amit & Schoemaker, 1993; Grant, 1991). Given that organizational capabilities are a special type of organizational resource, I distinguished them from other types of resources in this study.

In the context of information technology, organizational capabilities may exist in multiple areas (Wade & Hulland, 2004). Three examples of information technology capability areas are integrating information technology with the business, designing information technology architecture, and delivering information technology services (Wade & Hulland, 2004). In a discussion of information technology resource characteristics Bharadwaj (2000) provided an example of a company that had information technology capabilities in multiple areas. First, Bharadwaj (2000) explained that the company's information technology personnel are able to envision the business benefits of creating a new application, which denotes the capability area of integrating information technology with the business. Second, Bharadwaj (2000) discussed the flexibility of the company's information technology infrastructure, which denotes the capability area of designing information technology architecture. Third, Bharadwaj (2000) explained that a new information technology application for the company could be delivered in a short time frame, which denotes the capability area of delivering information technology services. Organizational capabilities regarding information technology can exist in multiple areas.

Information technology capabilities and other types of information technology resources may be associated with the concept of economic rents (Bharadwaj, 2000; Wade & Hulland, 2004). The concept of economic rents refers to potential above normal earnings that are sustained (Conner, 1991). In a resource-based view, the term economic rents is used interchangeably with the term competitive advantage (Barney, 2001). This study included assessing information technology resource importance as a proxy for the concept of economic rents.

In theory, resources that are valuable, rare, imperfectly imitable, and nonsubstitutable are potential sources of economic rents (Barney, 1991). This study included assessing information technology resource importance as a substitute for the characteristic of being valuable. This study also included assessing information technology resource feasibility which represents the inverse of three resource characteristics that are being rare, imperfectly imitable, and nonsubstitutable. This study included assessing information technology resource importance and feasibility to represent resource characteristics associated with economic rents.

According to Mata et al. (1995), managerial information technology skills are an example of a resource that is a possible source of economic rents. The resource characteristic of being valuable can be recognized in the article by Mata et al. (1995) when the authors discussed that managerial information technology skills, such as the ability to understand a company's business needs, are valuable in achieving the full benefits of information technology. The resource characteristic of being rare can be recognized in the article by Mata et al. (1995) when the authors discussed that developing managerial information technology skills depends on close relationships that may be rare between information technology personnel and personnel working in other areas of a company. The resource characteristic of being imperfectly imitable can be recognized in the article by Mata et al. (1995) when the authors discussed that tacit managerial information technology skills that cannot be codified may involve countless decisions that are imperfectly imitable. The resource characteristic of being nonsubstitutable can be recognized in the article by Mata et al. (1995) when the authors discussed that managerial information technology skills may be nonsubstitutable when they are immobile and embedded within a company. Managerial information technology skills provide an example of a resource that is a potential source of economic rents.

Some resources may become a source of economic rents when combined with other resources. Barney (1991) discussed physical technology resources as an example of resources that are not usually a source of economic rents. Physical technology resources are generally imitable (Barney, 1991). Physical technology resources may become a source of economic rents when combined with socially complex resources that are valuable, rare, imperfectly imitable, and nonsubstitutable (Barney, 1991). The combination of physical technology resources and socially complex resources may allow a company to more fully exploit physical technology resources (Barney, 1991). Combining resources may create a source of economic rents.

In sum, I centered this study around the concept of company resources. This study included distinguishing between physical, human, and organizational resources. Given that organizational capabilities are a special type of organizational resource, I distinguished them from other types of resources in this study. This study included assessing information technology resource importance and feasibility to represent the concept of economic rents and resource characteristics associated with economic rents. The resource-based view of the firm grounded this study conceptually.

Literature Review

Precision medicine can be characterized as a paradigm shift not unlike others that have occurred in history of healthcare. According to Fernandes et al. (2017), a paradigm shift is a change in basic concepts and practices of a scientific field. In a conceptual debate of precision medicine, Vegter (2018) explained that paradigm shifts in the history of healthcare include a shift toward using technology to improve diagnostics, a shift toward using statistics to define an illness as a deviation from the norm, and a shift toward widespread access to healthcare information. Precision medicine is a shift toward using a variety of data types to continually improve the accuracy of healthcare (König et al., 2017; Vegter, 2018). In a similar view, Tebani et al. (2016) discussed that precision medicine is a shift to provide more customized and accurate healthcare by incorporating a constantly improved understanding of biology based on a variety of measurements. Additionally, Prosperi et al. (2018) explained that the precision medicine paradigm involves using detailed patient information to make more accurate predictions in care. Furthermore, according to Ginsburg and Phillips (2018), precision medicine entails a shift from treatment to the prevention of disease. Precision medicine is a paradigm shift that builds on earlier advancements in healthcare knowledge (Vegter, 2018).

The paradigm shift associated with precision medicine has led to the formation of a complex field combining a variety of sophisticated topics. Researchers have addressed several complex topics regarding the field of precision medicine. For instance, in addition to discussing the complementary relationship between reductionist and integrative approaches to studying health issues Beckmann and Lew (2016) explained that the confluence of three disruptive forces affect precision medicine. According to Beckmann and Lew (2016), the disruptive forces include revolutionary advancements in high resolution data generating technology, innovative high speed computation capacities in information science, and the expansion of patient empowerment due to social media and the use of connected electronic devices. In another case of complex topics, Huang et al. (2016) explained that collaborative efforts are needed to implement several features of precision medicine and that some factors affecting precision medicine include big data analytics, training, financial models, quality control, and regulation. Vegter (2018) added to the list of sophisticated topics associated with precision medicine when discussing the profile of precision medicine which includes epistemological, bio-political, and ethical considerations. Vegter (2018) concluded the discussion by providing the view that the profile of precision medicine is differentiated by a focus on issues associated with prediction and prevention.

As part of describing the profile of precision medicine, Vegter (2018) claimed that big data science provides an epistemological base for precision medicine. There is general agreement that data analytics is a vital component of precision medicine. After clarifying that the terms precision medicine and personalized medicine are used interchangeably, Fröhlich et al. (2018) explained that precision medicine stems from a base of data science. According to Fröhlich et al. (2018), analyzing data from multiple sources provides a better understanding of a patient and is the key to making clinically useful predictions for precision medicine. Similarly, Prosperi et al. (2018) indicated that precision medicine is based on analyzing data from a variety of sources. In addition, Vegter (2018) claimed that data mirror the truth about a person's health and that an aim of precision medicine is to analyze every quantifiable aspect.

Even though there is general agreement that data analytics is an essential component of precision medicine, the emerging focus of precision medicine efforts continues to be debated. According to Vegter (2018), the focus of precision medicine efforts is still maturing, and some believe that precision medicine research should be at the intersection of a person's biology, lifestyle, and environment. In addition, Intille (2016) explained that the details of a national precision medicine research initiative are under development but may include investigating health factors associated with genetics, sleep, and pollution. In a review of precision medicine efforts around the globe, Lee et al. (2019) added to the debate by suggesting that there is a lack of longitudinal designs in precision medicine efforts given that time is a factor when assessing changes in health. In another view, Lau and Wu (2018) suggested that the basic question for precision medicine involves understanding how peoples' genomes and life histories affect wellbeing, probability of disease, and response to treatment. In the context of oncology, Kensler et al. (2016) provided support for the idea that precision medicine has a transformative role in the prevention of disease. According to Pasipoularides (2018), a focus of precision medicine in the context of cardiology is understanding relationships between genomics and disease. In the context of psychiatry, Fernandes et al. (2017) suggested the precision medicine can aid in matters of diagnosis, treatment, and prognosis. The debate regarding the emerging focus of precision medicine efforts continues.

Considering the emerging focus of precision medicine efforts, it is not surprising that healthcare delivery organizations are in early stages of applying precision medicine. The literature contains several cases of early applications of precision medicine in healthcare delivery organizations and a few of those cases are discussed here. In a case discussed by Arnall et al. (2019), as part of a newly formed precision medicine program, an academic cancer center conducted a pilot project to define the role of clinical pharmacy services for precision medicine. In another case, Fiore et al. (2016) discussed a pilot project for precision medicine and explained that a national government healthcare delivery organization demonstrated feasibility of incorporating precision medicine with clinical care in an oncology context focusing on military veterans with lung cancer. In a different case, according to Dunnenberger et al. (2016), a university affiliated health system developed a pharmacogenomics clinic and made adjustments to improve utilization after the clinic opened. In a different case, Dressler et al. (2018) explained that an integrated health system conducted a series of pilot research studies to aid in the development of an outpatient precision medicine clinic for the provision of pharmacogenomic services. Healthcare delivery organizations are in the early phases of using precision medicine.

Besides being in the early phases of using precision medicine, healthcare delivery organizations use complex and specialized resources for precision medicine. For instance, according to Nadauld et al. (2018), an academic medical center developed an in-house genomic test to analyze over 100 clinically relevant genes for precision medicine in an oncology context. Nadauld et al. (2018) also explained that the organization periodically considers modifying the genomic test to incorporate new discoveries and uses knowledge of molecular pathology fellows to help decide when modifications to the test are warranted. In another case, according to Walko et al. (2016), a cancer center uses a specialized committee to assist in interpreting genomic information for precision medicine. Walko et al. (2016) also discussed that the committee consists of a diverse group of experts including information specialists, financial strategists, basic scientists, translational scientists, molecular pathologists, oncologists, pharmacists, nurses, and genetic counselors. Walko et al. (2016) further explained that the committee reviews a patient case by considering the findings from a full literature review and the personal, clinical, and genomic characteristics of the patient. Healthcare delivery organizations use complex and specialized resources for precision medicine.

In addition to using complex and specialized resources for precision medicine, healthcare delivery organizations use information technology to facilitate precision medicine. According to Beckmann and Lew (2016), specialized information technology facilitates the clinical use of complex multiscale and multilevel data sets for precision medicine. In addition, Danahey et al. (2017) discussed that a university affiliated healthcare delivery organization uses information technology to condense information from thousands of literature sources into summaries that healthcare workers can use as an aid when making medication prescribing decisions for precision medicine. According to Danahey et al. (2017), the information technology solution involved building a clinical decision support system to simplify the clinical practice of precision medicine. Danahey et al. (2017) also explained that the summaries are displayed with links to primary literature sources. A different case discussed by Dressler et al. (2018) is in the context of integrating clinical decision support with clinical processes for pharmacogenomics, which is a form of precision medicine. According to Dressler et al. (2018), an integrated health system uses information technology to automatically analyze multiple patient data elements and deliver patient specific advice to healthcare workers to promote patient safety regarding medications. Information technology facilitates precision medicine in healthcare delivery organizations.

Given the use of information technology for precision medicine, a noteworthy gap in knowledge exists in that the literature does not contain a consensus of information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. The lack of agreement is apparent when considering multiple views present in the literature. Here are a few examples. In one view, Gómez-López et al. (2019) discussed that a type of information specialist known as a clinical bioinformatician is required to effectively implement precision medicine in healthcare delivery organizations, but clinical bioinformaticians are rare. In a different view, Caraballo, Hodge, et al. (2017) explained that commercial electronic health record systems and clinical decision support are essential to implement a type of precision medicine in a clinical setting, but the systems may not handle near future increases in data. In another view, Danahey et al. (2017) discussed that having the capability to integrate multiple data sources was essential to implement a form precision medicine at a university affiliated healthcare delivery organization, but the implementation involved custom building a sophisticated software system using several specialty resources. The literature does not contain a consensus of information technology resource importance and feasibility for precision medicine in healthcare delivery organizations.

A Delphi design provides useful methods to address topics concerning information technology resources when knowledge is incomplete. Delbecq et al. (1975) and Linstone and Turoff (2002) agreed that a Delphi design is suitable when there is incomplete information regarding a situation. Similarly, according to Skulmoski et al. (2007), a Delphi design is appropriate when there is incomplete knowledge about a problem and a researcher seeks to enhance an understanding of solutions using the judgment of experts. In one case of using a Delphi design Duncan (1995) addressed a situation of incomplete knowledge using a Delphi questionnaire to collect data from information technology executives about the importance of information technology resource characteristics regarding infrastructure flexibility. In another case, Niederman et al. (1991) conducted a three round Delphi study with information technology executives to understand the most important information technology management issues, which consequently are most deserving of resource investment. Researchers have used Delphi methods to enhance knowledge on topics regarding information technology resources.

Researchers have used Delphi methods to examine topics regarding information technology resources for data analytics. For instance, Akter et al. (2016) conducted a two round Delphi study and used themes in the collected data to identify 11 subdimensions of a big data analytics capability, which is considered an organizational information technology resource in a resource-based view. Similarly, Ranko et al. (2015) conducted a study using Delphi methods to advance a conceptual business analytics capability framework which expert participants helped refine by providing input regarding the structure, definitions, and relative importance of components. In another study, Côrte-Real et al. (2019) used Delphi methods to identify and rank 23 company level antecedents of business value generated using big data analytics. Several of the antecedents identified by Côrte-Real et al. (2019) can be categorized as organizational information technology resources including managerial capabilities, analytical capabilities, dynamic capabilities, and an analytical decision making culture. Another antecedent that Côrte-Real et al. (2019) called big data analytics applications can be categorized as a physical information technology resource. In a different article, Vidgen et al. (2017) discussed how Delphi methods were used to identify 31 organizational challenges regarding the use of big data analytics to generate business value and to reach a consensus of how the challenges rank in terms of importance. Organizations can use the list of challenges produced by Vidgen et al. (2017) as a checklist when building a business analytics capability. Researchers have examined topics regarding information technology resources for data analytics using Delphi methods.

In sum, a discussion of the literature regarding this study provides a variety of relevant points to consider. Precision medicine is a paradigm shift that builds on earlier advancements in healthcare knowledge which has led to the formation of a complex field combining a variety of sophisticated topics. Even though there is general agreement that data analytics is an essential component of precision medicine, the emerging focus of precision medicine efforts continues to be debated. Precision medicine practices are being incorporated in healthcare delivery organizations using complex resources, specialized resources, and information technology resources. Given the prevalent use of information technology for precision medicine, a noteworthy gap in knowledge exists in that the literature does not contain a consensus of information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. Previous researchers have used Delphi methods to examine topics concerning information technology resources. There is an assortment of considerations relevant to this study.

Information Delivery

The topic of information delivery is central to healthcare delivery organizations. Information delivery is essential to clinical, administrative, and operational processes in healthcare delivery organizations. The ability of a healthcare delivery organization to save the life of a patient may depend on the speed and accuracy of information delivery. Information delivery is a common topic in reports of precision medicine in healthcare delivery organizations. Several reports provide useful information about physical, human, and organizational forms of information technology resources used in information delivery for precision medicine. The following discussion is based on several early cases of precision medicine in healthcare delivery organizations that include discussion about information technology.

One theme that stands out in the literature is that information technology enhances information delivery for precision medicine in healthcare delivery organizations. For instance, according to Caraballo, Bielinski, et al. (2017), a multistate healthcare institution uses clinical decision support pop-up alert messages in an electronic health record system to automatically deliver sophisticated information quickly and provide advice to enable precision medicine. Similarly, Dressler et al. (2018) discussed a case in which a community health system uses pop-up alert messages in an electronic health record system to disseminate changes to patient safety policies across the organization for precision medicine. Additionally, Luzum et al. (2017) explained that the use of information technology to disseminate information for precision medicine to a widespread audience occurs in multiple healthcare delivery organizations using online sites. Healthcare delivery organizations use information technology to enhance information delivery for precision medicine.

In addition to being enhanced using information technology, information delivery for precision medicine in healthcare delivery organizations is performed through multiple channels. In a study that included survey methods to collect data regarding the implementation of genomic information resources, Rasmussen et al. (2016) explained that healthcare delivery organizations use several physical forms of information technology resources to deliver information for precision medicine. The physical information technology resources provided by Rasmussen et al. (2016) included electronic health record systems, content management systems, compliance education systems, personal health records, email, and websites. Similarly, in a study that included multiple case study methods to investigate the implementation of genomics in clinical practice, Sperber et al. (2017) explained that healthcare delivery organizations deliver information for precision medicine using numerous physical forms of information technology resources. More specifically, the physical information technology resources provided by Sperber et al. (2017) included electronic health record systems, patient portals containing health information, clinical decision support, best practice alerts, data warehouses, websites, online education modules, and online newsletters. Additionally, other channels to deliver information for precision medicine include printed handouts, faxes, and hard copies delivered in the mail (Danahey et al., 2017; Warner, Jain, et al., 2016). Healthcare delivery organizations use multiple channels to deliver information for precision medicine.

Healthcare delivery organizations not only use multiple channels, but also incorporate multiple information sources in information delivery practices for precision medicine. For instance, according to Herr et al. (2019), healthcare delivery organizations obtain recommendations for precision medicine from government agencies and specialty consortiums for use in delivering pharmacogenomic information using clinical decision support. Shifting to specific cases, Manzi et al. (2017) provided an account in which a pediatric teaching hospital uses primary literature articles and specialty consortiums as sources of information to make decisions regarding the delivery of pharmacogenomic information using clinical decision support for precision medicine. Similarly, Danahey et al. (2017) explained that a university affiliated healthcare delivery organization utilizes information from government agencies, specialty consortiums, and literature articles in the delivery of syntheses of information for precision medicine. Interestingly, Mukerjee et al. (2018) addressed a noteworthy consideration when using multiple information sources by explaining that discrepancies have been identified among different information sources for precision medicine. Information delivery practices for precision medicine in healthcare delivery organizations include multiple information sources.

As well as using multiple information sources, healthcare delivery organizations use electronic health record systems in a vital role to deliver information for precision medicine. According to Sperber et al. (2017), electronic health record systems are foundational to delivering information in the patient care process for precision medicine. Similarly, in the context of establishing precision medicine in healthcare delivery organizations Arwood et al. (2016) explained that delivering accurate and timely information for precision medicine is only feasible when using an electronic health record system. Reports of healthcare delivery organizations using electronic health record systems to deliver information for precision medicine are common. In fact, several reports describe how electronic health record systems are used to deliver pharmacogenomic information to healthcare workers (Hicks, Stowe, et al., 2016; Rosenman et al., 2017). Electronic health record systems are physical information technology resources that have a key role in information delivery for precision medicine in healthcare delivery organizations.

Besides using electronic health record systems in a vital role, healthcare delivery organizations adapt electronic health record systems to deliver information for precision medicine. According to Hicks, Stowe, et al. (2016), healthcare delivery organizations are required to customize the infrastructure of an electronic health record system for precision medicine. Additionally, Ohno-Machado et al. (2018) explained that healthcare delivery organizations deliver genomic information as allergies, clinical problems, and lab results depending on the implementation of the electronic health record system. Furthermore, healthcare delivery organizations deliver notifications for precision medicine within an electronic health record system using either clinical notes or inbox messages depending on the system implementation (Caraballo, Hodge, et al., 2017; Sperber et al., 2017). Hicks, Stowe, et al. (2016) provided an account of using an electronic health record system to deliver pharmacogenomic information. According to Hicks, Stowe, et al. (2016), the delivery of information for precision medicine at a multistate health system can be affected by the medications prescribed to a patient, the documentation of genomic information, and the reasons provided when healthcare workers acknowledge recommendations. Rasmussen et al. (2016) provided a discussion of customizing the delivery of genomic information for healthcare delivery organizations. Interestingly, according to Rasmussen et al. (2016), an area of opportunity for vendors of electronic health record systems is offering the ability to deliver information from external sources while allowing for local adaptation. Healthcare delivery organizations deliver information for precision medicine by adapting electronic health record systems.

In addition to adapting electronic health record systems, healthcare delivery organizations use information technology resources in specialized ways for information delivery due to the emerging state of precision medicine. For instance, according to Sperber et al. (2017), a university medical center uses a pharmacogenomics group to oversee the portions of patient test results considered clinically relevant, which are delivered using an electronic health record system. Sperber et al. (2017) also explained that portions of patient test results not considered clinically relevant are not stored in the electronic health record system but may later be moved into the electronic health record system if the emerging literature suggests clinical relevance. Similarly, Danahey et al.

(2017) described an account in which a university affiliated healthcare delivery organization only delivers portions of patient test results using clinical decision support that a group of people deem clinically relevant. According to Danahey et al. (2017), portions of test results not considered clinically relevant are stored in a non-production information technology environment for later consideration based on emerging literature. Because the field of precision medicine is emerging, healthcare delivery organizations deliver information for precision medicine using information technology resources in specialized ways.

The emerging literature regarding information delivery in healthcare delivery organizations for precision medicine regularly contains descriptions of the differences between passive and active forms of clinical decision support. According to Hicks et al. (2019), passive forms of clinical decision support remain in the background waiting for an end user to make a selection. In contrast to passive forms, Manzi et al. (2017) explained that active forms of clinical decision support tend to be interruptive and automatic. Delivering information to aid a healthcare worker in making a medication prescribing decision using clinical decision support provides a case that is useful to illustrate both the passive and active forms of clinical decision support. In a study of how clinical decision support impacts medication prescribing behaviors for precision medicine, O'Donnell et al. (2017) described an example of the passive form of clinical decision support in which a healthcare worker must deliberately access information used to aid in making a medication prescribing decision through a standalone web portal requiring a separate login. In contrast, Hicks et al. (2019) provided an example of an active form of clinical decision support in which a message pops up in an electronic health record system that interrupts the workflow of a healthcare worker to aid in making medication prescribing decisions. The differences between passive and active forms of clinical decision support are regularly described in reports regarding information delivery in healthcare delivery organizations for precision medicine.

As well as using different forms of clinical decision support, healthcare delivery organizations use clinical decision support alerts in different ways to deliver information for precision medicine. According to Sperber et al. (2017), there is a lack of standard methods for healthcare delivery organizations to create clinical decision support alerts for the delivery of precision medicine information. Similarly, Herr et al. (2019) discussed that the use of clinical decision support alerts to deliver information for precision medicine is not standard and can be affected by the expertise of information specialists, the functionality of electronic health record systems, and funding. Herr et al. (2019) also explained that healthcare delivery organizations vary the timing and use of dynamic versus static text in clinical decision support alerts for precision medicine. Shifting to specific cases, Manzi et al. (2017) described an account in which a children's hospital adapted clinical decision support alerts that were provided by another healthcare delivery organization that has a different clinical setting. According to Manzi et al. (2017), the children's hospital uses the alerts at varied times in the provision of precision medicine services to deliver information for preventive purposes. In another case, Hicks, Stowe, et al. (2016) explained that a multistate health system uses custom alerts to deliver information for precision medicine including guidance for patient testing, recommendations for prescribing medications, and links to supplemental information. Similarly, according to Sperber et al. (2017), a healthcare delivery organization uses alerts to deliver precision medicine information including patient test results, test result significance, suggested actions, and links to supplemental information. Healthcare delivery organizations use clinical decision support alerts in assorted ways to deliver information for precision medicine.

Besides using clinical decision support alerts, healthcare delivery organizations regularly use online sites to deliver information for precision medicine. According to Rasmussen et al. (2016), several healthcare delivery organizations deliver genomic information for precision medicine using online sites. Similarly, Luzum et al. (2017) explained that several healthcare delivery organizations use online sites to deliver an assortment of materials for precision medicine including videos, presentations, publications, continuing education, information about genomic services, supplemental information for clinical decision support, and newsletters summarizing journal articles relevant to healthcare workers. Interestingly, in a discussion of controlling the delivery of information for precision medicine, Rasmussen et al. (2016) made a distinction between local and remote hosting by explaining that healthcare delivery organizations deliver information that is under control of the healthcare delivery organization and also deliver information that is under the control of another organization. Healthcare delivery organizations regularly deliver information for precision medicine using online sites.

In addition to using online sites, healthcare delivery organizations develop custom software applications to deliver information for precision medicine. For instance, according to Aronson et al. (2016), an academic medical center developed a custom software application to deliver patient test results to healthcare workers for precision medicine. Similarly, Danahey et al. (2017) explained that a university affiliated healthcare delivery organization coordinated physical, human, and organizational forms of information technology resources to develop and monitor a custom software application used to deliver information indicating if medications could have undesirable affects based on inherited genomes. As is evident by the cases discussed, information delivery for precision medicine in healthcare delivery organizations can involve the development of custom software applications using multiple forms of information technology resources.

Healthcare delivery organizations not only use human and organizational forms of information technology resources in software development activities, but also in information delivery oversight activities for precision medicine. For instance, Manzi et al. (2017) provided an account in which a pediatric teaching hospital uses information specialists to serve on a pharmacogenomics committee to direct the delivery of information for precision medicine. Similarly, in the supplemental material of an article on developing clinical pharmacogenomics, Hicks, Stowe, et al. (2016) explained that a large health system uses a committee to review the language to be delivered in clinical decision support alerts for precision medicine. Information specialists and committees represent human and organizational forms of information technology resources that healthcare delivery organizations use in information delivery oversight activities for precision medicine.

As well as oversight activities, healthcare delivery organizations use information technology resources in maintenance activities for information delivery due to the emerging state of precision medicine. For instance, according to Danahey et al. (2017), the delivery of clinical decision support information in a university affiliated healthcare delivery organization involves the use of an automated query mechanism to identify new literature sources that may lead to altering the delivery of information for precision medicine. As another example, Caraballo, Bielinski, et al. (2017) provided a case in which clinical decision support within an electronic health record system is used to deliver pharmacogenomic information for precision medicine. Caraballo, Bielinski, et al. (2017) explained that a multistate healthcare delivery organization experiences noteworthy maintenance issues for clinical decision support due to changes in published guidelines. According to Caraballo, Bielinski, et al. (2017), clinically relevant genomic discoveries, dynamic genomic interpretations, and changes in nomenclature are factors to consider regarding maintenance of information delivery. Given that the field of precision medicine is emerging, healthcare delivery organizations use information technology resources for the maintenance of information delivery.

In sum, there is an assortment of relevant aspects to consider regarding information technology resources used in healthcare delivery organizations to deliver information for precision medicine. Information technology enhances information delivery for precision medicine in healthcare delivery organizations. Healthcare delivery organizations use physical, human, and organizational forms of information technology resources to deliver information for precision medicine. Healthcare delivery organizations use multiple information sources and multiple channels in information delivery practices for precision medicine. Healthcare delivery organizations commonly use online sites, electronic health record systems, and clinical decision support alerts to deliver information for precision medicine. Due to the emerging state of precision medicine, healthcare delivery organizations oftentimes use information technology resources in specialized ways for information delivery. Healthcare delivery organizations develop custom software applications and adapt electronic health record systems to deliver information for precision medicine. Healthcare delivery organizations use an assortment of information technology resources in information delivery oversight and maintenance activities. There are a variety of relevant considerations regarding information technology resources used to deliver information for precision medicine in healthcare delivery organizations.

Big Data Analytics

Healthcare delivery organizations can use big data analytics to address a broad range of issues. According to Kruse et al. (2016), there are several opportunities to apply big data analytics in healthcare delivery such as to improve the quality of patient care, increase operational efficiency, optimize decision making processes, and reduce costs. Similarly, in a discussion of investing in big data analytics by healthcare stakeholder organizations, Bates et al. (2018) explained that big data analytics are broadly applicable to enhancing healthcare delivery using predictive methods to enhance patient care quality, optimize operational processes, and improve resource utilization. Likewise, according to Guha and Kumar (2018), big data analytics can be used to improve the quality of patient care, increase operational efficiency, and lower costs. Additionally, in a systematic review of applications of big data analytics in the context of healthcare management, Kamble et al. (2019) discussed that big data analytics provides insights, enhances decision making, and improves service quality. Kamble et al. (2019) also provided a particular example of how healthcare organizations can use big data analytics in schedule planning. According to Kamble et al. (2019), big data analytics can be used to predict if a patient will attend a future appointment based on past attendance records. Big data analytics can be used to address a variety of issues associated with healthcare delivery organizations.

In addition to the broad applicability in healthcare delivery organizations, big data analytics are widely applicable to precision medicine in healthcare delivery. According to Vegter (2018), big data analytics are inherent in precision medicine. Additionally, Rumsfeld et al. (2016) explained that big data analytics are well suited for the size, complexity, and integration of data used for precision medicine. Furthermore, in a systematic review of applications of big data analytics in healthcare, Mehta and Pandit (2018) discussed that big data analytics are clinically useful for precision medicine. According to Mehta and Pandit (2018), big data analytics can be used to detect disease early, accurately predict the path of disease, and select targeted treatment for precision medicine. Big data analytics can be broadly applied to precision medicine in healthcare delivery organizations.

Given the broad applicability of big data analytics, it is not surprising that healthcare delivery organizations can use big data analytics to generate business value in several ways. In conceptual studies of how healthcare organizations can generate business value using big data analytics, Wang and Hajli (2017) and Wang, Kung, Wang, et al. (2018) concurred that the use of big data analytics in healthcare can lead to benefits that are managerial, organizational, structural, strategic, and operational. Similarly, based on a systematic review, Mehta and Pandit (2018) claimed that big data analytics can provide value in healthcare by generating insights for operational benefit, clinical benefit, and financial benefit. In different systematic review, Mikalef et al. (2018) argued that an organization can generate business value using big data analytics to produce transparency, enable experimentation, segment populations, improve decision making, and innovate new services. Additionally, in a discussion of creating value using big data analytics in healthcare, Lee and Yoon (2017) explained that big data analytics have demonstrated value in clinical decision support and precision medicine. Furthermore, in a systematic review of big data analytics in healthcare to identify types of organizational and social value creation, Galetsi et al. (2019) explained that healthcare organizations can obtain value by using big data analytics to provide personalized service, improve decision making, innovate new services, manage performance, coordinate healthcare information, create efficiency, avoid risks to patient care, customize services for population segments, achieve cost effectiveness, and protect privacy. Healthcare delivery organizations can create business value in several ways using big data analytics.

In regard to furthering the discussion of using big data analytics to create business value, the creation of business value with big data analytics is affected by a mix of organizational, human, and physical forms of information technology resources. In a case-based study of big data analytics and benefits for healthcare organizations, Wang, Kung and Byrd (2018) argued that a blend of process, people, and information technology provides the foundation to produce business value from information technology. Additionally, in a study using Delphi and interview methods to examine management challenges in generating business value from big data analytics, Vidgen et al. (2017) suggested that a blend of organization, process, people, and technology affects the creation of business value. A mix of different forms of information technology resources affects the use of big data analytics to generate business value.

As well as affecting the creation of business value, a mix of organizational, human, and physical forms of information technology resources can be used by organizations to improve business performance with big data analytics. In a study including survey and case study methods to investigate big data analytics resource configurations that can generate business value, Mikalef et al. (2019) explained that big data analytics can lead to high business performance based on a coalescence of organization, process, people, technology, context, and data. In addition, Akter et al. (2016) provided a study incorporating theoretical assumptions from sociomaterialism and a resource-based view of the firm, which is the conceptual framework used in this study. According to Akter et al. (2016), organizational performance has a statistically significant positive relationship with a mixture of big data analytics management, big data analytics talent, and big data analytics technology. Likewise, in a study using survey methods to test a big data analytics model, Wamba et al. (2017) argued that organizational performance has a statistically significant positive relationship with a blend of big data analytics management, big data analytics personnel, and big data analytics infrastructure. Furthermore, in a study that included creating and using a survey instrument for the assessment of big data analytics, Gupta and George (2016) explained that a combination of organizational, human, and physical resources has a statistically significant positive relationship with two different organizational performance measures. Organizations can use big data analytics to increase business performance with a blend of physical, human, and organizational forms of information technology resources.

To further the discussion of combining resources, a big data analytics capability is a special type of resource that organizations can build by combining organizational, human, and physical forms of information technology resources. According to Akter et al. (2016), a big data analytics capability is built by integrating organizational, human, and physical components. Similarly, Wamba et al. (2017) discussed that management, personnel, and infrastructure components are combined to form a big data analytics capability. Furthermore, Gupta and George (2016) argued that a combination of various resources including a data-driven culture, managerial skills, investments, and technology allow a company to create a big data analytics capability. As suggested in the literature, organizations can create a big data analytics capability using a blend of organizational, human, and physical forms of information technology resources.

A big data analytics capability includes organizational forms of resources in main roles. According to Mikalef et al. (2018), the main intangible resources that permit a company to develop a big data analytics capability are governance and data-driven culture. Similarly, Gupta and George (2016) explained that the intangible resources of data-driven culture and intensity of organizational learning are statistically significant in building a big data analytics capability. Additionally, Akter et al. (2016) and Wamba et al. (2017) concurred that statistically significant management elements of a big data analytics capability include investment, planning, control, and coordination. Organizational forms of resources have key roles in a big data analytics capability.

Besides organizational forms of resources, human forms of resources have significant roles in a big data analytics capability. According to Gupta and George (2016), the human resources of managerial skills and technical skills are statistically significant in building a big data analytics capability. Additionally, Akter et al. (2016) and Wamba et al. (2017) concurred that statistically significant personnel elements of a big data analytics capability include business knowledge, relational knowledge, technical knowledge, and technology management knowledge. Similarly, Mikalef et al. (2018) explained that the main knowledge resources that permit an organization to develop a big data analytics capability are business knowledge, relational knowledge, technical knowledge, and business analytics knowledge. Human forms of resources have main roles in a big data analytics capability.

Like human and organizational forms of resources, physical forms of resources have key roles in a big data analytics capability. According to Mikalef et al. (2018), the main tangible resources needed to develop a big data analytics capability include data, software, information systems, and infrastructure. Similarly, Gupta and George (2016) explained that statistically significant tangible resources in building a big data analytics capability include data, technology, and basic resources such as time and investment. Physical forms of resources have significant roles in a big data analytics capability.

In sum, a discussion of the literature about big data analytics provides several relevant points to consider regarding this study. Healthcare delivery organizations can broadly apply big data analytics for a range of issues including the provision of precision medicine services. Healthcare delivery organizations can use big data analytics to generate business value in several ways. The creation of business value with big data analytics is affected by a mix of organizational, human, and physical forms of information technology resources. A blend of different forms of information technology resources can be used to improve business performance with big data analytics. Organizations can build a special type of resource known as a big data analytics capability by combining organizational, human, and physical forms of information technology resources. There are several relevant considerations on the topic of big data analytics regarding this study.

Genomic Testing

Genomic testing is widely applicable to precision medicine in healthcare delivery organizations. According to Ronquillo et al. (2017), thousands of genomic tests for precision medicine exist and have several purposes. Similarly, Khoury (2017) explained that genomic tests for precision medicine are broadly available for disease prevention, diagnosis, and treatment. Examples of genomic testing applications for precision medicine include the prevention, diagnosis, and treatment of cancer and cardiovascular disease (Krasi et al., 2019; Warner, Jain, et al., 2016), which are among the leading causes of death globally (Cao et al., 2017). Additionally, reports indicate that healthcare workers regularly use genomic test information in patient care decisions for precision medicine (Dressler et al., 2018; Nadauld et al., 2018). Healthcare delivery organizations can broadly apply genomic testing for precision medicine.

To further the discussion of genomic testing, reports of genomic testing regularly include similar process steps. For instance, Aronson et al. (2016) discussed that the genomic testing process at an academic medical center includes ordering a test, performing the technical laboratory procedures, interpreting the technical results, and delivering the results to healthcare workers. Similarly, Warner, Jain, et al. (2016) explained that the process of genomic testing involves ordering a test, generating technical lab results, interpreting technical lab results, and delivering results to healthcare workers. Similar process steps for genomic testing are regularly discussed in reports.

Along with information about process, reports contain information regarding information technology resources used in genomic testing. Reports of genomic testing provide useful information about physical, human, and organizational forms of information technology resources used for precision medicine. The following discussion is based on information technology implementations for precision medicine in healthcare delivery organizations.

Genomic testing process includes genomic test ordering procedures in which healthcare delivery organizations use information technology resources for precision medicine. For instance, according to Luzum et al. (2017), multiple healthcare systems use electronic health record systems to order pharmacogenetic tests for precision medicine.

Similarly, in the context of oncology, Levit et al. (2019) explained that healthcare delivery organizations use electronic health record systems and clinical pathway systems to order genomics tests for precision medicine. In a tutorial based on the experience of two healthcare delivery organizations, Arwood et al. (2016) discussed that clinical decision support can facilitate the ordering of genomic tests for precision medicine. According to Arwood et al. (2016), clinical decision support can provide important information to healthcare workers in the genomic test ordering process. In keeping with the conceptual framework, electronic health record systems, clinical pathway systems, and clinical decision support are examples of physical information technology resources. Procedures to order genomic tests for precision medicine in healthcare delivery organizations incorporate information technology resources.

As well as using information technology resources in procedures to order genomic tests, healthcare delivery organizations use customized information technology resources in genomic test laboratory procedures for precision medicine. For instance, according to Manzi et al. (2017), a pediatric teaching hospital developed a customized web-based software application to automatically translate raw genomic test output data into a standard nomenclature. The ability to fulfill a need by creating and implementing custom software is an example of an organizational capability, which is a type of organizational information technology resource. In another case, Aronson et al. (2016) explained that an academic medical center's genetic testing laboratory uses multiple customized information technology components. According to Aronson et al. (2016), the customized information technology components include an enterprise gateway infrastructure system that can accommodate custom built laboratory information management systems, a specialized system to support the use of synthetic nucleotides, and a bioinformatic data pipeline to process raw genomic test output data. Genomic test laboratory procedures for precision medicine in healthcare delivery organizations include the use of customized information technology resources.

Healthcare delivery organizations not only use customized information technology resources in genomic test laboratory procedures, but also incorporate specialized information technology resources in procedures to interpret technical genomic test results for precision medicine. For instance, in a discussion of genomic testing practice models for precision medicine, Walko et al. (2016) explained that a clinical cancer center developed a database with the assistance of a bioinformatics team to bring together information from a variety of internal and external sources specifically relevant to interpreting genomic test laboratory results for precision medicine. Walko et al. (2016) also discussed that bioinformatics specialists serve on a committee responsible for interpreting technical genomic test results for precision medicine. The use of bioinformatics specialists provides an example of human information technology resources. In a different case, Aronson et al. (2016) provided an account in which an academic medical center performs tasks associated with the interpretation of technical genomic test results using multiple special purpose information technology components. According to Aronson et al. (2016), the special purpose information technology components include a genomic knowledge base, a case repository, a spreadsheet template which organizes relevant information, and customizable report templates. As another example, Manzi et al. (2017) explained that a pediatric teaching hospital uses a specially designed software platform and carefully developed report templates containing dynamic variables in procedures to interpret technical genomic test results for precision medicine. Procedures to interpret technical genomic test results for precision medicine in healthcare delivery organizations include the use of specialized information technology resources.

Besides using specialized information technology resources in procedures to interpret technical genomic test results, healthcare delivery organizations incorporate assorted information technology resources in procedures to deliver genomic test results for precision medicine. For instance, in the context of pharmacogenomics, Caraballo, Hodge, et al. (2017) explained that an academic medical center uses translation tables in an electronic health record system to deliver standardized genomic test results that can appear in modules as clinical problems, allergies, pop-up alerts, and inbox messages. Caraballo, Hodge, et al. (2017) also explained that the academic medical center coordinated among multiple laboratories to use standard definitions for the delivery of genomic test results. In another case, Rosenman et al. (2017) provided an account in which the main campus of a healthcare delivery organization delivers genomic test results for precision medicine using email, fax, and an electronic health record system. Rosenman et al. (2017) also explained that the test results can appear in modules of the electronic health record system as full text reports, pop-up alerts, and clinical problems. In a different account, according to Hicks, Stowe, et al. (2016), a multistate healthcare delivery organization uses an electronic health record system to deliver genomic test results in the form of lab results, pop-up alerts, and medication ordering considerations.

Procedures to deliver genomic test results for precision medicine in healthcare delivery organizations include the use of assorted information technology resources.

The use of information technology resources for precision medicine in healthcare delivery organizations can be affected by the type of genomic test results. According to Fujii et al. (2018), test results regarding the somatic genome can lose their relevance. For instance, the TP53 and PIK3CA genes provide an example in which testing for somatic genomic variation may need to be repeated when treating metastatic breast cancer because the genes can mutate (Fujii et al., 2018). Whereas, according to Keeling et al. (2019), test results regarding the inherited genome can be relevant throughout a person's lifetime for precision medicine. According to Hicks, Dunnenberger, et al. (2016), due to the potential lifetime usefulness of test results regarding the inherited genome the test results should be displayed independent of time. Additionally, Hinderer et al. (2017) and Arwood et al. (2016) agreed that special consideration should be given to the storage of genomic test results that have lifetime relevancy for patients. Furthermore, Caudle et al. (2018) provided the view that genomic test results that are relevant over a person's life should be stored with standardized nomenclature to enable transfer to different electronic health record systems. The type of genomic test results can affect the use of information technology resources for precision medicine in healthcare delivery organizations.

In sum, a discussion of genomic testing provides several relevant points to consider regarding this study. Genomic testing is widely applicable to precision medicine in healthcare delivery organizations. Genomic testing processes commonly include test ordering procedures, laboratory test procedures, technical test result interpretation procedures, and test result delivery procedures. Healthcare delivery organizations use physical, human, and organizational forms of information technology resources in genomic testing for precision medicine. Healthcare delivery organizations use customized, specialized, and assorted information technology resources in genomic testing procedures. The type of genomic test results can affect the use of information technology resources for precision medicine in healthcare delivery organizations. There are several relevant considerations on the topic of genomic testing regarding this study.

Summary and Conclusions

As part of performing the literature review, I identified multiple frequently occurring views that represent what is known regarding topics associated with this study. The first view is that the field of precision medicine is emerging. Second, data analytics is a vital component of precision medicine. Third, healthcare delivery organizations are in early stages of applying precision medicine. Fourth, healthcare delivery organizations use information technology to facilitate precision medicine. Fifth, healthcare delivery organizations use specialized and customized information technology resources for precision medicine. Sixth, healthcare delivery organizations use an assortment of physical, human, and organizational forms of information technology resources for precision medicine.

In addition to identifying themes in the literature I have found a lack of literature about how researchers view certain qualities of information technology resources for precision medicine in healthcare delivery organizations. I conducted this study in part because the literature does not contain a consensus of information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. A detailed discussion of the research methods for this study is included in Chapter 3.

Chapter 3: Research Method

The purpose of this classical Delphi study was to determine how a panel of precision medicine information technology experts view information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. A discussion of the research method, design, and procedures is included in Chapter 3. I provide a rationale for selecting a qualitative method and a Delphi design. The role of the researcher section includes a discussion of my participation in this study. In addition, I explain the participant selection logic and the sampling strategy. The instrumentation section contains a discussion about the questionnaire for each round. I also discuss procedures for recruitment, participation, and data collection. I include information about how I analyzed data in connection with the research questions. Furthermore, I discuss issues of trustworthiness in terms of credibility, transferability, dependability, and confirmability. I also describe procedures concerning ethical issues. The chapter concludes with a summary of the important points.

Research Design and Rationale

Overarching research question: How does a panel of precision medicine information technology experts view information technology resource importance and feasibility for precision medicine in healthcare delivery organizations?

Subquestion 1: How does a panel of precision medicine information technology experts view information technology resource importance for precision medicine in healthcare delivery organizations?

Subquestion 2: How does a panel of precision medicine information technology experts view information technology resource feasibility for precision medicine in healthcare delivery organizations?

As the research questions indicate, the main concept that I investigated in this study is centered around information technology resources for precision medicine in healthcare delivery organizations. There is a gap in knowledge regarding information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. There are several unknowns regarding the future use of information technology resources for precision medicine in healthcare delivery organizations, and reporting consensus information from a Delphi study may aid people in making information technology resource decisions.

I selected the qualitative research method for this study based on its being well suited to address the research questions. According to Williams (2007), a researcher selects the research method according to the type of data most appropriate for responding to the research questions. Williams (2007) also mentioned that researchers can use a qualitative method to understand details in situations that are complex. Similarly, Ravitch and Carl (2016) explained that qualitative research is descriptive and fitting when pursuing complexity. Additionally, Woods et al. (2016) discussed that qualitative research combines knowledge and understanding to make judgements regarding the circumstances. Addressing the research questions involved gathering assessment information from knowledgeable people regarding a complex topic, which made a qualitative method suitable for this study.

When considering the literature, a Delphi design was appropriate for this study given that addressing the research questions involved assessing importance and feasibility information for a complex topic that is evolving and has many unknowns. According to Rikkonen and Tapio (2009), a Delphi design is appropriate for topics in which changes in trends are probable. Additionally, Delbecq et al. (1975) and Linstone and Turoff (2002) concurred that a Delphi design is fitting when there is incomplete information regarding a situation. Furthermore, Linstone and Turoff (2002) offered the view that a Delphi design allows a group of people to jointly address a complex problem and is useful to assess importance and feasibility of options. Linstone and Turoff (2002) also explained that the need for a Delphi design can result from certain characteristics, including when exact analytics are not suitable for working on a problem or when the participants needed to examine a complex problem have not had prior communication. In addition, Delbecq et al. (1975) discussed that a Delphi design can be useful for planning activities regarding information technology. A Delphi design was well suited for this study in that addressing the research questions involved assessing importance and feasibility information for a complex topic that is evolving and has many unknowns.

I did not select a variety of research traditions because they were less suitable to address the research questions when compared to a qualitative Delphi design. For instance, according to Yilmaz (2013), a quantitative method is appropriate to measure relationships between variables using preconstructed instruments into which participant perspectives are expected to fit. Additionally, Yilmaz (2013) discussed that a quantitative method is not fitting to capture the thoughts of participants in their own words.

Furthermore, McCusker and Gunaydin (2015) explained that a quantitative method is susceptible to excluding contextual detail. Additional examples of research traditions that I did not select for this study include grounded theory, phenomenology, and ethnography. According to Hays and Wood (2011), grounded theory is suitable when the goal is to develop theory, phenomenology is fitting when the purpose is to describe the lived experiences of participants, and ethnography is typically used when the goal is to identify social patterns and norms. Another example of a research tradition that I did not select is a mixed methods design. Leech and Onwuegbuzie (2009) provided the view that a mixed methods design is mostly used for research questions that cannot be answered using a single research tradition. I reviewed several research traditions that were less fitting to address the research questions when compared to a qualitative Delphi design.

Role of the Researcher

Using the literature in support of conducting an ethically sound study by incorporating procedures to minimize potential researcher bias was part of my role as a researcher using a Delphi design. According to Avella (2016), in an effort to lessen potential researcher bias, Delphi participant selection procedures should exclude individuals with any type of personal or professional relationship with the researcher. Additionally, Jenkins and Smith (1994) discussed that Delphi investigators can reduce the potential for researcher bias by making an effort to preserve the wording of participants found in collected text data. Furthermore, Kim and Yeo (2018) provided the view that potential researcher bias can be reduced when using a Delphi method by specifying procedures to assess if consensus has been reached among the participants. To minimize potential researcher bias, I incorporated the advice discussed into procedures associated with participant selection and data analysis.

As a researcher using a Delphi design, my role included being an impartial observer that interacted with participants. According to Avella (2016), a researcher using a Delphi design should focus on recording and coordinating in an impartial manner rather than contributing information. Additionally, Hirschhorn (2019) explained that the Delphi process is directed by a coordinator that interacts with participants by distributing questionnaires and results. Similarly, Raveenthiran and Sarin (2015) discussed that the Delphi method involves a panel director facilitating responses from participants by disseminating questionnaires, collecting responses, analyzing responses, and distributing results. My role as a researcher using a Delphi design involved being an objective observer that interacted with participants.

Methodology

Participant Selection Logic

The selection of participants is an important topic in a qualitative Delphi research study. According to O'Reilly and Parker (2013), creating a saturated sample in qualitative research involves selecting participants to create a collection of perspectives adequate to provide the depth and breadth of data needed to address the research questions. Additionally, Paré et al. (2013) explained that the selection of participants is critical for a Delphi study, which is dependent on the knowledge of the panel members. Furthermore, Goodman (1987) provided the view that if Delphi participants are knowledgeable about the subject under investigation, then the study data are expected to be sound. In sum, conducting a sound qualitative Delphi research study depends on selecting knowledgeable participants.

Sampling for this study incorporated the Delphi research practice of using nonprobability purposive sampling supplemented with snowball sampling to identify participants. According to Hasson et al. (2000), nonprobability purposive sampling is often used by Delphi researchers to select experts for the purpose of applying knowledge to a specific problem. Additionally, Skulmoski et al. (2007) explained that purposive sampling can be supplemented with snowball sampling to identify additional participants for Delphi studies. Furthermore, Habibi et al. (2014) discussed that nonprobability snowball sampling is suitable when it may be difficult to locate potential participants. I used nonprobability purposive and snowball sampling in this study.

I applied purposive and snowball sampling techniques in this study using multiple participant selection criteria, which were mainly based on the literature. Delbecq et al. (1975) explained that it is important for Delphi participants to have knowledge to contribute and good writing ability. Similarly, according to Avella (2016), potential Delphi participants should have expertise and the ability to write fluently. Likewise, Skulmoski et al. (2007) discussed that Delphi participants are required to be knowledgeable regarding the topic and able to communicate effectively. Additionally, according to Avella (2016), Delphi researchers can avoid potential bias using the relationship status between a potential participant and the researcher as a participant selection criterion. Grisham (2009), de Manincor et al. (2015), and Skinner et al. (2016) concurred that a minimum number of years of applicable professional experience can be used when selecting participants in a Delphi study. In this study, I included participants from the population of individuals that met the participant selection criteria, which were that an individual: (a) could describe cases illustrating good versus poor decisions regarding information technology resources for precision medicine in healthcare delivery organizations, (b) had a minimum of 3 years of professional experience dealing with information technology for precision medicine in healthcare delivery, (c) could write fluently in English, (d) did not have a personal or professional relationship with me, and (e) was at least 18 years old. Applying the participant selection criteria produced a homogenous sample in that participants had specialty knowledge within a given domain.

I sought a Delphi panel of at least 25 participants for this study. According to Delbecq et al. (1975), sample sizes for Delphi studies vary and 10 – 15 participants may be sufficient when the group is homogenous. Similarly, according to Hong et al. (2019), sample sizes vary, and a sufficient homogenous Delphi sample is usually small, such as 10 – 15 participants. Furthermore, Donohoe and Needham (2009) explained that participant attrition is a reality in Delphi studies and attrition rates of 50% have been reported. Likewise, Briedenhann and Butts (2006) discussed that a Delphi sample size should allow for attrition and cited an attrition rate of 48%. In sum, the desired sample size for this study was at least 25 to guard against attrition.

Forming an adequate sample entailed following recruitment procedures. I used a study invitation email to contact potential participants directly (see Appendix A). In addition to describing the study, the message in the invitation included the opportunity to suggest other individuals that might be interested in participating. Okoli and Pawlowski

(2004) and Rowe and Wright (2011) agreed that recruiting for a Delphi study can include snowball sampling. In the invitation, I also included a sentence explaining that a monetary gift of up to 30 U.S. dollars would be provided. I performed targeted recruiting using email addresses of authors that have written articles related to the research questions. Briedenhann and Butts (2006) and Donohoe and Needham (2009) agreed that potential participants for a Delphi can be identified using the literature. According to Rowe and Wright (2011) and Okoli and Pawlowski (2004), the literature is a useful source of information when forming a sample in a Delphi study. The literature contains an assortment of authors that may have knowledge regarding the research questions. In addition, I performed targeted searches on the internet to identify individuals believed to possess knowledge related to the research questions. According to Goluchowicz and Blind (2011), targeted internet searches can be used to identify panelists in a Delphi study. Using an approach similar to Lin and Song (2015), I attempted to recruit people having different work settings including academia and industry. I sent targeted study invitations individually. I stopped sending invitations after an adequate sample was formed. Given that the recruiting effort targeted people believed to have knowledge related to the research questions, I asked volunteers that provided consent to complete the eligibility questionnaire. I used responses to the eligibility questionnaire to determine if volunteers met the participant selection criteria. For reference, Appendix B contains screenshots of the eligibility questionnaire. Recruitment procedures provided a means to form a sample.

Instrumentation

Three questionnaires, one for each round, provided the data collection instrumentation in accordance with the Delphi research tradition. Hsu and Sandford (2007), Linstone and Turoff (2002), and Delbecq et al. (1975) agreed that a Delphi study is conducted using a sequence of meticulously designed questionnaires to collect data in which the responses collected from a questionnaire are used as input for the next questionnaire. Delbecq et al. (1975) also explained that data collection stops once a consensus is formed among the participants. Hasson et al. (2000) discussed that determining the number of rounds is crucial given that too few can result in nonmeaningful results and too many can cause participant fatigue. Powell (2003), Hsu and Sandford (2007), and Custer et al. (1999) concurred that typically three rounds are sufficient to reach consensus in a Delphi study. The instrumentation for data collection consisted of three questionnaires, one for each round.

The Round 1 questionnaire contained open-ended questions (see Appendix C). Hsu and Sandford (2007), Delbecq et al. (1975), and Powell (2003) agreed that typically the Round 1 questionnaire contains open-ended questions that provide the basis for data collection in that the collected responses will be incorporated into questionnaires that follow. Powell (2003) also explained that open-ended questions prompt participants to consider a topic broadly and allow for elaboration. According to Kalaian and Kasim (2012), open-ended questions in the first round should be focused on the issue being investigated. I used literature sources as the basis to determine the content of the Round 1 questionnaire. After reviewing the literature, I constructed the Round 1 questionnaire using open-ended questions that were focused on addressing the research questions.

I structured the Round 2 questionnaire so that participants could rate the importance and feasibility of information technology resources identified in Round 1 as well as optionally provide additional information technology resources (see Appendix D). Powell (2003), Hsu and Sandford (2007), and Kalaian and Kasim (2012) concurred that the Round 2 questionnaire commonly involves rating concepts derived from Round 1. Kalaian and Kasim (2012) also explained that the Round 2 questionnaire often contains structured closed-ended questions using a Likert-type scale. Sun et al. (2019), Linstone and Turoff (2002), and Klenk and Hickey (2011) agreed that ordinal 5-point Likert-type scales can be used to rate importance and feasibility in a Delphi study. I adopted the scales for importance and feasibility from Gordijn et al. (2016) and Linstone and Turoff (2002), respectively. Leyenaar et al. (2018), Custer et al. (1999), and Ludwig (1997) concurred that a Delphi questionnaire structured to rate concepts can include a place for participants to optionally suggest additional concepts. Considering that I could not determine the content of the Round 2 questionnaire prior to conducting Round 1, it is worth noting that the dependence of the Round 2 questionnaire content on the results of Round 1 provides support for the validity of the content. The procedure to convert Round 1 responses to rating questions for the Round 2 questionnaire entailed analyzing the responses using thematic analysis to condense the data. Condensing the data included removing redundant information technology resources. I added the resulting set of unique information technology resources to the Round 2 questionnaire in the form of importance and feasibility rating questions. In sum, the structure of the Round 2 questionnaire allowed participants to optionally provide additional information technology resources as well as rate the importance and feasibility of information technology resources derived from Round 1 using ordinal 5-point Likert-type scales.

The structure of the Round 3 questionnaire allowed participants to rerate the importance and feasibility of information technology resources from Round 2 that did not have consensus of importance, feasibility, or both as well as rate the importance and feasibility of additional information technology resources collected in Round 2 (see Appendix E). Leyenaar et al. (2018), Ward et al. (2014), and Wester and Borders (2014) agreed that the Round 3 questionnaire can be structured to rerate concepts from Round 2 that do not have consensus. Similar to the procedure used to convert Round 1 responses to rating questions for the Round 2 questionnaire, the procedure to assess additional information technology resources collected in Round 2 entailed performing thematic analysis which included remove redundancies. New information technology resources that were identified in Round 2 were added to the Round 3 questionnaire in the form of importance and feasibility rating questions. The procedure to determine the rated information technology resources from Round 2 that were to be included in the Round 3 questionnaire to be rerated entailed assessing if there was consensus of importance and feasibility. I discuss the procedure that I used to decide if there was consensus in the data analysis plan section below. When an information technology resource that was rated in Round 2 did not have consensus of importance, feasibility, or both, the information technology resource was added to the Round 3 questionnaire in the form of importance and feasibility rating questions. I structured the Round 3 questionnaire to allow participants to rerate the importance and feasibility of information technology resources from Round 2 that did not have consensus of importance, feasibility, or both as well as rate the importance and feasibility of additional information technology resources that were identified in Round 2.

Pilot and field tests of questionnaires are not typical in Delphi studies and were not part of this study. According to Avella (2016), pilot studies and field tests are not commonly used in Delphi studies. Additionally, Keeney et al. (2001) discussed that only a few Delphi researchers conduct pilot tests. Furthermore, in a review of Delphi studies about information systems, Paré et al. (2013) reported that less than one fifth of the studies included instrument pretesting. Similarly, Clibbens et al. (2012) performed a review of Delphi studies regarding healthcare of which less than one fourth included a pilot study. Because pilot and field tests of questionnaires are not typical in Delphi studies, I did not include the tests in this study.

Procedures for Recruitment, Participation, and Data Collection

As previously discussed, I performed targeted recruiting using email. I used the literature and the internet to identify people believed to have knowledge related to the research questions. In the invitation emails, I asked potential participants to email me if they had an interest in participating. I emailed a consent form which included details about the study to people that expressed an interest. The consent form explained that the amount of the monetary gift was dependent on the level of participation. Completing each of the Round 1, 2, and 3 questionnaires increased the amount of the gift 10 U.S. dollars for a possible total of $30. I asked individuals that wished to volunteer to provide consent via email. I requested volunteers that provided consent to complete the eligibility questionnaire. I provided access to the eligibility questionnaire using a Survey Monkey website link. Clyne et al. (2012), Eleftheriadou et al. (2015), and Garofalo and Aggarwal (2018) concurred that Survey Monkey can be used to administer questionnaires in a Delphi study. I assessed responses to the eligibility questionnaire to determine if volunteers met all the participant selection criteria. I sent an email to volunteers that did not meet the participant selection criteria thanking them for volunteering and informing them that they were not selected to participate in the study. I invited all respondents to the eligibility questionnaire deemed eligible, according to the participant selection criteria, to complete the Round 1 questionnaire. People that did not complete the Round 1 questionnaire in the allotted 2 week timeframe were excluded from future requests to participate. Individuals that completed the Round 1 questionnaire made up the study sample. I stopped recruiting after an adequate sample was formed.

Data collection entailed three rounds of questionnaires. The questionnaire for each round should have taken approximately 15 minutes to complete. Okoli and Pawlowski (2004), Soobiah et al. (2019), and Wilkes et al. (2016) concurred that 15 minutes to complete a questionnaire in a Delphi study is suitable. I scheduled 2 weeks for each of the Round 1, 2, and 3 questionnaires to collect responses. Strear et al. (2018), Toronto (2017), and Delbecq et al. (1975) agreed that a 2 week timeframe for participants to complete a questionnaire is appropriate in a Delphi study. I used Survey Monkey website links to provide participants access to the questionnaire for each round. In an attempt to enhance questionnaire response rates, reminder emails were sent to nonresponding participants on day 7 and day 11 in each 2 week questionnaire timeframe. Hasson et al. (2000) and Jenkins and Smith (1994) agreed that sending reminders is a Delphi study technique used to improve response rates.

Part of the Delphi process is to provide participants controlled feedback between the Round 1, 2, and 3 questionnaires. Hsu and Sandford (2007) and Meijering and Tobi (2016) concurred that controlled feedback in a Delphi study consists of a summary of results from the previous questionnaire. I provided controlled feedback to participants in the form of summarized results. I emailed the Round 1 results to participants as an attachment before distributing the website link for the Round 2 questionnaire. Similarly, I emailed the Round 2 results to participants prior to distributing the website link for the Round 3 questionnaire. I used Survey Monkey to generate the summary figures provided in the Round 2 results.

When planning the overall schedule, I included a 2 week period after each of the Round 1 and 2 questionnaires to allow for data analysis, sending feedback to participants, creating the questionnaire for the next round, and review by Walden University personnel. The use of a 2 week period between rounds is an approach that has been used by other Delphi researchers (Strear et al., 2018). When considering the time between questionnaires, I initially estimated the total data collection period to be 2.5 months. After data collection was complete, I sent a conclusion email containing a summary of the study results to the participants.

Data Analysis Plan

I analyzed text data using thematic analysis. Powell (2003), Brady (2015), and de Loë et al. (2016) concurred that thematic analysis is typically performed in a Delphi study. I exported the text data from the Survey Monkey website into Microsoft Excel for analysis. The use of Excel is common in previous Delphi studies (Briedenhann & Butts, 2006; O'Rourke et al., 2014). During the text data analysis, I made an effort to preserve the wording used by participants as much as possible. Jenkins and Smith (1994) discussed that preserving the words of Delphi participants is a tactic to minimize potential researcher bias. I read the text data multiple times to become familiar with the information technology resources in the data. According to Braun and Clarke (2006), repeated reading of the data is a commonly used technique in the thematic analysis process to immerse yourself in the data. After familiarization with the information technology resources, I assigned at least one categorization code to each information technology resource that I identified. Condensing the coded text data included removing redundant information technology resources. The resulting set of information technology resources is what participants rated in terms of importance and feasibility. I used information technology resource importance and feasibility ratings to address research subquestions 1 and 2. I performed thematic analysis on the text data collected to develop a list of individual information technology resources that could be rated.

I analyzed information technology resource importance and feasibility ratings to assess if there was consensus among the participants. I exported statistical information for importance and feasibility ratings from Survey Monkey into Excel for analysis. Given that importance and feasibility ratings were both derived from ordinal 5-point Likert-type scales, I used similar procedures to determine if there was consensus for each type of rating. Consensus could have occurred at either end of a scale. Survey Monkey provided the percent of responses received for each point on a scale. Using Excel, I summed the percent of responses received for the first and second points of a scale in addition to summing the percent of responses received for the fourth and fifth points of a scale. Fox et al. (2016) and Sheinis and Selk (2018) agreed that summing responses at both ends of a scale is appropriate in a Delphi study. I considered consensus to occur when a summed value totaled at least 75%, which is a threshold commonly used in earlier Delphi studies, according to Diamond et al. (2014). There were three possible results when analyzing ratings data for an information technology resource. Depending on which type of rating, if there was consensus at the beginning of a scale, I considered an information technology resource either not important or not feasible. If there was consensus at the end of a scale, I considered an information technology resource either important or feasible. I considered importance or feasibility of an information technology resource to be undetermined if there was not consensus. I analyzed information technology resource importance and feasibility ratings to address research subquestions 1 and 2.

I analyzed demographic data collected using the eligibility questionnaire using descriptive statistics to characterize the sample. After exporting responses to the eligibility questionnaire from Survey Monkey, I generated statistical information for demographic data using Excel. The use of descriptive statistics protects the identities of participants. The analysis of demographic data that were nominal and ordinal entailed calculating frequency and percent values, similar to how Bobonich and Cooper (2012) and Wiener et al. (2009) did. Like Nakatsu and Iacovou (2009) and Wilson et al. (2003), I calculated the mean value for the years of professional experience. The analysis of the demographic data entailed the use of descriptive statistics to characterize the sample.

Issues of Trustworthiness

Credibility

Credibility, sometimes referred to as internal validity, deals with the truthfulness of the study results (Krefting, 1991; Morse, 2015). The literature contains several techniques to help increase rigor and confidence in study findings. According to Shenton (2004), confidence in the accuracy of qualitative research can be enhanced by adopting research methods used in similar studies, using methods that encourage participants to be frank, welcoming scrutiny of the research project by academic scholars, and reviewing findings of similar studies. In this study, I included each tactic mentioned to improve credibility. The research methods were mainly adopted from previous Delphi studies or had been described by Delphi scholars. I kept participant identity confidential, which encouraged participants to be frank. As part of the dissertation process, multiple Walden University faculty members examined the research project and provided feedback. I reviewed findings of similar studies during the literature review. I believe that the techniques discussed have increased rigor and confidence in the truthfulness of the study results.

Transferability

Transferability, referred to as external validity in quantitative studies, is about the applicability of the study findings in other contexts (Krefting, 1991; Thomas & Magilvy, 2011). Providing thick description of the study context enables readers to assess if the study results are applicable in other contexts (Cope, 2013; Morse, 2015). Shenton (2004) provided guidance on the information that researchers should provide to enable transferability, which includes the number and type of participants, the data collection methods, the number and duration of data collection events, and the duration of the data collection phase. I followed the guidance mentioned to address the trustworthiness criterion of transferability using thick description. I described the study context by providing detailed information regarding the sample and data collection. The information provided may aid readers in assessing if the findings of this study are transferable to other contexts.

Dependability

Dependability, referred to as reliability on occasion, concerns the consistency of the findings if the study were to be repeated (Morse, 2015; Shenton, 2004). The literature contains an assortment of techniques that can be used to help ensure consistency in study results. Krefting (1991) and Thomas and Magilvy (2011) concurred that providing thick description of research methods is an appropriate strategy to help establish dependability. In addition, Krefting (1991) discussed that having methodologists examine the research plan is another way to enhance dependability. Furthermore, Morse (2015) and Thomas and Magilvy (2011) agreed that the use of an audit trail is a suitable tactic to improve dependability. According to Thomas and Magilvy (2011), an audit trail includes a description of the study purpose, a discussion of how the sample was formed, an explanation of data collection methods and time frames, and a discussion of techniques used to enhance credibility of the findings. In accord with the literature references, the techniques I used to enhance dependability included providing thick description of research methods, having methodologists examine the research plan, and using an audit trail as discussed.

Confirmability

Confirmability, sometimes referred to as objectivity, deals with the neutrality of the results in that the findings should be based on the data collected from participants and not affected by researcher bias (Krefting, 1991; Shenton, 2004). Engels and Kennedy (2007) explained that the ability to trace findings back to original sources is a requirement of confirmability. Anney (2014), Bowen (2009), and Tobin and Begley (2004) concurred that an audit trail supports confirmability. In addition, according to Cope (2013), providing participant quotes in connection with resulting themes is a valid way to demonstrate that the results originate from the collected data. In this study, I enhanced confirmability by using an audit trail and by including participant quotes in connection with themes.

Ethical Procedures

The institutional review board at Walden University reviewed this study. Walden University is the only organization involved with this study. I needed approval by the institutional review board prior to conducting this study. The institutional review board approval number is 01-26-21-0646612. I believe the institutional review board has considered several ethical aspects including factors associated with recruitment, informed consent, data collection, and the treatment of data.

As previously discussed, targeted recruitment of study participants involved emailing the study invitation directly to individuals believed to have knowledge related the research questions. In the invitation, I asked potential participants to email me if they had an interest in participating. I emailed a consent form that included details about the study to people that expressed an interest. I asked individuals that wished to provide informed consent to do so via email. I emailed volunteers that provided consent a Survey Monkey website link to access the eligibility questionnaire. Similarly, I emailed website links to participants to provide access to the questionnaire for each round. I believe that communicating with each participant individually using email enhanced the ability to keep participant identities confidential. I kept participant identities confidential including in reports associated with this study.

I downloaded research data from the password protected Survey Monkey website and stored the data on my password protected computer. I deleted data located on the Survey Monkey website after the study ended. I will store the research data for a minimum of 5 years on my personal computer. I may store the study data longer than 5 years for publication purposes. When it comes time to destroy the study data located on my computer, I will delete the files.

Summary

In sum, there were several important considerations regarding the methods used in this study. A qualitative method and a Delphi design were appropriate to address the research questions. I used multiple tactics to minimize potential researcher bias. I gave the creation of a study sample careful consideration. I performed data collection using three questionnaires, one for each round. In addition, I used data analysis results to determine which information technology resources were considered important and feasible. I also used several tactics to enhance the trustworthiness components of credibility, transferability, dependability, and confirmability. Furthermore, I addressed ethical aspects of the study. Having discussed the study methods in Chapter 3, Chapter 4 includes information regarding the study results.

Chapter 4: Results

The purpose of this classical Delphi study was to determine how a panel of precision medicine information technology experts view information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. Determining a consensus of information technology resource importance and feasibility may help address the problem of people having limited information when making resource decisions for precision medicine in healthcare delivery organizations. This Delphi study could provide information that aids people in making sound information technology resource decisions for precision medicine in healthcare delivery organizations. The research questions were as follows.

Overarching research question: How does a panel of precision medicine information technology experts view information technology resource importance and feasibility for precision medicine in healthcare delivery organizations?

Subquestion 1: How does a panel of precision medicine information technology experts view information technology resource importance for precision medicine in healthcare delivery organizations?

Subquestion 2: How does a panel of precision medicine information technology experts view information technology resource feasibility for precision medicine in healthcare delivery organizations?

This chapter includes information regarding the study results. The next section contains a discussion of the research setting, which is followed by a section about demographics of the study sample. I provide details regarding data collection and data analysis. I also discuss evidence of trustworthiness in terms of credibility, transferability, dependability, and confirmability. In addition, I provide the study results. Chapter 4 concludes with a summary of the findings.

Research Setting

I conducted the study remotely using email to communicate with participants. Little information is available about conditions participants were exposed to that may have influenced the participants at the time of the study. One indicator of organizational conditions is primary work setting, which I included as a demographic question. I limited the possible responses to the primary work setting question to academia, industry, and government. I provide the results of the primary work setting question in Table 1. Besides primary work setting, no further information is available about conditions participants were exposed to that may have influenced the participants at the time of the study.

Demographics

Recruitment results are summarized as follows. I distributed an estimated total of 15,000 study invitations via email during the period from 1/26/2021 to 3/30/2021. The exact number is unknown because I received numerous email replies explaining that the study invitation could not be delivered. I sent the consent form via email to 153 people that replied to me after receiving the study invitation. A total of 90 people provided consent. After a person provided consent, I emailed the person a link to the eligibility questionnaire with a note explaining that the link was unique to the person. The note indicated that responses would not be anonymous. Altogether, 79 people completed the eligibility questionnaire. Even though the invitation and consent form clearly provided the eligibility requirements upfront, several people were ineligible based on their responses to the eligibility questionnaire. According to responses to the eligibility questionnaire, 63 people were eligible to participate. I invited all respondents to the eligibility questionnaire deemed eligible, according to the participant selection criteria, to complete the Round 1 questionnaire. The study sample only included people that completed the Round 1 questionnaire. I sent an email to people that did not complete the Round 1 questionnaire explaining that they would not be asked to participate in the study going forward.

In addition to completing the Round 1 questionnaire, every member of the sample met the participant selection criteria based on the responses to the eligibility questionnaire. The participant selection criteria were that an individual: (a) could describe cases illustrating good versus poor decisions regarding information technology resources for precision medicine in healthcare delivery organizations, (b) had a minimum of 3 years of professional experience dealing with information technology for precision medicine in healthcare delivery, (c) could write fluently in English, (d) did not have a personal or professional relationship with me, and (f) was at least 18 years old. The participant selection criteria characterize the sample.

The sample is not only characterized by the participant selection criteria, but also by statistical information. The average number of years of professional experience dealing with information technology for precision medicine in healthcare delivery was 14.6 years for the study sample. As shown in Table 1, a high percentage of participants reported working in an industry setting. Most participants reported having a doctorate degree (see Table 2). Participants primary job function varied (see Table 3). The four participants that selected *other* for the primary job function, provided entries of: (a) doctor, (b) physician informaticist - clinical informatics, (c) founder and chief executive officer for clinical cloud, and (d) independent consultant. As shown in Table 4, the majority of participants resided in the United States.

Table 1

Participants Primary Work Setting

Work setting	Participants	
	n	%
Industry	34	65
Academia	16	31
Government	2	4

Table 2

Participants Highest Degree Earned

Degree	Participants	
	n	%
Doctorate	34	65
Master’s	13	25
Bachelor’s	5	10
Associate’s	0	0
High school	0	0

Table 3

Participants Primary Job Function

Job function	Participants	
	n	% [a]
Executive	19	37
Researcher	12	23
Director	9	17
Professor	4	8
Other	4	8
Manager	3	6
Engineer	1	2
Analyst	0	0

[a] Percent values do not total 100 due to rounding.

Table 4

Country in Which Participants Resided

Country	Participants	
	n	% [a]
United States	38	73
India	3	6
United Kingdom	2	4
Australia	1	2
Brazil	1	2
Canada	1	2
Netherlands	1	2
South Africa	1	2
South Korea	1	2
Spain	1	2
Sweden	1	2
Turkey	1	2

[a] Percent values do not total 100 due to rounding.

Data Collection

Data collection occurred remotely by recording data using Survey Monkey. Participants completed the questionnaire for each round online. I provide data collection timeframes in Table 5. The timeframes for the Round 2 questionnaire and the Round 3 questionnaire correspond to the request for participants to complete each questionnaire within 2 weeks. The timeframe for the Round 1 questionnaire was longer than 2 weeks because I continued to perform recruitment activities concurrently with data collection for Round 1. I distributed the Round 1 questionnaire during the period from 3/25/2021 to

4/5/2021. I provide the number of participants that completed the questionnaire for each round in Table 6.

Table 5

Data Collection Timeframes

Questionnaire	Start date	End date	Days (n)
Round 1 questionnaire	3/25/2021	4/11/2021	18
Round 2 questionnaire	4/16/2021	4/29/2021	14
Round 3 questionnaire	5/8/2021	5/21/2021	14

Table 6

Questionnaire Completion Rates

Questionnaire	Questionnaires distributed	Questionnaires completed	Completion rate
Round 1 questionnaire	63	52	83%
Round 2 questionnaire	52	45	87%
Round 3 questionnaire	52	43	83%

I received a few emails from participants when conducting Round 2 that are noted here. One person suggested that it may be beneficial to allow respondents to enter comments for each item rated on the Round 2 questionnaire. Three other participants suggested that they would prefer to rate a smaller list of items than what resulted from Round 1. In sum, a few participants sent me comments during Round 2.

Data Analysis

The process to perform thematic analysis on the text data collected during Round 1 involved familiarization and coding. After exporting the data from Survey Monkey into Microsoft Excel, I read the responses multiple times to become familiar with the concepts in the data. In a few cases, I used the Google search engine to find background information about concepts that I knew little about. Additionally, I emailed two participants in an attempt to clarify their responses. Once familiar with the concepts in the Round 1 data, I began assigning category codes to the responses. I developed, applied, and modified the codes in an iterative manner during the coding process. The first pass entailed assigning at least one category code to each response. I proceeded by sorting the data using the category codes to group the responses. I reviewed and adjusted the category codes multiple times until the codes were applied consistently. I performed familiarization and coding steps as part of the thematic analysis process.

After coding was complete, I condensed the Round 1 text data into themes. To reduce the potential for researcher bias when forming themes, I made an effort to preserve the wording used by participants as much as possible. When forming themes, I noted and removed redundancies in the data. In cases where multiple responses conveyed basically the same idea, I typically created the theme using the words from a descriptive response. Additionally, I did not create themes for responses that did not appear to address the research questions. For instance, I did not create themes for responses of *x*, *y*, and *same as answer #2*. Tables 7 through 13 provide examples of the thematic analysis in that the tables contain participant responses and category codes for specific themes that resulted during Round 1. I created themes by condensing the text data collected during Round 1.

Table 7

Reponses Used to Create the Theme Named: Advanced Clinical Decision Support Capabilities

Participant number	Response	Category codes
3	Clinical decision support	Decision support
4	Clinical decision support system	Decision support
5	Knowledge based system (clinical decision support system)	Decision support and knowledge
6	Clinical decision support matrix	Decision support
19	Decision support tools for ordering	Decision support and ordering
28	CDST that enables evidence-based guidance on multiple factors	Decision support and evidence based
32	Decision support systems	Decision support
33	Advanced clinical decision support capabilities	Decision support and advanced
36	Robust clinical decision support and just-in-time point of care educational resources to support evidence based best practice	Decision support, robust, point of care, educational, evidence based, and best practice
40	CDS at clinic as well as pharmacy levels	Decision support and pharmacy
45	Decision support systems	Decision support
45	Decision support systems linking data with clinical decision making	Decision support
49	Point of care clinical decision support	Decision support and point of care
51	Clinical decision support	Decision support
52	Clinical decision support built on this data to help guide clinicians with complex decisions	Decision support and complex

Note. CDS is an acronym for clinical decision support and CDST stands for clinical decision support tool.

Table 8

Reponses Used to Create the Theme Named: Artificial Intelligence Platforms

Participant number	Response	Category codes
3	Artificial intelligence	Artificial intelligence
14	Artificial intelligence platforms	Artificial intelligence
16	Data analytics, artificial intelligence, and machine learning	Artificial intelligence, analytics, and machine learning
22	AI/ML	Artificial intelligence and machine learning
25	IA [a]	Artificial intelligence
28	AI	Artificial intelligence
37	Artificial intelligence for discovery & personalization of treatment	Artificial intelligence, discovery, personalization, and treatment
39	AI	Artificial intelligence
39	AI	Artificial intelligence
47	Machine learning - artificial intelligence	Artificial intelligence and machine learning

Note. AI is an acronym for artificial intelligence and ML stands for machine learning.

[a] The multilingual Spanish speaking participant intended to enter AI, which was clarified via email.

Table 9

Reponses Used to Create the Theme Named: Cloud Computing

Participant number	Response	Category codes
2	Cloud services capable of hosting patient data and running arbitrarily complex machine learning models that can be easily updated	Cloud, patient data, complex, and machine learning
7	Cloud based data processing and computing environment for model building and deployment	Cloud, data processing, and model
10	Server for data processing or access to cloud computing	Cloud, server, and data processing
16	Agnostic VNA/cloud technology	Cloud and vendor neutral archive
17	Cloud infrastructure	Cloud
20	Secure cloud platform for genomic data	Cloud and genomic data
26	Cloud access	Cloud
31	Redshift DB	Cloud and data warehouse
44	Cloud computing	Cloud
48	Cloud / federated / distributed solutions that store data (Amazon, Storj/Sia,..)	Cloud, federated, and distributed

Note. VNA is an acronym for vendor neutral archive and DB stands for database.

Table 10

Reponses Used to Create the Theme Named: Data Governance and Stewardship

Participant number	Response	Category codes
3	Data stewardship	Data stewardship
5	Data governance	Data governance
27	Data management	Data management
27	Data governance	Data governance
29	Data governance / stewardship	Data governance and data stewardship
38	Data management	Data management
42	Data management	Data management

Table 11

Reponses Used to Create the Theme Named: Data Scientists

Participant number	Response	Category codes
12	Data scientist - creates and/or manages analytics, visualizations	Data scientist, analytics, and visualization
15	Data scientist	Data scientist
22	Data scientist	Data scientist
23	Data scientists	Data scientist
24	Data scientists	Data scientist
27	Not all places will do discovery, but for those that do, trained data scientists to find the correlations needed for precision medicine	Data scientist, discovery, and find correlations
29	Data scientist	Data scientist
37	Data scientists	Data scientist

Table 12

Reponses Used to Create the Theme Named: Next Generation DNA Sequencing Technology

Participant number	Response	Category codes
7	Next generation sequencing (NGS) DNA sequencing technology	Sequencing, next generation, and DNA
10	Access to good sequencing equipment to ensure quality	Sequencing and quality
14	Genome sequencing	Sequencing and genomic
22	Gene sequencer	Sequencing and genomic
43	NGS sequencing platforms	Sequencing and next generation

Note. NGS is an acronym for next generation sequencing and DNA stands for deoxyribonucleic acid.

Table 13

Reponses Used to Create the Theme Named: Storage Solutions for Large Data Sets

Participant number	Response	Category codes
5	Storage plan (server side)	Storage and server
10	Space for backup and data storage	Storage and backup
18	Storage solutions for large data sets	Storage and big data
29	Data storage for both pre and post analysis	Storage
40	Storage	Storage

Not only was thematic analysis performed in Round 1, but also in Round 2 since the Round 2 questionnaire provided an opportunity to list additional information technology resources. The thematic analysis process used in Round 2 was basically the same as the process used in Round 1. One additional step I performed in Round 2 was to check that a theme had not already been identified in Round 1. Generally speaking, additional themes were created by condensing the text data collected during Round 2.

I analyzed importance ratings collected during the second and third rounds to determine if there was consensus among the participants. For each information technology resource that was rated, Survey Monkey automatically calculated the percent of responses received for each point on the 5-point importance scale. I exported the percent information from Survey Monkey into Excel. I used Excel formulas to sum percent values and determine if there was consensus. Consensus of importance could have occurred in two different cases. The first case was when at least 75% of the ratings fell in the rating categories of unimportant or very unimportant. If the first case was met, I considered the information technology resource to be not important. The second case was when at least 75% of the ratings fell in the rating categories of important or very important. If the second case was met, I considered the information technology resource to be important. When neither the first nor the second case occurred, I considered the information technology resource to have undetermined importance.

Similar to the importance ratings, I analyzed feasibility ratings during Round 2 and Round 3 to determine if there was consensus among the participants. The analysis process for feasibility ratings parallels the analysis process used for importance ratings. After Survey Monkey autogenerated the percent of responses received for each point on the 5-point feasibility scale, I exported the percent information into Excel. I used Excel formulas to sum percent values and determine if there was consensus. Consensus of feasibility could have occurred in two different cases. The first case was when at least 75% of the ratings fell in the rating categories of probably infeasible or definitely infeasible. If the first case was met, I considered the information technology resource to be not feasible. The second case was when at least 75% of the ratings fell in the rating categories of probably feasible or definitely feasible. If the second case was met, I considered the information technology resource to be feasible. When neither the first nor the second case occurred, I considered the information technology resource to have undetermined feasibility.

Evidence of Trustworthiness

Credibility

Credibility, sometimes referred to as internal validity, deals with the truthfulness of the study results (Krefting, 1991; Morse, 2015). According to Shenton (2004), confidence in the accuracy of qualitative research can be enhanced by adopting research methods used in similar studies, reviewing findings of similar studies, using methods that encourage participants to be frank, and welcoming scrutiny of the research project by academic scholars. In this study, I included each tactic mentioned to improve credibility. The research methods were mainly adopted from previous Delphi studies or were described by Delphi scholars. I reviewed findings of similar studies during the literature review. To encourage participants to be frank, I kept participant identity confidential. As part of the dissertation process, multiple Walden University faculty members examined the research project and provided feedback. I used multiple techniques to increase rigor and confidence in the truthfulness of the study results.

Transferability

Transferability, referred to as external validity in quantitative studies, is about the applicability of the study findings in other contexts (Krefting, 1991; Thomas & Magilvy, 2011). Providing thick description of the study context enables readers to assess if the study results are applicable in other contexts (Cope, 2013; Morse, 2015). Shenton (2004) provided guidance on the information researchers should provide to enable transferability, which includes the number and type of participants, the data collection methods, the number and duration of data collection events, and the duration of the data collection phase. I followed the guidance mentioned to address the trustworthiness criterion of transferability using thick description. I described the study context by providing detailed information regarding the sample and data collection. The information provided may aid readers in assessing if the findings of this study are transferable to other contexts.

Dependability

Dependability, referred to as reliability on occasion, concerns the consistency of the findings if the study were to be repeated (Morse, 2015; Shenton, 2004). Krefting (1991) and Thomas and Magilvy (2011) concurred that providing thick description of research methods is an appropriate strategy to help establish dependability. In addition, Krefting (1991) discussed that having methodologists examine the research plan is another way to enhance dependability. Furthermore, Morse (2015) and Thomas and Magilvy (2011) agreed that the use of an audit trail is a suitable tactic to improve dependability. According to Thomas and Magilvy (2011), an audit trail includes a description of the study purpose, a discussion of how the sample is formed, an explanation of data collection methods and time frames, and a discussion of techniques used to enhance credibility of the findings. In accord with the literature references, the techniques I used to enhance dependability included providing thick description of research methods, having methodologists examine the research plan, and using an audit trail as discussed.

Confirmability

Confirmability, sometimes referred to as objectivity, deals with the neutrality of the results in that the findings should be based on the data collected from participants and not affected by researcher bias (Krefting, 1991; Shenton, 2004). Engels and Kennedy (2007) explained that the ability to trace findings back to original sources is a requirement of confirmability. Anney (2014), Bowen (2009), and Tobin and Begley (2004) concurred that an audit trail supports confirmability. In addition, according to Cope (2013), providing participant quotes in connection with resulting themes is a valid way to demonstrate that the results originate from the collected data. In this study, I enhanced confirmability by using an audit trail and by including participant quotes in connection with themes.

Study Results

Round 1

The Round 1 questionnaire generated 447 participant responses, which resulted in a total of 114 information technology resources to be rated in Round 2. The full list of 114 information technology resources is available in Appendix F. In addition, information technology resources resulting from Round 1 are broken down in Table 14 according to the resource-based view of the firm, which served as the conceptual framework. In a resource-based view, an organizational capability is a special subtype of organizational resource (Makadok, 2001). The total number of organizational resources in Table 14 includes 37 organizational capabilities.

Table 14

Round 1 Results Summary According to the Conceptual Framework

Resource type	No. of information technology resources
Physical	49
Organizational	43
Human	22

Round 2

Of the 114 information technology resources that were rated in Round 2, the predetermined consensus thresholds for importance and feasibility were met for 59. All 59 information technology resources were considered to be important and feasible. A list of the important and feasible information technology resources is provided in Table 15 along with the resource type according to the conceptual framework. The entries in Table 15 are ordered by the percent agreement of being important and then by the percent agreement of being feasible.

Table 15

Information Technology Resources Deemed Important and Feasible During Round 2

Information technology resource	Resource type [a]	% agreement of being important [b]	% agreement of being feasible [c]
Advanced clinical decision support capabilities	Organizational [capability]	98	89
Data quality	Organizational [capability]	98	84
Application programming interface (API) management and integration	Organizational	93	87
Data governance and stewardship	Organizational	93	84
Ability to integrate external clinical decision support with the EHR	Organizational [capability]	93	78
Ontologies for data to make disparate data accessible	Physical	93	78
Clinical informatics	Organizational [capability]	91	96
Trained bioinformatics professionals	Human	91	93
Clinical informaticists	Human	91	91
Data scientists	Human	91	87
Data integration strategy	Organizational	91	80
Data security officer - ensures integrity of data sources	Human	89	93
Application development, testing, deployment, maintenance, and support	Organizational [capability]	89	91
Big data analysis	Organizational [capability]	89	91
Connectors for external data systems using standards (e.g., HL7-FHIR)	Physical	89	89
Data science	Organizational [capability]	89	89
Next generation DNA sequencing technology	Physical	89	89
Support for clinical terminology standards (e.g., ICD, SNOMED-CT, LOINC, and RxNorm)	Organizational [capability]	89	89

Information technology resource	Resource type [a]	% agreement of being important [b]	% agreement of being feasible [c]
Clinical decision support knowledge	Human	89	84
Ability to deliver results in understandable and tangible format to patients	Organizational [capability]	89	82
Data modeling	Organizational [capability]	89	82
A common data model for patient data that enables rapid prototyping (e.g., OHDSI OMOP CDM)	Physical	89	78
Well-annotated database for variant classification	Physical	89	76
Clinical staff knowledgeable in physician workflow, pathology, and molecular testing	Human	87	89
Data architects	Human	87	89
Data visualization	Organizational [capability]	87	89
Evidence based medicine clinical pathway tools	Physical	87	78
Integrated knowledge resources that support informed decision making	Physical	84	91
Storage solutions for large data sets	Physical	84	91
Clinical informatics team composed of physician informaticists, molecular medicine subspecialists, and geneticists	Human	84	87
Curated data	Physical	84	84
Development, maturity, and uptake of standards for data exchange (including sequencing, genomics, proteomics, results, etc.)	Organizational [capability]	84	84
Data security software - not just ransomware protection but true data provenance and protections against data tampering	Physical	84	82
Big data analytics framework for aggregating, cleaning, and organizing data for meaningful analysis	Organizational	84	80
Ability to capture and represent patient-entered data and device output and integrate with transactional medical data	Organizational [capability]	84	76

Information technology resource	Resource type [a]	% agreement of being important [b]	% agreement of being feasible [c]
Ability to map over time as terminologies, such as ICD, change	Organizational [capability]	84	76
Data harmonization and normalization to ensure data is accurately ingested and used	Organizational [capability]	84	76
Access to educational content about precision medicine for patients and providers	Physical	82	89
Genomic storage and processing system (i.e., genomics ancillary system)	Physical	82	89
Data engineer	Human	82	80
Expertise in machine learning	Human	82	80
Integration and extension of context in data standards	Organizational [capability]	82	80
Additional programming personnel to support building advanced clinical decision support	Human	82	78
Software developer subject matter experts to develop integrated tools that maximize the use of data	Human	82	78
Fast Healthcare Interoperability Resources (FHIR) expertise	Human	80	91
Bioinformatics	Organizational [capability]	80	89
Data engineering	Organizational [capability]	80	80
Remote patient monitoring technology	Physical	80	80
Ability to represent key precision medicine data elements (e.g., gene names, genomic variants, and phenotypes) as structured data in the EHR	Organizational [capability]	80	78
Systems integration specialist	Human	78	84
Biomedical information retrieval (IR) systems	Physical	78	82
Translational informatics	Organizational [capability]	78	82
CMIO, CHIO, or CCIO - to enable clinical application of new knowledge from analytics	Human	78	80

Information technology resource	Resource type [a]	% agreement of being important [b]	% agreement of being feasible [c]
Additional processing capacity for huge databases holding precision medicine data	Physical	78	78
Digital front door framework - strong digital connectivity with patients when not in a facility or clinic	Organizational	78	78
High performance computing (HPC) environment, such as graphics processing unit (GPU) clusters or supercomputers, to process protected health information	Physical	78	78
Analytic dashboards	Physical	76	93
Statistical thinking	Human	76	80
Virtual patient portal for information exchange and real time documentation	Physical	76	76

Note. An information technology resource was considered important when at least 75% of the ratings fell in the rating categories of important or very important. An information technology resource was considered feasible when at least 75% of the ratings fell in the rating categories of probably feasible or definitely feasible. The acronyms include: (a) CCIO, chief clinical informatics officer; (b) CDM, common data model; (c) CHIO, chief health information officer; (d) CMIO, chief medical information officer; (e) DNA, deoxyribonucleic acid; (f) EHR, electronic health record; (g) FHIR, Fast Healthcare Interoperability Resources; (h) HL7, Health Level Seven; (i) ICD, International Classification of Diseases; (j) LOINC, Logical Observation Identifiers Names and Codes; (k) OHDSI, Observational Health Data Sciences and Informatics; (l) OMOP, Observational Medical Outcomes Partnership; and (m) SNOMED-CT, Systemized Nomenclature of Medicine - Clinical Terms.

[a] The resource type for an organizational resource that has a resource subtype of organizational capability is denoted as *organizational [capability]*. [b] The percent of responses in the important or very important rating categories. [c] The percent of responses in the probably feasible or definitely feasible rating categories.

Considering that only 59 out of the 114 information technology resources rated in Round 2 met the predetermined consensus thresholds for importance and feasibility, further assessment was needed for the 55 information technology resources that were considered to have undetermined importance, undetermined feasibility, or both. I provided summary information about importance and feasibility ratings for the 55 information technology resources to participants prior to Round 3 (see Appendix G). The summary information allowed participants to consider the group's position relative to their own. In Round 3, I asked participants to rerate the 55 information technology resources in an attempt to determine importance and feasibility.

The raw data collected in Round 2 included a total of 80 free text responses, which resulted in identifying 45 additional information technology resources using thematic analysis. A list of the 45 additional information technology resources can be found at the end of Appendix G. I added the additional information technology resources to the Round 3 questionnaire to be rated in terms of importance and feasibility. Table 16 provides a summary of the 45 additional information technology resources identified during Round 2 according to the conceptual framework. The resource subtype known as an organizational capability accounts for 14 of the organizational resources in Table 16.

Table 16

Summary of Additional Information Technology Resources Identified During Round 2

Resource type	No. of additional information technology resources
Organizational	17
Human	15
Physical	13

Round 3

Of the 100 information technology resources that participants rated in Round 3, the predetermined consensus thresholds for importance and feasibility were met for 18. All 18 information technology resources were considered important and feasible. A list of the 18 information technology resources is provided in Table 17 along with the resource type according to the conceptual framework. I grouped the entries in Table 17 by the round that the information technology resource originated in. Within the groups, I ordered the table entries by the percent agreement of being important and then by the percent agreement of being feasible.

Table 17

Information Technology Resources Deemed Important and Feasible During Round 3

Information technology resource	Resource type [a]	% agreement of being important [b]	% agreement of being feasible [c]
Originated during Round 1			
Integration of EHR, genomic, and pharmacologic platforms	Organizational [capability]	91	79
Natural language processing	Physical	88	77
Application programming interface (API) with labs that offer genetic or precision testing	Physical	81	77
Clinical decision support customizability	Physical	81	77
Computational biology	Organizational [capability]	79	84
Cloud computing	Physical	77	93
Ability to capture genetic variants and their meaning in genomic sequence	Organizational [capability]	77	77
Originated during Round 2			
Collaborative teams that include experienced physicians working with engineers and data scientists	Human	95	86
The necessary subject matter experts across a variety of disciplines (e.g., integration, genomics, data science, data architecture, etc.)	Human	86	86
Clinical decision support architect	Human	84	91
Fast Healthcare Interoperability Resources (FHIR)	Physical	84	88
Someone that has knowledge of both clinical informatics and bioinformatics	Human	84	86
Someone with expertise to create precision clinical decision support	Human	84	84
Fast Healthcare Interoperability Resources (FHIR) clinical decision support tool	Physical	84	81

Information technology resource	Resource type [a]	% agreement of being important [b]	% agreement of being feasible [c]
Application programming interface (API) development by EHR vendors	Organizational [capability]	84	79
Predictive analysis	Organizational [capability]	81	77
Data standardization experts	Human	79	81
Scientific publication access	Physical	77	79

Note. An information technology resource was considered important when at least 75% of the ratings fell in the rating categories of important or very important. An information technology resource was considered feasible when at least 75% of the ratings fell in the rating categories of probably feasible or definitely feasible. EHR is an acronym for electronic health record.

[a] The resource type for an organizational resource that has a resource subtype of organizational capability is denoted as *organizational [capability]*. [b] The percent of responses in the important or very important rating categories. [c] The percent of responses in the probably feasible or definitely feasible rating categories.

Considering that only 18 out of the 100 information technology resources rated in Round 3 met the predetermined consensus thresholds for importance and feasibility, the other 82 information technology resources were considered to have undetermined importance, undetermined feasibility, or both. I list the 82 information technology resources in Table 18 along with the resource type according to the conceptual framework.

Table 18

Information Technology Resources Considered to Have Undetermined Importance, Undetermined Feasibility, or Both

Information technology resource	Resource type [a]	Importance [b]		Feasibility [c]	
		% agreement of being not important [d]	% agreement of being important [e]	% agreement of being not feasible [f]	% agreement of being feasible [g]
Originated during Round 1					
Ability to capture granular phenotypes using EHR data (i.e., deep phenotyping)	Organizational [capability]	5	88	16	58
Access to electronic medical records and clinical genomics research data	Physical	0	86	5	72
Ability to enable pragmatic clinical trials that seamlessly integrate with the standard course of care	Organizational [capability]	2	86	9	60
Ability to evaluate the effectiveness of artificial intelligence and machine learning models that use genomic, social determinant, and EHR data	Organizational [capability]	2	86	14	58
Platform integration across devices	Organizational [capability]	2	81	2	74
Ability to record and catalogue raw unstructured patient data (e.g., notes, images, etc.)	Organizational [capability]	9	81	12	65
IT infrastructure to capture real time events (e.g., emergency department admissions related to adverse drug events)	Physical	5	81	7	65

Information technology resource	Resource type [a]	Importance [b]		Feasibility [c]	
		% agreement of being not important [d]	% agreement of being important [e]	% agreement of being not feasible [f]	% agreement of being feasible [g]
Ability to rapidly adopt new and evolving standards (e.g., FHIR and genomic implementation guides)	Organizational [capability]	5	81	7	60
Data capture for patients in different populations to avoid bias based on location, sex, social determinants of health, or chronic conditions	Organizational [capability]	2	81	9	60
Big data platform - large scale analytics support incorporating whole-view data for a patient (e.g., clinical, biometric, sequencing, population health, etc.)	Physical	0	79	12	53
Ability to execute and maintain artificial intelligence and machine learning models and integrate them into clinicians' workflows seamlessly	Organizational [capability]	2	79	9	44
Enhanced ability to capture and use patient provided information to incorporate patient preferences into treatment plan and capture patient reported outcomes	Organizational [capability]	0	77	2	67
Analysis provenance and traceability of results	Organizational [capability]	2	77	2	60
Automated event detection and reporting systems for drug reaction, medication dispensing, etc.	Physical	0	77	7	60
Ability to develop artificial intelligence and machine learning models using genomic, social determinant, and EHR data	Organizational [capability]	9	77	9	49

Information technology resource	Resource type [a]	Importance [b]		Feasibility [c]	
		% agreement of being not important [d]	% agreement of being important [e]	% agreement of being not feasible [f]	% agreement of being feasible [g]
Adaptable and expandable data architecture	Physical	2	72	2	74
Clinical bioinformatics in which clinical and bioinformatic aspects can be used with artificial intelligence and machine learning	Organizational [capability]	2	72	0	74
An integrated data environment that can support medical care, financial transactions, quality improvement, and research	Physical	7	72	12	53
Access to a global database and a database that is relevant to the local population	Physical	0	72	19	40
Clinical trials infrastructure built in	Physical	0	70	2	67
Multimodal clinical data repository	Physical	0	70	2	67
IT infrastructure connected to a data warehouse for health services research and economic estimates for the impact of personalized medicine (e.g., emergency department admissions and expenses related to adverse drug events before and after the introduction of a pharmacogenetic program to screen all adults for FDA related drug-gene interactions)	Physical	2	70	7	60
Artificial intelligence platforms	Physical	0	67	0	72

Information technology resource	Resource type [a]	Importance [b]		Feasibility [c]	
		% agreement of being not important [d]	% agreement of being important [e]	% agreement of being not feasible [f]	% agreement of being feasible [g]
Native interoperability and application programming interface (API) connectivity between EHR, electronic case report form (eCRF), and biobank databases	Physical	2	67	2	65
Artificial intelligence in solving protein structures and understanding their role in different pathway mechanisms	Physical	2	67	5	44
Terminologists	Human	5	65	5	70
Data lakes that can be federated	Physical	7	65	0	63
Artificial intelligence in next generation sequencing technologies	Physical	2	65	5	58
Agile management	Organizational	2	60	0	70
Federated data analytics	Organizational [capability]	5	60	7	63
Knowledge graphs	Physical	2	60	0	63
Artificial intelligence and machine learning to detect the severity of diseases using computed tomography (CT) images	Physical	9	58	7	65
Mobile device data and metadata	Physical	7	58	5	63
Artificial intelligence in drug discovery using simple molecular docking and virtual screening approaches	Physical	5	58	7	53
Cloud services specialist	Human	9	56	2	88

Information technology resource	Resource type [a]	Importance [b]		Feasibility [c]	
		% agreement of being not important [d]	% agreement of being important [e]	% agreement of being not feasible [f]	% agreement of being feasible [g]
Temporal reasoning	Human	7	56	9	51
Semantic modeling	Organizational [capability]	7	56	2	42
Agnostic cloud technology and a vendor neutral archive	Physical	14	53	5	49
Edge computing that allows local processing of medical data (e.g., smart watch)	Physical	9	51	0	72
Computer vision	Physical	5	49	0	67
Chatbots or other tools that streamline patient outreach by not requiring a clinician	Physical	19	49	5	60
Artificial intelligence chips (also called artificial intelligence hardware or artificial intelligence accelerators)	Physical	16	47	9	42
Pathway software to enable the understanding of mechanisms (e.g., Elsevier Pathway Studio)	Physical	16	44	0	60
Conversational artificial intelligence	Physical	12	44	5	51
Expertise in conversational artificial intelligence	Human	21	37	5	49
Drools and CQL developers	Human	14	35	0	53
Blockchain technology	Physical	28	30	5	53
Blockchain specialist	Human	33	30	7	51

Information technology resource	Resource type [a]	Importance [b]		Feasibility [c]	
		% agreement of being not important [d]	% agreement of being important [e]	% agreement of being not feasible [f]	% agreement of being feasible [g]
Originated during Round 2					
Interoperability across different platforms (e.g., EHR, genomic data, etc.)	Organizational [capability]	0	98	7	72
Knowledge management with clinical and IT personnel	Organizational [capability]	5	86	2	74
Interoperability experts	Human	0	84	0	70
Fast Healthcare Interoperability Resources (FHIR) genomics standards for discrete results, data alignment, and storage	Physical	2	84	0	65
Knowledge about EHR integration options that minimize alert fatigue and provide precision recommendations	Human	2	79	7	72
Preparation for clinical decision support that scales to thousands of rules	Organizational	2	79	0	70
Genomics laboratory information system that stores sequencing data and can translate results into an understandable narrative for the provider	Physical	2	79	5	65
Preparation for precision medication that leverages molecular (e.g., DNA) findings	Organizational	0	77	5	74
More sustainable genomic nomenclature (e.g., Human Genome Variation Society nomenclature)	Physical	5	77	0	70

Information technology resource	Resource type [a]	Importance [b]		Feasibility [c]	
		% agreement of being not important [d]	% agreement of being important [e]	% agreement of being not feasible [f]	% agreement of being feasible [g]
Software engineering	Organizational [capability]	2	74	0	84
Substitutable Medical Apps and Reusable Technology (SMART) on Fast Healthcare Interoperability Resources (FHIR)	Physical	2	74	0	77
Pilot testing capabilities	Organizational [capability]	5	74	5	72
Genomic nomenclature converting tools across multiple IT platforms	Physical	5	74	0	58
Pilot testing environment	Physical	5	72	5	81
Program manager for precision medicine initiative execution	Human	2	72	2	79
Machine learning capability	Organizational [capability]	5	72	0	72
Real world data literacy	Human	2	72	12	51
Use case design	Organizational [capability]	2	70	2	77
Patient data and educational resources outside the EHR	Physical	7	67	12	67
Transnational knowledge base (e.g., CPIC guideline)	Physical	7	65	0	63

Information technology resource	Resource type [a]	Importance [b]		Feasibility [c]	
		% agreement of being not important [d]	% agreement of being important [e]	% agreement of being not feasible [f]	% agreement of being feasible [g]
Human factor engineering - taking clinician and patient personas into account	Organizational [capability]	5	65	5	53
Knowledge about deep learning	Human	9	63	2	72
Translational knowledge engineering	Organizational [capability]	7	63	5	56
Task force to implement new technologies	Human	2	60	2	67
Open source commercial software	Physical	19	60	14	49
Increased number of full-time equivalents (FTEs)	Human	5	60	14	47
Contract specialist among providers, researchers, vendors, and the government	Human	12	56	5	58
Computer vision expertise	Human	5	47	2	63
3D printing	Organizational [capability]	28	40	0	79
Supercomputer management	Organizational	19	37	7	56
Healthcare virtual and augmented reality	Organizational [capability]	28	37	5	47
Nanotechnology	Organizational [capability]	26	33	7	42
Development of quantum computing solutions	Organizational [capability]	23	30	9	35

Information technology resource	Resource type [a]	Importance [b]		Feasibility [c]	
		% agreement of being not important [d]	% agreement of being important [e]	% agreement of being not feasible [f]	% agreement of being feasible [g]
No code and low code machine learning solutions	Physical	19	28	9	30

Note. An information technology resource was considered to have undetermined importance when at least 75% of the ratings did not fall in the rating categories of unimportant or very unimportant and at least 75% of the ratings did not fall in the rating categories of important or very important. An information technology resource was considered to have undetermined feasibility when at least 75% of the ratings did not fall in the rating categories of probably infeasible or definitely infeasible and at least 75% of the ratings did not fall in the rating categories of probably feasible or definitely feasible. The acronyms include (a) CPIC, Clinical Pharmacogenetics Implementation Consortium; (b) CQL, Clinical Quality Language; (c) DNA, deoxyribonucleic acid; (d) EHR, electronic health record; (e) FDA, Food and Drug Administration; (f) FHIR, Fast Healthcare Interoperability Resources; and (g) IT, information technology.

[a] The resource type for an organizational resource that has a resource subtype of organizational capability is denoted as *organizational [capability]*. [b] Adding the percent agreement of being not important to the percent agreement of being important and then subtracting the sum from 100 will approximate the percent of responses in the rating category of neutral. [c] Adding the

percent agreement of being not feasible to the percent agreement of being feasible and then subtracting the sum from 100 will approximate the percent of responses in the rating category of may or may not be feasible. [d] The percent of responses in the unimportant or very unimportant rating categories. [e] The percent of responses in the important or very important rating categories. [f] The percent of responses in the probably infeasible or definitely infeasible rating categories. [g] The percent of responses in the probably feasible or definitely feasible rating categories.

Summary

A total of 159 information technology resources were identified and rated in terms of importance and feasibility. The predetermined consensus thresholds for importance and feasibility were met for 77 information technology resources. All 77 information technology resources that met the predetermined consensus thresholds were considered important and feasible. Table 19 summarizes the 77 information technology resources considered important and feasible according to the conceptual framework, which was the resource-based view of the firm. I considered the other 82 information technology resources to have undetermined importance, undetermined feasibility, or both. I provide a summary of the information technology resources that did not reach the predetermined consensus threshold for importance, feasibility, or both in Table 20.

Table 19

Summary of Information Technology Resources Deemed Important and Feasible

Resource type	No. of information technology resources
Organizational	30 [a]
Physical	25
Human	22

Note. An information technology resource was considered to be important when at least 75% of the ratings fell in the rating categories of important or very important. An information technology resource was considered to be feasible when at least 75% of the ratings fell in the rating categories of probably feasible or definitely feasible.

[a] The resource subtype of organizational capability accounts for 25 of the organizational resources.

Table 20

Summary of Information Technology Resources Considered to Have Undetermined Importance, Undetermined Feasibility, or Both

Resource type	No. of information technology resources considered important and having undetermined feasibility	No. of information technology resources considered feasible and having undetermined importance	No. of information technology resources having undetermined importance and undetermined feasibility
Organizational	15 [a]	3 [b]	12 [c]
Physical	7	2	28
Human	2	2	11

Note. An information technology resource was considered important when at least 75% of the ratings fell in the rating categories of important or very important. An information technology resource was considered feasible when at least 75% of the ratings fell in the rating categories of probably feasible or definitely feasible. An information technology resource was considered to have undetermined importance when at least 75% of the ratings did not fall in the rating categories of unimportant or very unimportant and at least 75% of the ratings did not fall in the rating categories of important or very important. An information technology resource was considered to have undetermined feasibility when at least 75% of the ratings did not fall in the rating categories of probably infeasible or definitely infeasible and at least 75% of the ratings did not fall in the rating categories of probably feasible or definitely feasible.

[a] The resource subtype of organizational capability accounts for 13 of the organizational resources. [b] The resource subtype of organizational capability accounts for 3 of the

organizational resources. [c] The resource subtype of organizational capability accounts for 10 of the organizational resources.

Having presented the study results, the next chapter concludes the study. Chapter 5 includes an interpretation of the findings and limitations. In addition, the last chapter includes recommendations for additional research, study implications, and a conclusion section.

Chapter 5: Discussion, Conclusions, and Recommendations

The purpose of this classical Delphi study was to determine how a panel of precision medicine information technology experts view information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. When considering the literature, a Delphi design was appropriate for this study given that addressing the research questions involved assessing importance and feasibility information for a complex topic that is evolving and has many unknowns. According to Rikkonen and Tapio (2009), a Delphi design is appropriate for topics in which changes in trends are probable. In addition, Delbecq et al. (1975) and Linstone and Turoff (2002) concurred that a Delphi design is fitting when there is incomplete information regarding a situation. In accord with Linstone and Turoff (2002), the Delphi design allowed a group of people to jointly address a complex problem and assess importance and feasibility of options.

An important reason I conducted this study is that people have incomplete information to use when making decisions regarding information technology resources for precision medicine in healthcare delivery organizations. The study results may provide information to aid people in making well-informed information technology resource decisions for precision medicine in healthcare delivery organizations. Of the 159 information technology resources rated by participants, the predetermined consensus thresholds for importance and feasibility were met for 77 information technology resources. All 77 information technology resources were considered important and feasible. I considered the other 82 information technology resources to have undetermined importance, undetermined feasibility, or both. The next section of this chapter includes an interpretation of the findings. Then I discuss study limitations, recommendations for further research, and implications regarding practice, theory, and positive social change. The last section of the chapter concludes the study.

Interpretation of Findings

To my knowledge, this is the first study conducted to determine how a panel of precision medicine information technology specialists view information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. The study results extend the information found in the literature in that the results contain a consensus of information technology resources considered important and feasible for precision medicine in healthcare delivery organizations. The results unite several separate discussions in the literature to form a more comprehensive view on the subject that I investigated.

Information technology resources regarding data science that were deemed important and feasible for precision medicine in healthcare delivery organizations are in line with writings about data science in the context of precision medicine. For instance, the literature contains claims that precision medicine is deeply connected to data science and that big data science provides an epistemological base for precision medicine (Fröhlich et al., 2018; Vegter, 2018). Although the study results do not definitively prove the claims made in the literature regarding data science, the findings provide support for the claims. The information technology resources deemed important and feasible for precision medicine in healthcare delivery organizations not only include data science, which I categorized as an organizational capability according to the conceptual framework, but also include data scientists, who are human information technology resources. Five additional information technology resources deemed important and feasible include expertise in machine learning, statistical thinking, data visualization, predictive analysis, and natural language processing. The concepts embedded in the five additional information technology resources are often associated with data science (Misnevs & Jackiva, 2016; Raschka et al., 2020). Information technology resources regarding data science that were deemed important and feasible are in line with writings about data science.

Given the link between precision medicine and data science, it comes as no surprise that information technology resources considered important and feasible for precision medicine in healthcare delivery organizations that incorporate big data are in accord with literature references. As an example, Wu et al. (2017) and Gligorijević et al. (2016) agreed that big data analytics enable precision medicine. In accord with Wu et al. (2017) and Gligorijević et al. (2016), information technology resources considered important and feasible for precision medicine in healthcare delivery organizations include big data analysis, which I categorized as an organizational resource, and a big data analytics framework for aggregating, cleaning, and organizing data for meaningful analysis, which I categorized as an organizational capability. As another example, Moscatelli et al. (2018) discussed an optimized way to store big data for precision medicine. In accord with Moscatelli et al. (2018), storage solutions for large data sets were considered a physical information technology resource that is important and feasible for precision medicine in healthcare delivery organizations. Information technology resources considered important and feasible that incorporate big data are in accord with literature references.

With the connections of precision medicine to big data and data science, it makes sense that information technology resources deemed important and feasible for precision medicine in healthcare delivery organizations that are related to data standards are congruent with discussions in the literature. For instance, in a discussion of using electronic health record systems for precision medicine, Sitapati et al. (2017) explained that terminology standards enable healthcare organizations to exchange health data. Congruent with the discussion by Sitapati et al. (2017), support for clinical terminology standards was deemed an important and feasible information technology resource for precision medicine in healthcare delivery organizations. In keeping with the conceptual framework, I categorized support for clinical terminology standards as an organizational capability. Sitapati et al. (2017) also explained that standards for some types of data used in precision medicine need further development and adoption. Congruent with the view provided by Sitapati et al. (2017), the development, maturity, and uptake of standards for data exchange was deemed an important and feasible information technology resource for precision medicine in healthcare delivery organizations and was categorized as an organizational capability. The literature contains several articles that include discussions about data standards in the context of precision medicine. As another example, Warner, Rioth, et al. (2016) discussed the use of the Fast Healthcare Interoperability Resources standard in the creation of a software program to deliver genomic information in a clinical environment for oncologic precision medicine. Congruent with the discussion by Warner, Rioth, et al. (2016), both the physical information technology resource named Fast Healthcare Interoperability Resources and the human counterpart named Fast Healthcare Interoperability Resources expertise were deemed important and feasible for precision medicine in healthcare delivery organizations. Information technology resources related to data standards deemed important and feasible for precision medicine in healthcare delivery organizations are congruent with discussions in the literature.

Information technology resources dealing with clinical decision support considered important and feasible for precision medicine in healthcare delivery organizations are consistent with cases found in the literature. For example, in one case Hicks, Stowe, et al. (2016) explained that a multistate health system used custom rules for clinical decision support when implementing pharmacogenomics, which is a form of precision medicine. Consistent with the case discussed by Hicks, Stowe, et al. (2016), clinical decision support customizability was considered an important and feasible physical information technology resource for precision medicine in healthcare delivery organizations. In another case, Danahey et al. (2017) discussed how a university affiliated healthcare delivery organization integrated a standalone clinical decision support system with an electronic health record system to aid healthcare workers when making medication prescribing decisions for precision medicine. Consistent with the case discussed by Danahey et al. (2017), the ability to integrate external clinical decision support with the electronic health record was considered an information technology resource that is important and feasible for precision medicine in healthcare delivery organizations and was categorized as an organizational capability. In a third case, Dolin et al. (2018) developed a clinical decision support service for pharmacogenomics using Fast Healthcare Interoperability Resources. Consistent with the case discussed by Dolin et al. (2018), a Fast Healthcare Interoperability Resources clinical decision support tool was considered an important and feasible physical information technology resource for precision medicine in healthcare delivery organizations. Information technology resources dealing with clinical decision support considered important and feasible are consistent with cases found in the literature.

Information technology resources regarding interdisciplinary efforts deemed important and feasible for precision medicine in healthcare delivery organizations are in line with literature references. Prosperi et al. (2018) explained that precision medicine requires interdisciplinary expertise. Additionally, Xu et al. (2021) provided the view that medical informatics in the context of precision medicine has an interdisciplinary nature. Furthermore, Brown (2016) discussed that technical solutions for precision medicine can be enabled using interdisciplinary efforts. In line with Prosperi et al. (2018), Xu et al. (2021), and Brown (2016), human information technology resources deemed important and feasible for precision medicine in healthcare delivery organizations include: (a) the necessary subject matter experts across a variety of disciplines; (b) a clinical informatics team composed of physician informaticists, molecular medicine subspecialists, and geneticists; and (c) collaborative teams that include experienced physicians working with engineers and data scientists. Information technology resources regarding interdisciplinary efforts deemed important and feasible are in line with literature references.

Information technology resources considered important and feasible for precision medicine in healthcare delivery organizations that are related to genomics are in accord with discussions in the literature. For example, Rasmussen et al. (2019) discussed that a university affiliated healthcare delivery organization developed an ancillary genomics system that imports genomic test results from laboratories, processes the test results, and provides the test results to an electronic health record system. In accord with the discussion by Rasmussen et al. (2019), a genomic storage and processing system was considered an important and feasible physical information technology resource for precision medicine in healthcare delivery organizations. As another example, Manzi et al. (2017) discussed that a children's hospital records genomic variants and interpretations of the variants in an electronic health record system for pharmacogenomics. In accord with the discussion by Manzi et al. (2017), the ability to capture genetic variants and their meaning in genomic sequence was considered an important and feasible information technology resource for precision medicine in healthcare delivery organizations and was categorized as an organizational capability. As a third example, Swaminathan et al. (2016) discussed three application programming interfaces focused on genomics that can be used to access genomic data sources, such labs that perform genetic testing. In accord with the discussion by Swaminathan et al. (2016), an application programming interface with labs that offer genetic or precision testing was considered an important and feasible physical information technology resource for precision medicine in healthcare delivery organizations. Information technology resources considered important and feasible that are related to genomics are in accord with discussions in the literature.

Limitations of the Study

A limitation was that this study was subject to self-selection bias in that the sample was composed of specialists who chose to participate. Knowledgeable experts may have opted not to participate in the study due to time constraints, indifference to the study, or insufficient compensation. In addition to offering a modest monetary gift, I partially addressed the first limitation by using questionnaires that did not require a substantial amount of time to complete.

Another limitation was that I used a cross-sectional design rather than a longitudinal design. A cross-sectional investigation is useful to analyze data for a specific point in time (Babbie, 2017) and does not provide information on how time may be an influence (Caruana et al., 2015). An example of the cross-sectional design limitation is that, according to McCoy (2017) and Vogl et al. (2018), research participants' perspectives may change over time. I partially addressed the second limitation by using a process to form consensus among the study participants. A consensus approach may have created a balanced perspective and incorporated persisting elements regarding the research questions.

A third limitation was that most of the participants stated they reside in the United States. There are many differences in healthcare systems of other countries when compared to healthcare in the United States. (Toth, 2016). The generalizability of the study to countries not represented in the sample is unknown. Considering differences in healthcare systems across different countries is beyond the scope of this study.

Recommendations

Having identified several information technology resources for precision medicine in healthcare delivery organizations, there are multiple opportunities to conduct additional research about the information technology resources. One research opportunity is to further investigate information technology resources that I considered to have undetermined importance, undetermined feasibility, or both. As of this writing, it is unknown why some information technology resources have undetermined importance or feasibility. Another research opportunity is to explore contextual information regarding the information technology resources. The need for a specific information technology resource may be affected by the context in which it is used. A third opportunity for further research about the information technology resources identified is to investigate particular groupings of information technology resources. It is possible that some combinations of information technology resources may be more beneficial than others. Another opportunity to conduct additional research is to explore how the information technology resources that I categorized as organizational capabilities are built and embedded within a company in the context of precision medicine. It may be useful to understand how much time and effort is needed to create an organizational capability. There are multiple opportunities to conduct further research about the information technology resources that I identified.

Based on the study limitations, there are multiple opportunities to conduct further research on the central topic that I examined. To recap the limitations, I conducted the study at a point in time using a sample of individuals that mostly resided in the United States and chose to participate knowing they were eligible to receive a modest monetary gift. Since I conducted the study at a point in time, there is a research opportunity to revisit the topic that I examined in the future. Given that the field of precision medicine is emerging, new developments could affect information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. Considering that most participants stated they resided in the United States, further research could be conducted on the topic that I examined by targeting foreign countries. Research focused on foreign countries could result in additional insights. Because the study was dependent on individuals who chose to participate knowing they were eligible to receive a modest monetary gift, there is a research opportunity to conduct a study on the topic that I examined by using stronger incentives to entice knowledgeable individuals to participate. Using stronger incentives to attract knowledgeable individuals could result in incorporating other viewpoints. There are multiple opportunities to conduct further research based on the study limitations.

Implications

At a societal level, the study results could give rise to positive social change by enabling progress toward improved healthcare quality using information technology resources for precision medicine in healthcare delivery organizations. Information technology resources for precision medicine are underutilized, which can lead to adverse effects healthcare quality (Caraballo, Bielinski, et al., 2017). Having created a list of information technology resources considered important and feasible, the study results could create a shared vision of what is needed to fulfill information technology resource requirements for precision medicine in healthcare delivery organizations. Creating a shared vision could lead to improved utilization of information technology resources for precision medicine in healthcare delivery organizations as well as improved healthcare quality. The study results could prompt positive social change at a societal level by enabling progress toward improved healthcare quality.

In addition to positive social change at a societal level, the study results could lead to positive social change at an organizational level by informing information technology resource decisions for precision medicine in healthcare delivery organizations. For instance, reports indicate there is a shortage of information specialists with the skills necessary to implement precision medicine (Gómez-López et al., 2019; Hulsen et al., 2019). Positive social change could result by educational organizations considering the study results when making decisions about enhanced curricula targeted at people who function as human information technology resources for precision medicine in healthcare delivery organizations. Enhanced curricula may help alleviate the shortage of information specialists. As another example, multiple reports suggest that commercially available information technology products are not mature in terms of meeting the requirements for precision medicine in healthcare delivery organizations (Hoffman et al., 2016; Warner, Rioth, et al., 2016). Positive social change could result by commercial vendors considering the study results when making decisions about the creation of new physical information technology resources that would meet the requirements for precision medicine in healthcare delivery organizations. As a third example, reports indicate that data storage approaches used in early precision medicine implementations may be insufficient for the long term (Danahey et al., 2017; Hicks, Dunnenberger, et al., 2016). Positive social change could result by healthcare delivery organizations considering the study results when making decisions about the creation of adaptable data storage solutions for precision medicine. Adaptability could help increase the longevity of data storage solutions. The study results could lead to positive social change by informing decisions made by organizations regarding information technology resources for precision medicine in healthcare delivery organizations.

Besides positive social change at organizational and societal levels, the study results may lead to positive social change at an individual level by advancing the intellect of people. I conducted this study in part because the literature did not contain a consensus of information technology resource importance and feasibility for precision medicine in healthcare delivery organizations. Considering that this study addresses a literature gap, individuals that read this dissertation may benefit intellectually. The study results may lead to positive social level change at an individual level.

As well as having implications for positive social change, the study results could accelerate developments in theory. Given the emerging state of the field of precision medicine, the results could provide a new perspective to advance concepts associated with information technology resource planning when future circumstances are unclear. Additionally, having determined information technology resource importance and feasibility, the study results could inform conceptual models concerning the evolution of information technology resources for precision medicine. Furthermore, the results could lead to a better understanding of how the dynamics of information technology resources for precision medicine influence society. The study results could contribute to different types of advancements in theory.

In addition to social and theoretical advances, the study results could contribute to improvements in practice. The results could aid people in making strategic planning decisions regarding information technology resources for precision medicine in healthcare delivery organizations. Additionally, the study results could be insightful to people when prioritizing resource investment options. Furthermore, the results could be useful to people when assessing opportunities to create new information technology resources for precision medicine in healthcare delivery organizations. This study could lead to improvements in practice in multiple ways.

The study results could enable practitioners to be more efficient. Practitioners could save time by using the list of information technology resources as a checklist of resources to consider when making decisions regarding precision medicine in healthcare delivery organizations. Additionally, practitioners could use the list of information technology resources to consider information technology resources in an organized and more complete way. Furthermore, the list of information technology resources could be used by practitioners as a delegation aid when assigning tasks. There are multiple ways in which the study results could enable practitioners to be more efficient.

Conclusions

Healthcare delivery organizations have a tremendous opportunity to use insights from the emerging field of precision medicine to improve the quality of healthcare (Starkweather et al., 2018; Weinshilboum & Wang, 2017). Achieving the potential benefits of precision medicine entails utilizing diverse and complex types of healthcare data with the aid of information technology (Gligorijević et al., 2016; Gómez-López et al., 2019). However, healthcare delivery organizations underutilize information technology resources for precision medicine which can lead to adverse effects on the quality of services provided (Caraballo, Bielinski, et al., 2017). In addition, people have limited information to use when making decisions regarding information technology resources for precision medicine in healthcare delivery organizations given the emerging state of precision medicine.

The study results provide information that could benefit individuals, organizations, and society regarding information technology resources for precision medicine in healthcare delivery organizations. People that consider the results could benefit intellectually. Organizations could benefit by using the study results to inform decisions regarding information technology resources. The study results could benefit society by creating a shared vision and enabling progress toward improved healthcare quality.

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Appendix A: Study Invitation

Email subject: IT Resources for Precision Medicine

Email message:

Hello,

You are invited to participate in a research study I am conducting as a PhD candidate. The intent is to use the knowledge of experts to form a list of important and feasible IT resources to enable precision medicine in healthcare delivery organizations. The study results could lead to new products from commercial vendors, enhanced curricula at universities, and improved processes in healthcare delivery organizations.

The study involves creating a list of key IT resources and forming consensus of the resources considered to be important and feasible. This will be accomplished using a succession of 3 relatively brief online questionnaires. Participant identity will be kept confidential. A monetary gift up to 30 U.S. dollars will be provided.

You are receiving this invitation to participate because you may have knowledge related to the research topic. To be eligible for the study, an individual must: (a) be at least 18 years old, (b) be able to write fluently in English, (c) not have a personal or professional relationship with the researcher, (d) have a minimum of 3 years of professional experience dealing with IT for precision medicine in healthcare delivery, and (e) be able to describe cases illustrating good versus poor decisions regarding IT resources for precision medicine in healthcare delivery organizations.

If you are interested in participating, please let me know by emailing me at the address shown below. More information about the study will be provided to those that express an interest. In addition, if you know someone believed to meet the eligibility criteria, please send me their email address.

Thanks in advance,

Nick

Nicholas Bertram, PhD candidate
[redacted] [note: The email address has been redacted]

Appendix B: Eligibility Questionnaire

Eligibility Questionnaire

Please respond to all questions. Click the submit button at the bottom when you are finished.

1) **Are you at least 18 years old?**

- ◯ Yes
- ◯ No

2) **In which country do you primarily reside?**

[▾]

3) **Can you write fluently in English?**

- ◯ Yes
- ◯ No

4) **What is the highest degree you have earned?**

- ◯ High School
- ◯ Associate's
- ◯ Bachelor's
- ◯ Master's
- ◯ Doctorate

5) **What is your primary work setting?**

- ◯ Academia
- ◯ Industry
- ◯ Government

6) **Which of the following best describes your primary job function?**

- ◯ Executive
- ◯ Director
- ◯ Manager
- ◯ Professor
- ◯ Researcher
- ◯ Engineer
- ◯ Analyst
- ◯ Other (specify below)

7) **Do you have a personal or professional relationship with the researcher?**

◯ Yes ◯ No

8) **How many years of professional experience do you have dealing with information technology for precision medicine in healthcare delivery?**

0 100

9) **Can you describe cases illustrating good versus poor decisions regarding information technology resources for precision medicine in healthcare delivery organizations?**

◯ Yes ◯ No

100%

Submit

Appendix C: Round 1 Questionnaire

Round 1 Questionnaire

Please provide 3 to 5 brief responses to each question. Click the submit button at the bottom when you are finished.

IT capabilities:

In your opinion, what specialized information technology capabilities are key for healthcare delivery organizations to possess to enable precision medicine now and in the years to come?

IT capability 1:

IT capability 2:

IT capability 3:

IT capability 4:

IT capability 5:

IT resources:

In your opinion, what specialized information technology resources are key for healthcare delivery organizations to possess to enable precision medicine now and in the years to come?

IT resource 1:

IT resource 2:

IT resource 3:

IT resource 4:

IT resource 5:

Submit

Appendix D: The Beginning Portion of Each Section in the Round 2 Questionnaire

IT Capabilities and Resources Collected During Round 1

Please rate the importance and feasibility of each IT capability and resource in regard to healthcare delivery organizations possessing the IT capability or resource to enable precision medicine now and in the years to come.

When you are done, click the next button at the bottom to continue.

1) **A common data model for patient data that enables rapid prototyping (e.g., OHDSI OMOP CDM)**

- ◯ Very Unimportant
- ◯ Unimportant
- ◯ Neutral
- ◯ Important
- ◯ Very Important

- ◯ Definitely Infeasible
- ◯ Probably Infeasible
- ◯ May or May Not be Feasible
- ◯ Probably Feasible
- ◯ Definitely Feasible

Additional IT Capabilities and Resources

The last two questions are optional and allow for brief responses. You have the opportunity to provide additional IT capabilities and resources. Click the submit button at the bottom when you are finished.

Additional IT capabilities:
In your opinion, what specialized information technology capabilities are key for healthcare delivery organizations to possess to enable precision medicine now and in the years to come?

Additional IT capability 1:

Additional IT capability 2:

Additional IT capability 3:

Additional IT resources:
In your opinion, what specialized information technology resources are key for healthcare delivery organizations to possess to enable precision medicine now and in the years to come?

Additional IT resource 1:

Additional IT resource 2:

Additional IT resource 3:

Appendix E: The Beginning Portion of Each Section in the Round 3 Questionnaire

IT Capabilities and Resources That Were Rated in Round 2, but Did Not Reach the Predetermined Consensus Threshold for Importance, Feasibility, or Both

Please rate the importance and feasibility of each IT capability and resource in regard to healthcare delivery organizations possessing the IT capability or resource to enable precision medicine now and in the years to come.

When you are done, click the next button at the bottom to continue.

1) **Ability to capture genetic variants and their meaning in genomic sequence**

- ◯ Very Unimportant
- ◯ Unimportant
- ◯ Neutral
- ◯ Important
- ◯ Very Important

- ◯ Definitely Infeasible
- ◯ Probably Infeasible
- ◯ May or May Not be Feasible
- ◯ Probably Feasible
- ◯ Definitely Feasible

Additional IT Capabilities and Resources That Were Collected During Round 2

Please rate the importance and feasibility of each IT capability and resource in regard to healthcare delivery organizations possessing the IT capability or resource to enable precision medicine now and in the years to come.

Click the submit button at the bottom when you are finished.

56) **3D printing**

- ◯ Very Unimportant
- ◯ Unimportant
- ◯ Neutral
- ◯ Important
- ◯ Very Important

- ◯ Definitely Infeasible
- ◯ Probably Infeasible
- ◯ May or May Not be Feasible
- ◯ Probably Feasible
- ◯ Definitely Feasible

Appendix F: Round 1 Results That Were Sent to Participants

Round 1 Results

The Round 1 questionnaire asked for specialized information technology capabilities and resources that are key for healthcare delivery organizations to possess to enable precision medicine now and in the years to come. The table below contains the results in alphabetical order.

Round 1 Results
1) A common data model for patient data that enables rapid prototyping (e.g., OHDSI OMOP CDM)
2) Ability to capture and represent patient-entered data and device output and integrate with transactional medical data
3) Ability to capture genetic variants and their meaning in genomic sequence
4) Ability to capture granular phenotypes using EHR data (i.e., deep phenotyping)
5) Ability to deliver results in understandable and tangible format to patients
6) Ability to develop artificial intelligence and machine learning models using genomic, social determinant, and EHR data
7) Ability to enable pragmatic clinical trials that seamlessly integrate with the standard course of care
8) Ability to evaluate the effectiveness of artificial intelligence and machine learning models that use genomic, social determinant, and EHR data
9) Ability to execute and maintain artificial intelligence and machine learning models and integrate them into clinicians' workflows seamlessly
10) Ability to integrate external clinical decision support with the EHR
11) Ability to map over time as terminologies, such as ICD, change
12) Ability to rapidly adopt new and evolving standards (e.g., FHIR and genomic implementation guides)
13) Ability to record and catalogue raw unstructured patient data (e.g., notes, images, etc.)
14) Ability to represent key precision medicine data elements (e.g., gene names, genomic variants, and phenotypes) as structured data in the EHR
15) Access to educational content about precision medicine for patients and providers
16) Access to electronic medical records and clinical genomics research data

17) Access to a global database and a database that is relevant to the local population
18) Adaptable and expandable data architecture
19) Additional processing capacity for huge databases holding precision medicine data
20) Additional programming personnel to support building advanced clinical decision support
21) Advanced clinical decision support capabilities
22) Agile management
23) Agnostic cloud technology and a vendor neutral archive
24) An integrated data environment that can support medical care, financial transactions, quality improvement, and research
25) Analysis provenance and traceability of results
26) Analytic dashboards
27) Application development, testing, deployment, maintenance, and support
28) Application programming interface (API) management and integration
29) Application programming interface (API) with labs that offer genetic or precision testing
30) Artificial intelligence and machine learning to detect the severity of diseases using computed tomography (CT) images
31) Artificial intelligence chips (also called artificial intelligence hardware or artificial intelligence accelerators)
32) Artificial intelligence in drug discovery using simple molecular docking and virtual screening approaches
33) Artificial intelligence in next generation sequencing technologies
34) Artificial intelligence in solving protein structures and understanding their role in different pathway mechanisms
35) Artificial intelligence platforms
36) Automated event detection and reporting systems for drug reaction, medication dispensing, etc.
37) Big data analysis
38) Big data analytics framework for aggregating, cleaning, and organizing data for meaningful analysis

39) Big data platform - large scale analytics support incorporating whole-view data for a patient (e.g., clinical, biometric, sequencing, population health, etc.)
40) Bioinformatics
41) Biomedical information retrieval (IR) systems
42) Blockchain specialist
43) Blockchain technology
44) Chatbots or other tools that streamline patient outreach by not requiring a clinician
45) Clinical bioinformatics in which clinical and bioinformatic aspects can be used with artificial intelligence and machine learning
46) Clinical decision support customizability
47) Clinical decision support knowledge
48) Clinical informaticists
49) Clinical informatics
50) Clinical informatics team composed of physician informaticists, molecular medicine subspecialists, and geneticists
51) Clinical staff knowledgeable in physician workflow, pathology, and molecular testing
52) Clinical trials infrastructure built in
53) Cloud computing
54) Cloud services specialist
55) CMIO, CHIO, or CCIO - to enable clinical application of new knowledge from analytics
56) Computational biology
57) Computer vision
58) Connectors for external data systems using standards (e.g., HL7-FHIR)
59) Conversational artificial intelligence
60) Curated data
61) Data architects
62) Data capture for patients in different populations to avoid bias based on location, sex, social determinants of health, or chronic conditions

63) Data engineer
64) Data engineering
65) Data governance and stewardship
66) Data harmonization and normalization to ensure data is accurately ingested and used
67) Data integration strategy
68) Data lakes that can be federated
69) Data modeling
70) Data quality
71) Data science
72) Data scientists
73) Data security officer - ensures integrity of data sources
74) Data security software - not just ransomware protection but true data provenance and protections against data tampering
75) Data visualization
76) Development, maturity, and uptake of standards for data exchange (including sequencing, genomics, proteomics, results, etc.)
77) Digital front door framework - strong digital connectivity with patients when not in a facility or clinic
78) Drools and CQL developers
79) Edge computing that allows local processing of medical data (e.g., smart watch)
80) Enhanced ability to capture and use patient provided information to incorporate patient preferences into treatment plan and capture patient reported outcomes
81) Evidence based medicine clinical pathway tools
82) Expertise in conversational artificial intelligence
83) Expertise in machine learning
84) Fast healthcare interoperability resources (FHIR) expertise
85) Federated data analytics
86) Genomic storage and processing system (i.e., genomics ancillary system)

87) High performance computing (HPC) environment, such as graphics processing unit (GPU) clusters or supercomputers, to process protected health information
88) Integrated knowledge resources that support informed decision making
89) Integration and extension of context in data standards
90) Integration of EHR, genomic, and pharmacologic platforms
91) IT infrastructure connected to a data warehouse for health services research and economic estimates for the impact of personalized medicine (e.g., emergency department admissions and expenses related to adverse drug events before and after the introduction of a pharmacogenetic program to screen all adults for FDA related drug-gene interactions)
92) IT infrastructure to capture real time events (e.g., emergency department admissions related to adverse drug events)
93) Knowledge graphs
94) Mobile device data and metadata
95) Multimodal clinical data repository
96) Native interoperability and application programming interface (API) connectivity between EHR, electronic case report form (eCRF), and biobank databases
97) Natural language processing
98) Next generation DNA sequencing technology
99) Ontologies for data to make disparate data accessible
100) Pathway software to enable the understanding of mechanisms (e.g., Elsevier Pathway Studio)
101) Platform integration across devices
102) Remote patient monitoring technology
103) Semantic modeling
104) Software developer subject matter experts to develop integrated tools that maximize the use of data
105) Statistical thinking
106) Storage solutions for large data sets
107) Support for clinical terminology standards (e.g., ICD, SNOMED-CT, LOINC, and RxNorm)

108) Systems integration specialist
109) Temporal reasoning
110) Terminologists
111) Trained bioinformatics professionals
112) Translational informatics
113) Virtual patient portal for information exchange and real time documentation
114) Well-annotated database for variant classification

Appendix G: Round 2 Results That Were Sent to Participants

Round 2 Results That Are Relevant to the Round 3 Questionnaire

A portion of the Round 2 questionnaire asked for importance and feasibility ratings of IT capabilities and resources in regard to healthcare delivery organizations possessing the IT capability or resource to enable precision medicine now and in the years to come. The importance ratings for each IT capability and resource were analyzed to determine the importance result according to the rules in the following table.

Potential Importance Result	Result Rule
Important	Result occurs when at least 75% of the ratings fall within the rating categories of Important or Very Important
Not Important	Result occurs when at least 75% of the ratings fall within the rating categories of Unimportant or Very Unimportant
Undetermined Importance	Result occurs when the rules to be considered Important or Not Important are not met

Similarly, the feasibility ratings for each IT capability and resource were analyzed to determine the feasibility result according to the rules in the following table.

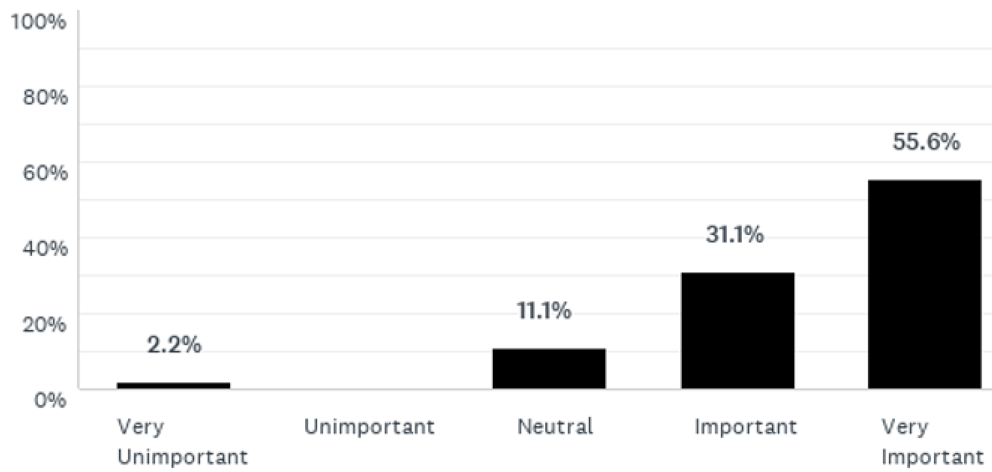
Potential Feasibility Result	Result Rule
Feasible	Result occurs when at least 75% of the ratings fall within the rating categories of Probably Feasible or Definitely feasible
Not Feasible	Result occurs when at least 75% of the ratings fall within the rating categories of Probably Infeasible or Definitely Infeasible
Undetermined Feasibility	Result occurs when the rules to be considered Feasible or Not Feasible are not met

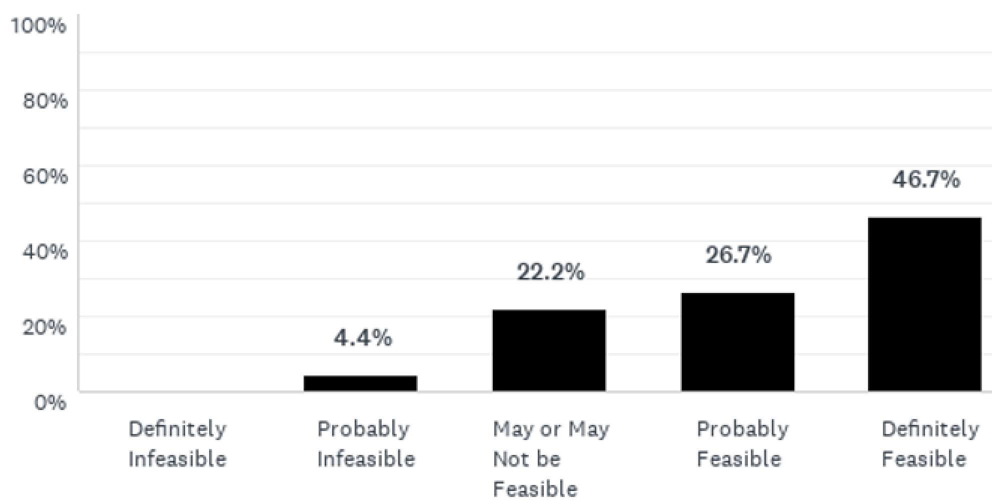
59 of the 114 IT capabilities and resources that were rated in Round 2 are considered to be important and feasible. The assessment is complete for the 59 important and feasible IT capabilities and resources. The overall study summary that will be provided after Round 3 will list the 59 IT capabilities and resources.

The other 55 IT capabilities and resources that were rated in Round 2 are considered to have undetermined importance, undetermined feasibility, or both. In accordance with traditional Delphi research methods, participants will be asked to rerate the 55 IT capabilities and resources in Round 3 in an attempt to determine the importance and feasibility according to the result rules shown above. The Round 2 rating results for each of the 55 IT capabilities and resources are provided below in alphabetical order so that participants can consider the group's position relative to their own during Round 3.

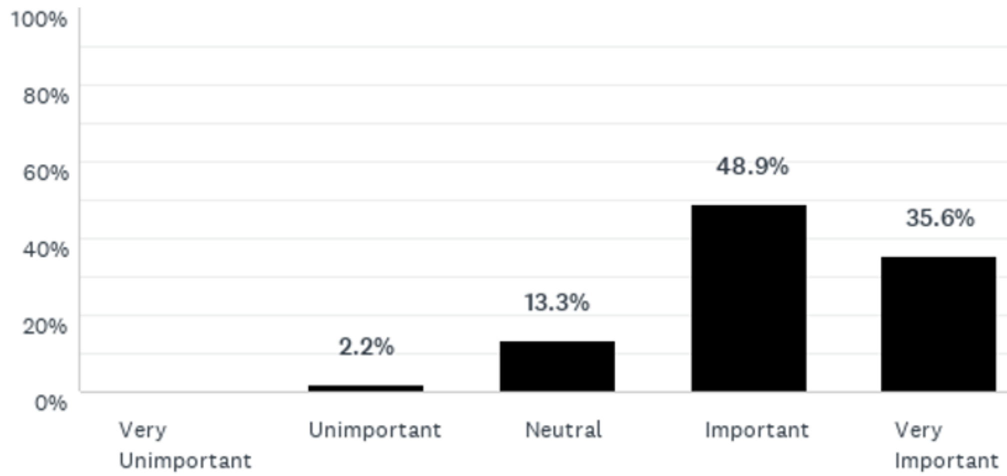
The Round 2 questionnaire also allowed people to enter additional IT capabilities and resources if they desired. The results of the additional IT capabilities and resources are listed in alphabetical order at the end of this document. Participants will be asked to rate the importance and feasibility of the additional IT capabilities and resources during Round 3.

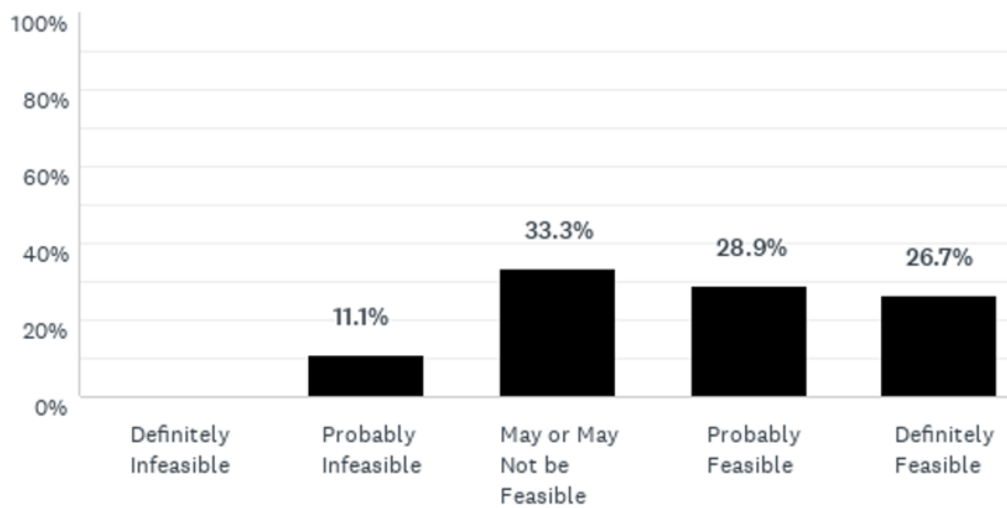
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
1) Ability to capture genetic variants and their meaning in genomic sequence	
Importance result:	Important
Feasibility result:	Undetermined feasibility



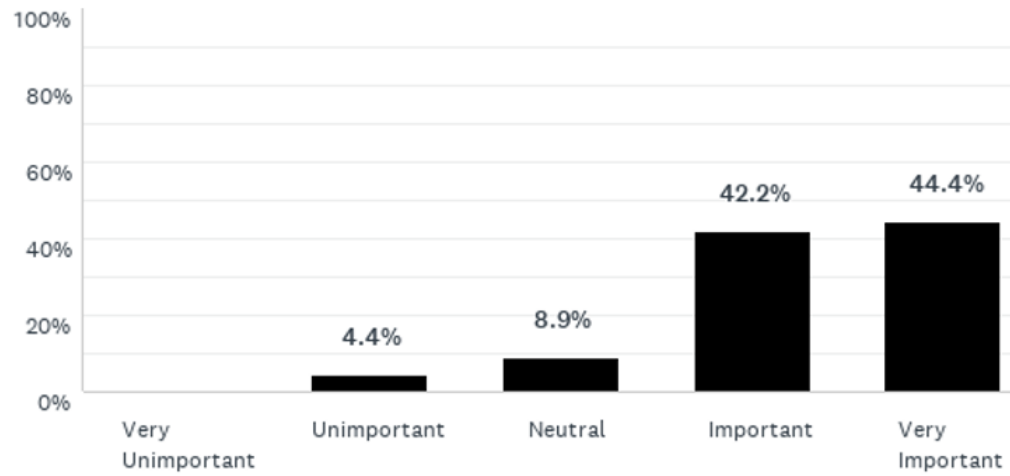


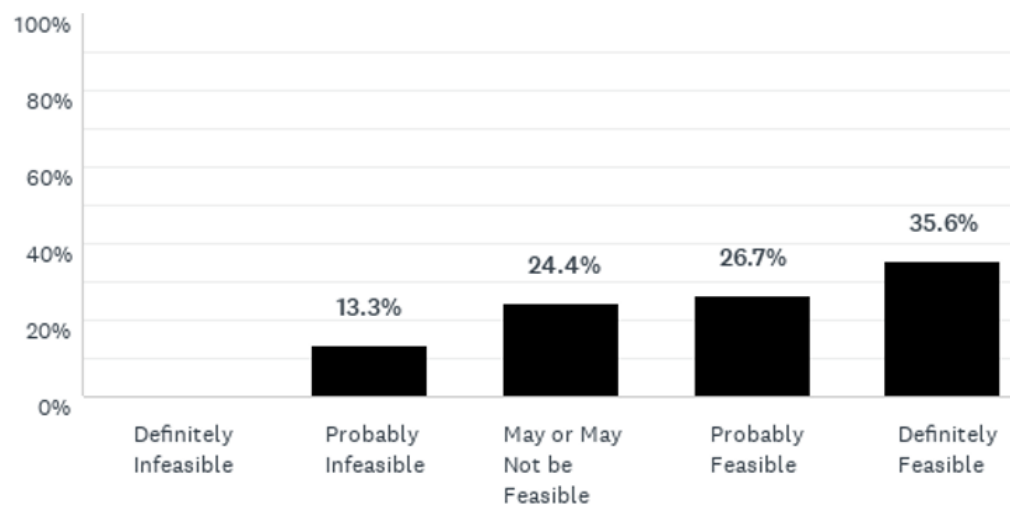
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
2) Ability to capture granular phenotypes using EHR data (i.e., deep phenotyping)	
Importance result:	Important
Feasibility result:	Undetermined feasibility



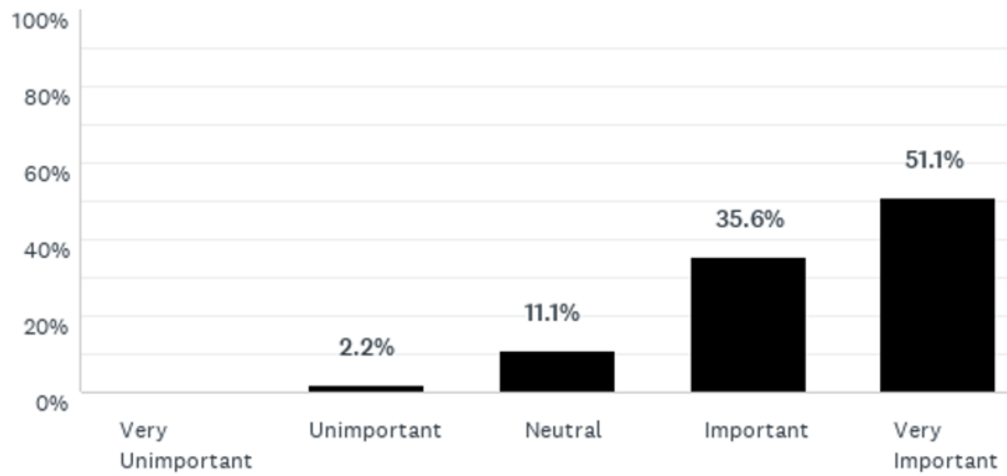


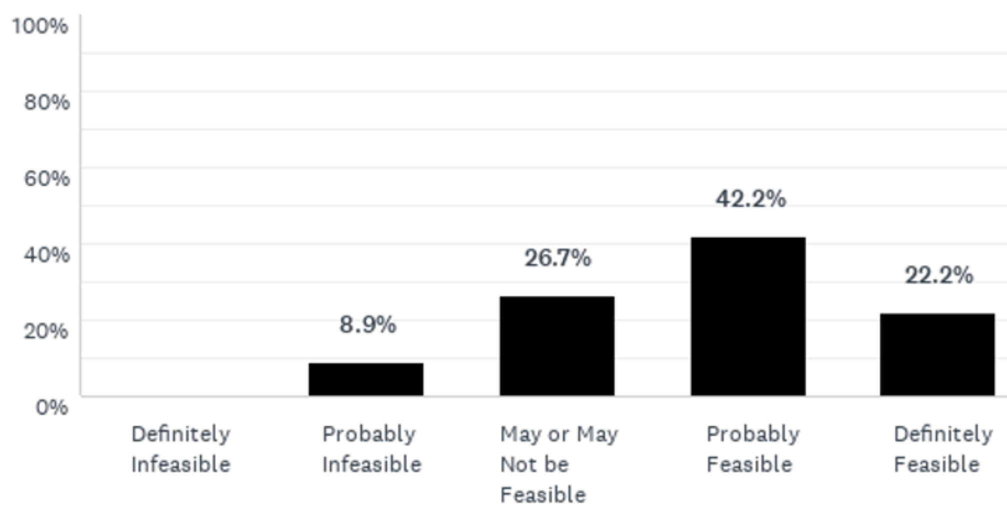
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
3) Ability to develop artificial intelligence and machine learning models using genomic, social determinant, and EHR data	
Importance result:	Important
Feasibility result:	Undetermined feasibility



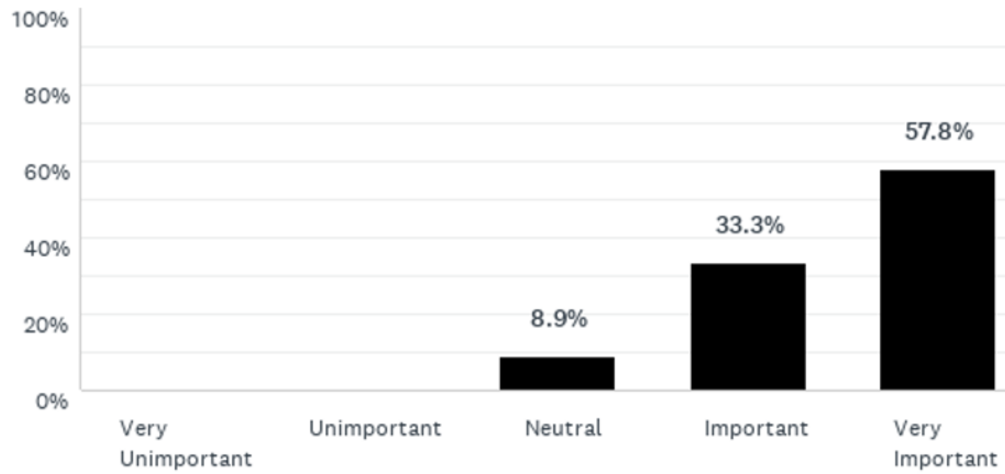


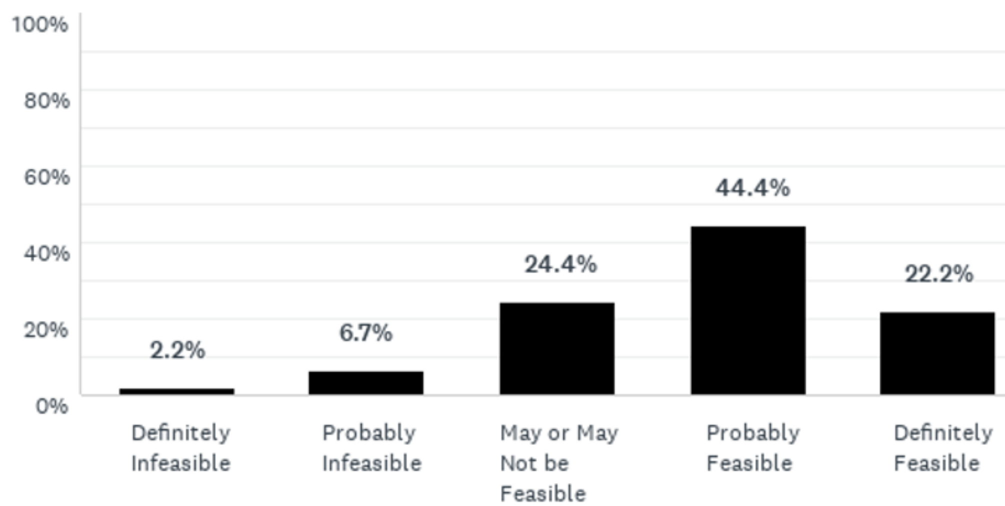
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
4) Ability to enable pragmatic clinical trials that seamlessly integrate with the standard course of care	
Importance result:	Important
Feasibility result:	Undetermined feasibility



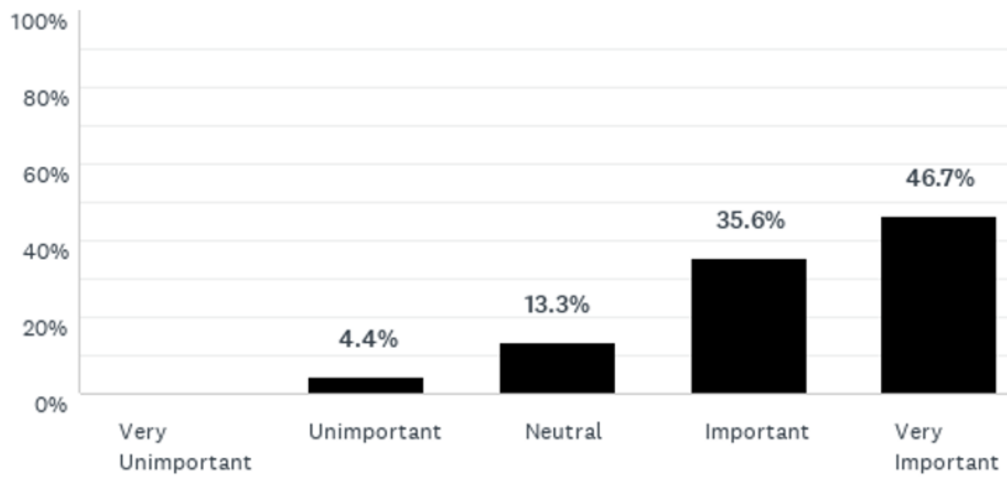


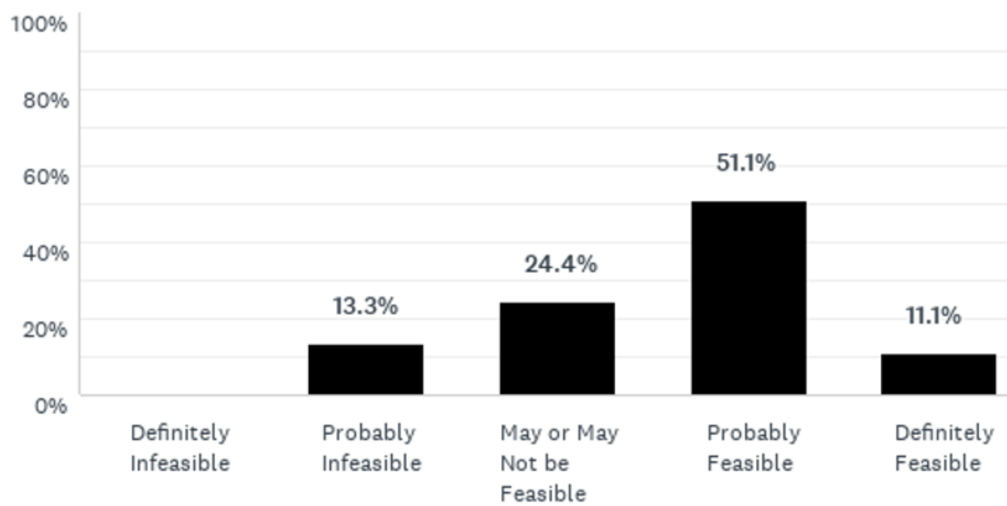
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
5) Ability to evaluate the effectiveness of artificial intelligence and machine learning models that use genomic, social determinant, and EHR data	
Importance result:	Important
Feasibility result:	Undetermined feasibility



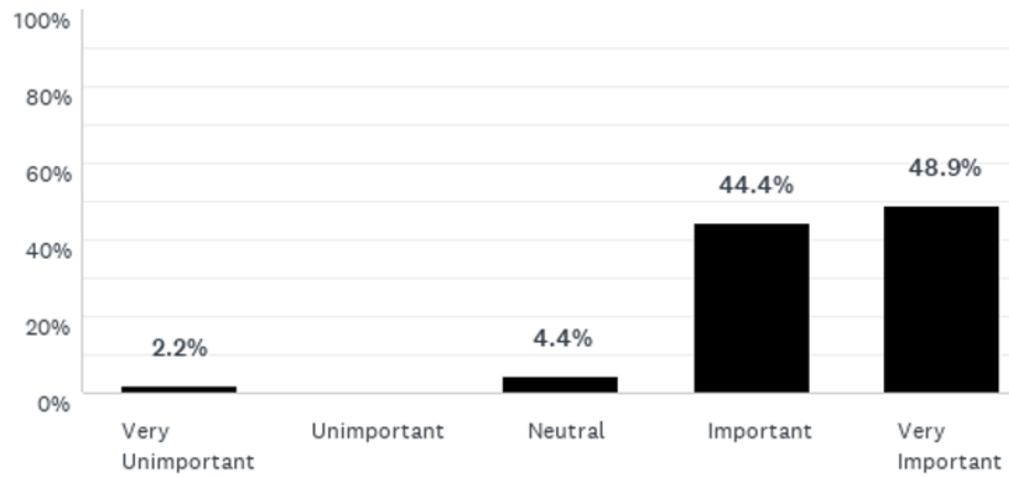


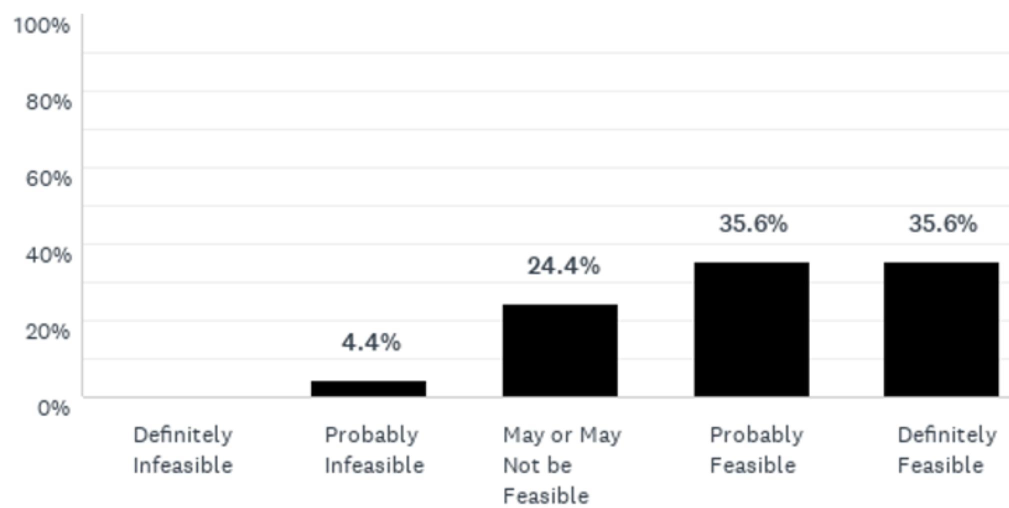
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
6) Ability to execute and maintain artificial intelligence and machine learning models and integrate them into clinicians' workflows seamlessly	
Importance result:	Important
Feasibility result:	Undetermined feasibility



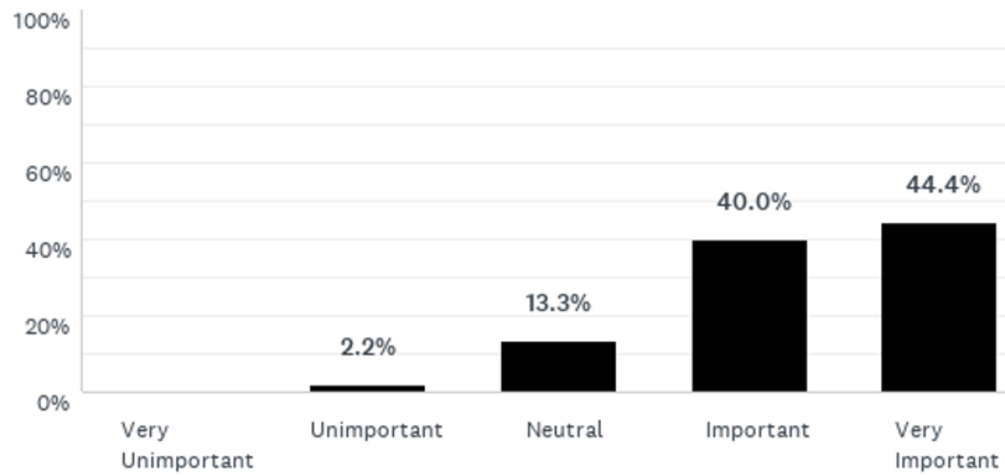


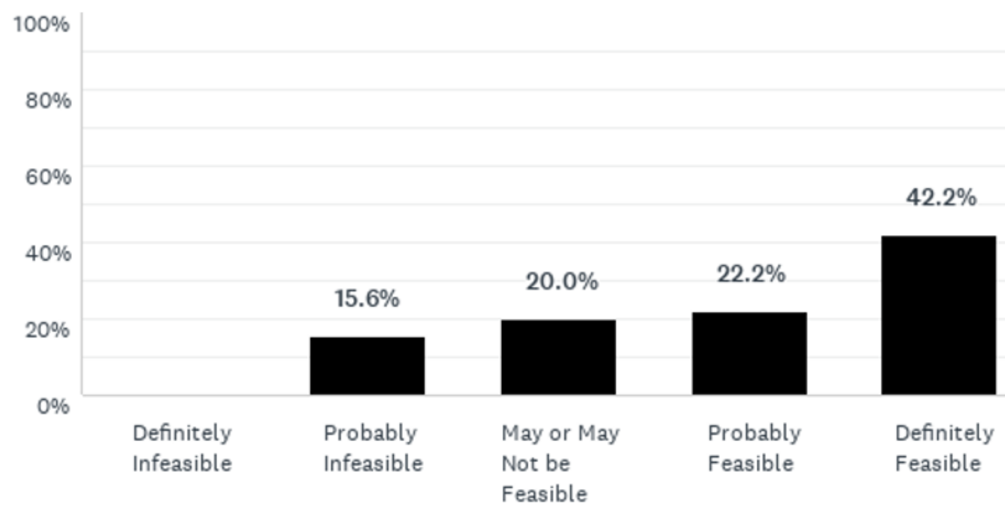
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
7) Ability to rapidly adopt new and evolving standards (e.g., FHIR and genomic implementation guides)	
Importance result:	Important
Feasibility result:	Undetermined feasibility



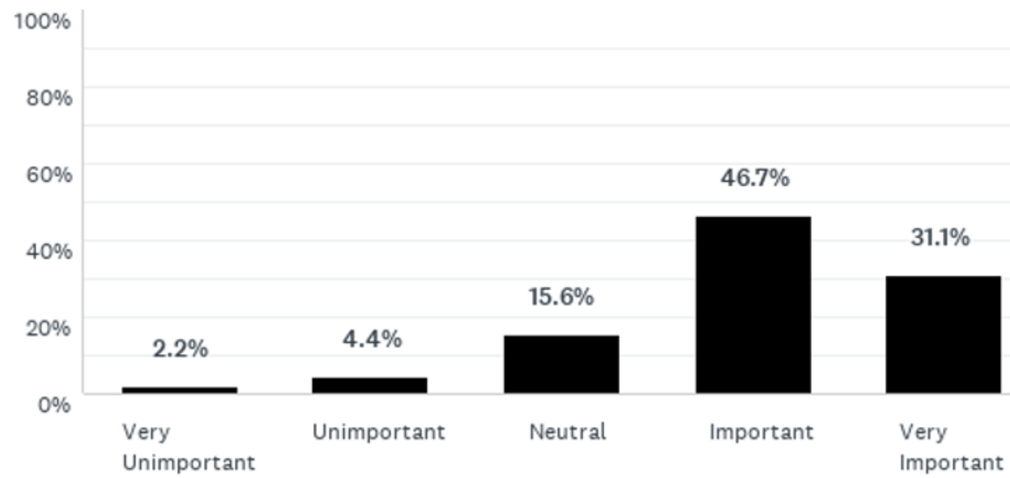


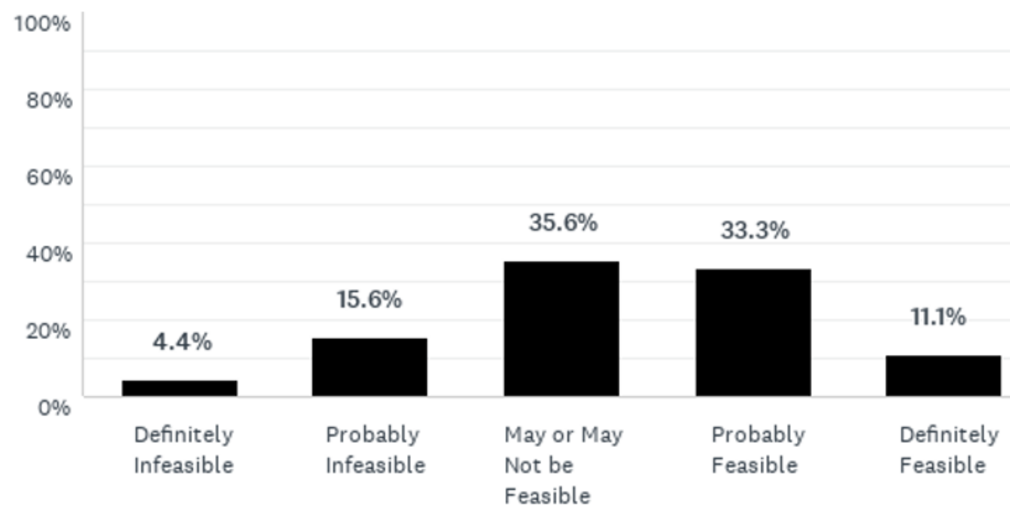
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
8) Ability to record and catalogue raw unstructured patient data (e.g., notes, images, etc.)	
<u>Importance result:</u>	Important
<u>Feasibility result:</u>	Undetermined feasibility



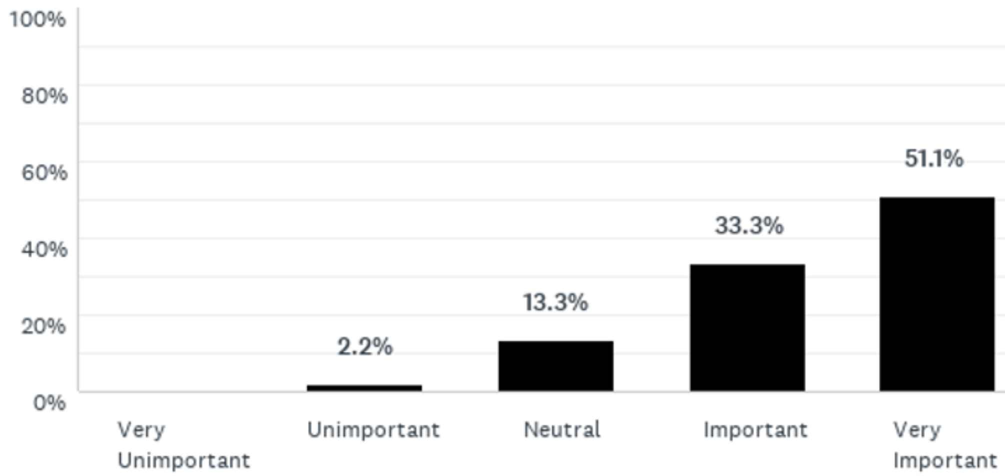


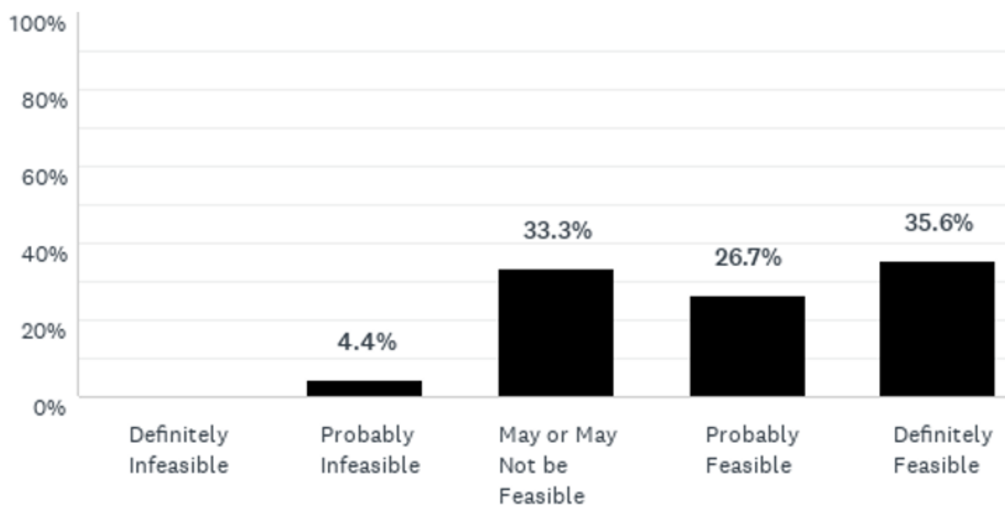
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
9) Access to a global database and a database that is relevant to the local population	
Importance result:	Important
Feasibility result:	Undetermined feasibility



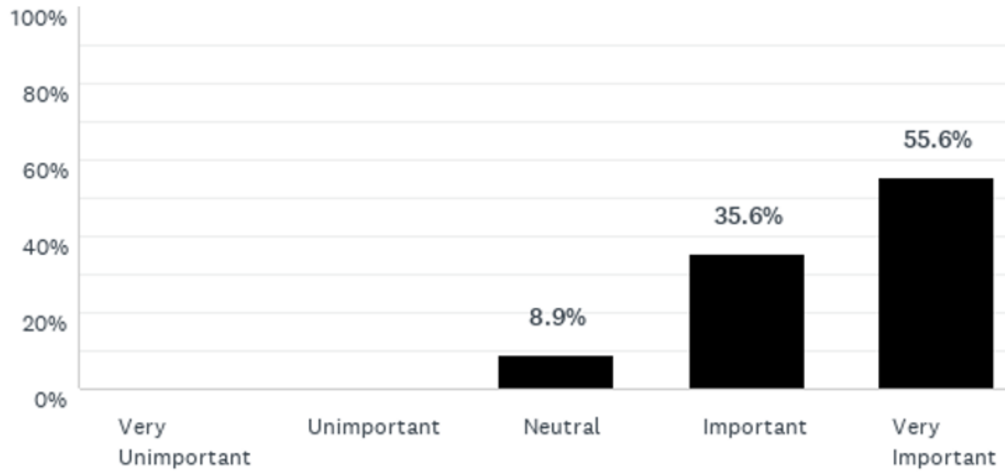


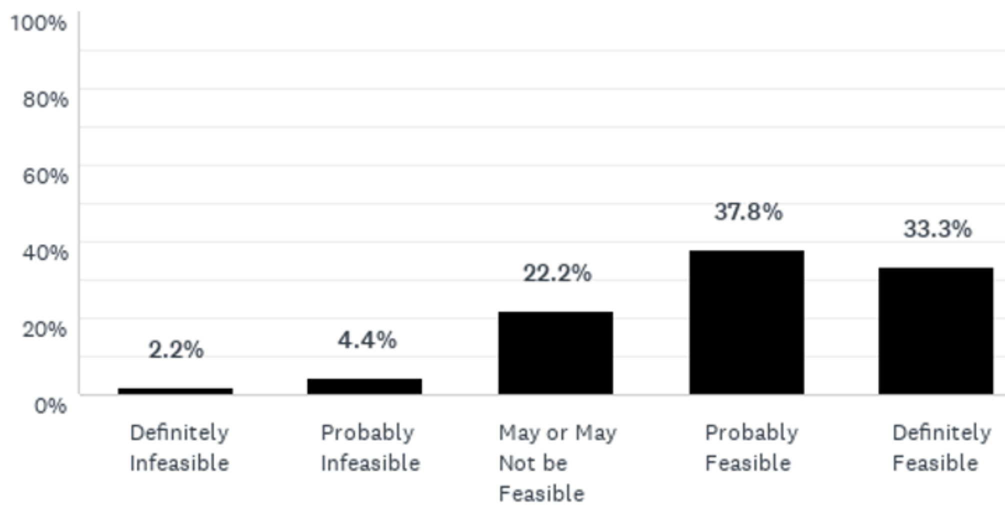
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
10) Access to electronic medical records and clinical genomics research data	
Importance result:	Important
Feasibility result:	Undetermined feasibility



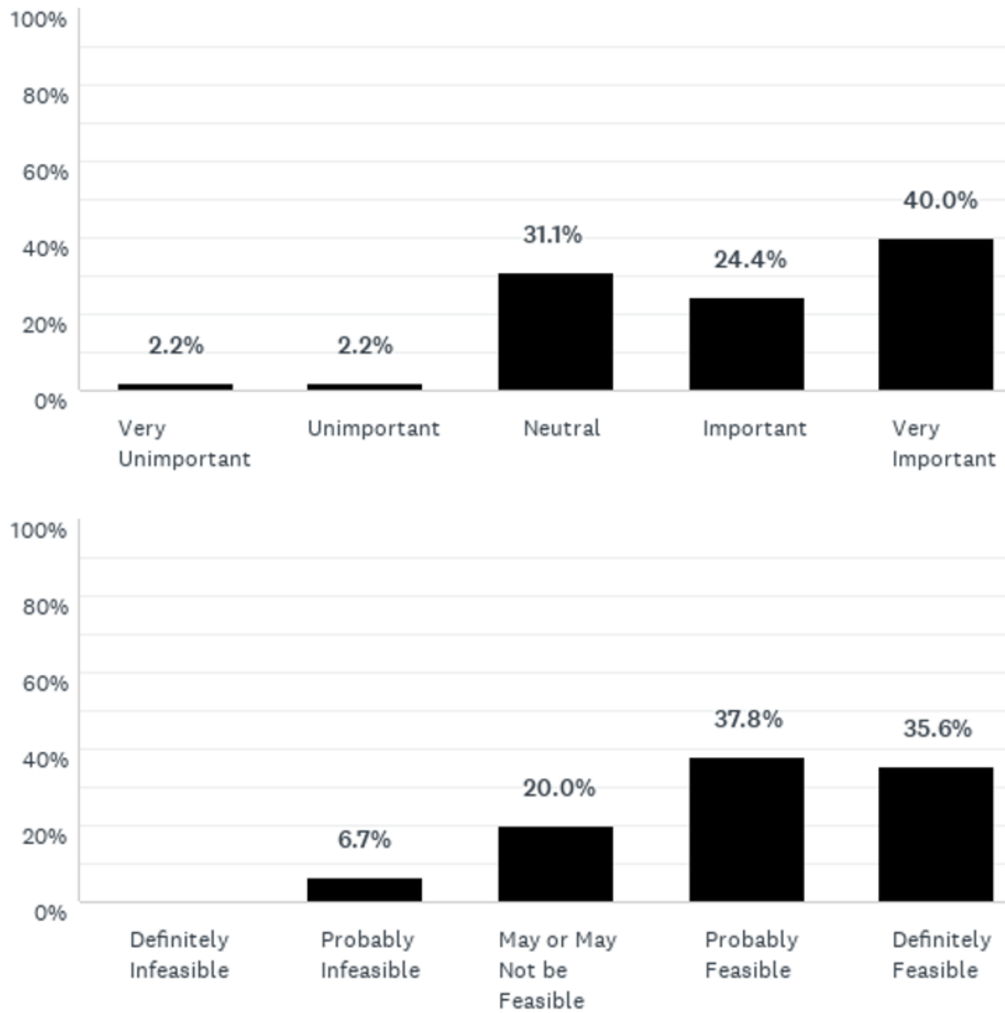


IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
11) Adaptable and expandable data architecture	
<u>Importance result:</u>	Important
<u>Feasibility result:</u>	Undetermined feasibility

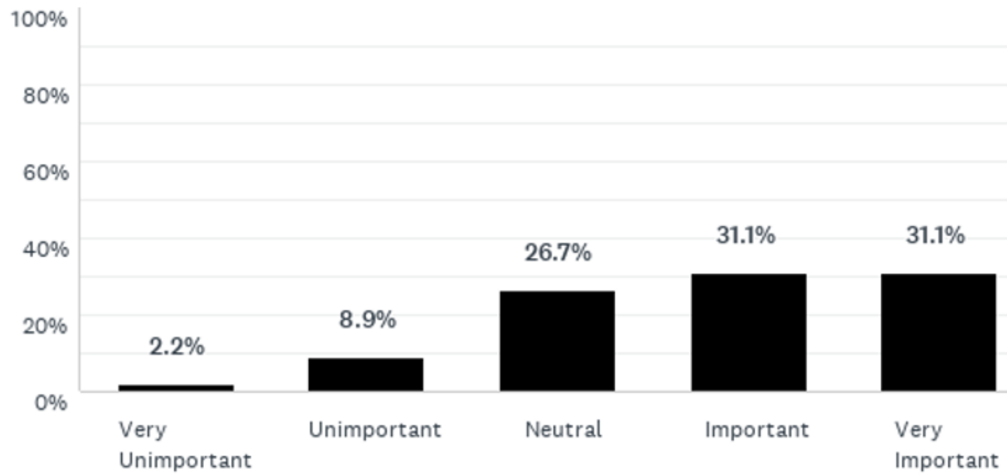


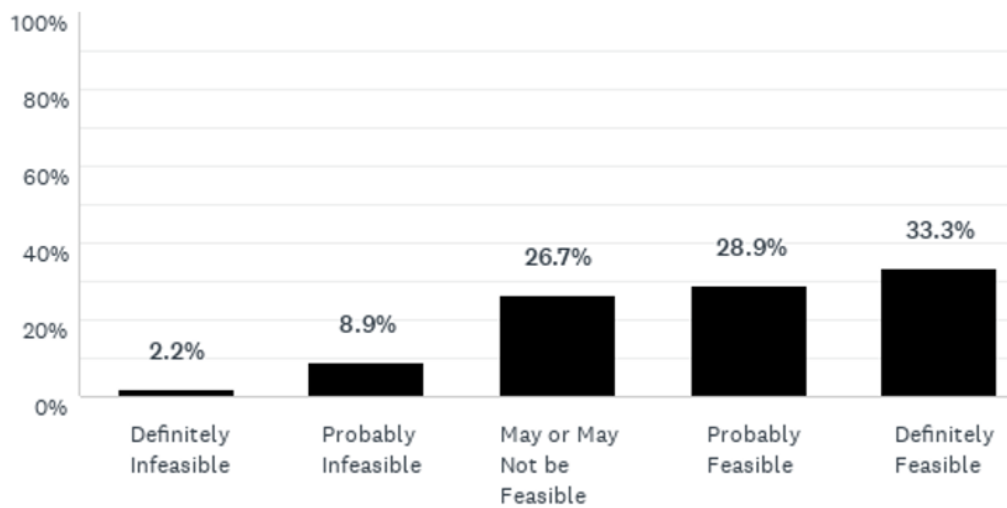


IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
12) Agile management	
<u>Importance result:</u>	Undetermined importance
<u>Feasibility result:</u>	Undetermined feasibility

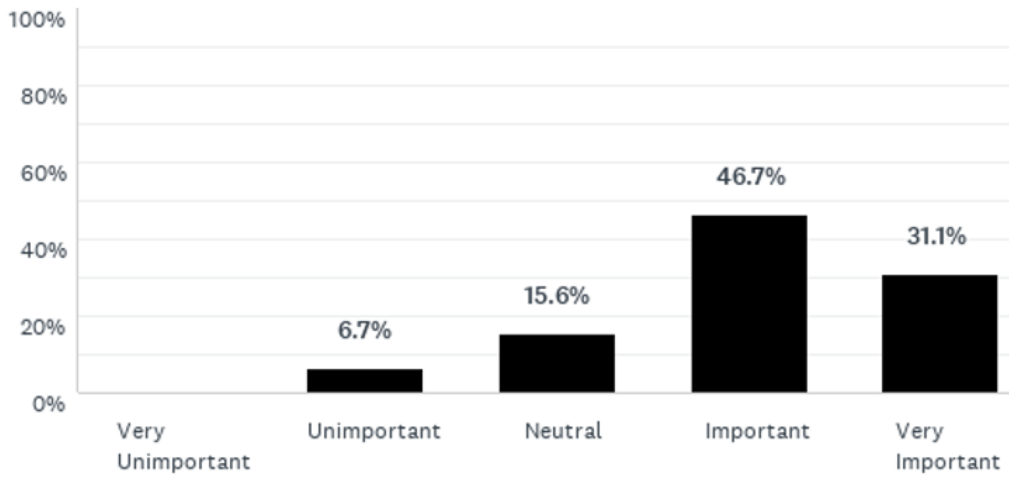


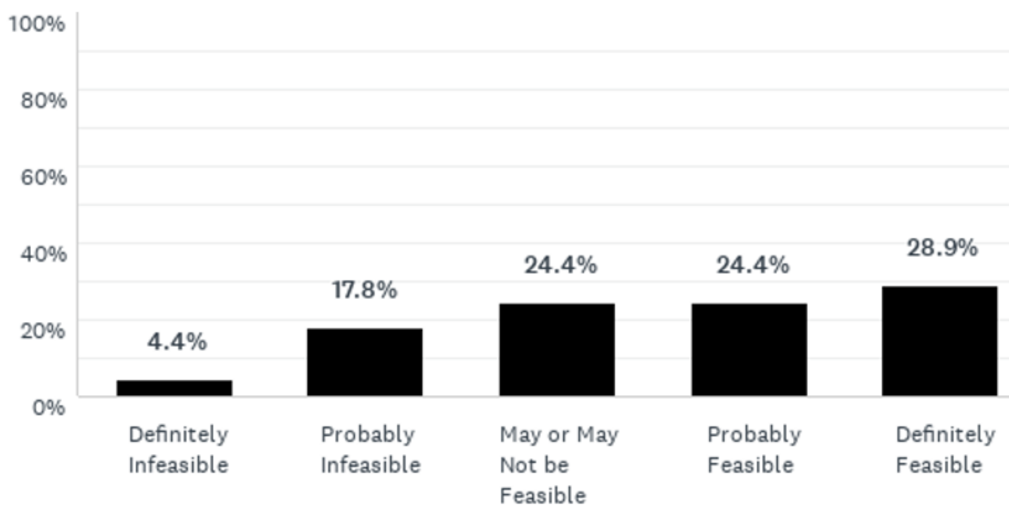
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
13) Agnostic cloud technology and a vendor neutral archive	
<u>Importance result:</u>	Undetermined importance
<u>Feasibility result:</u>	Undetermined feasibility



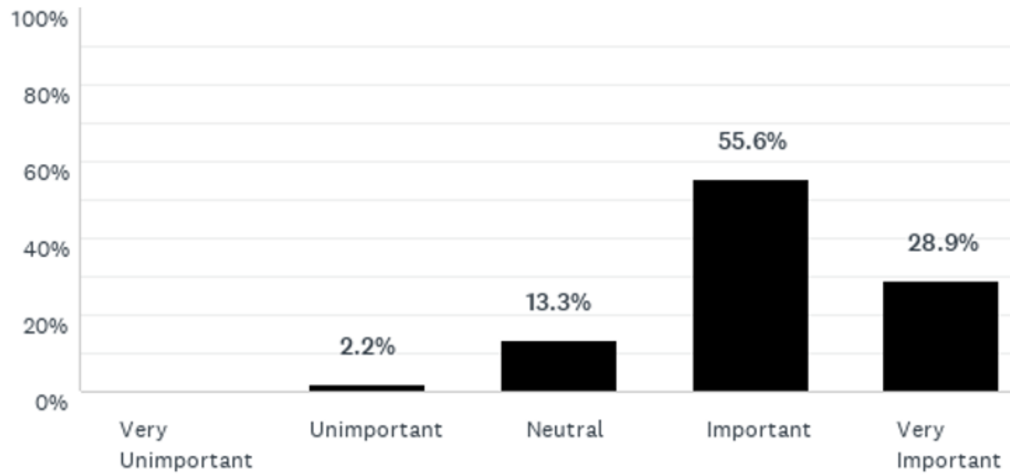


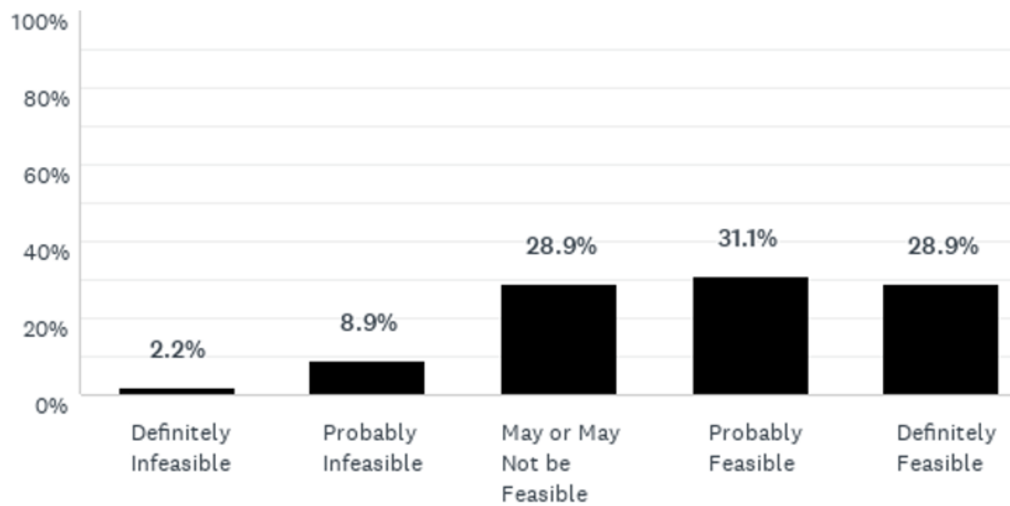
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
14) An integrated data environment that can support medical care, financial transactions, quality improvement, and research	
Importance result:	Important
Feasibility result:	Undetermined feasibility



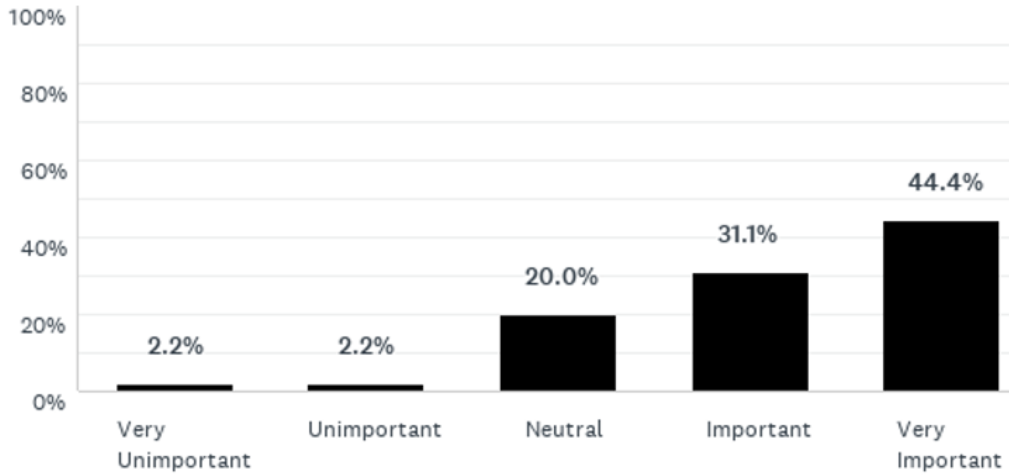


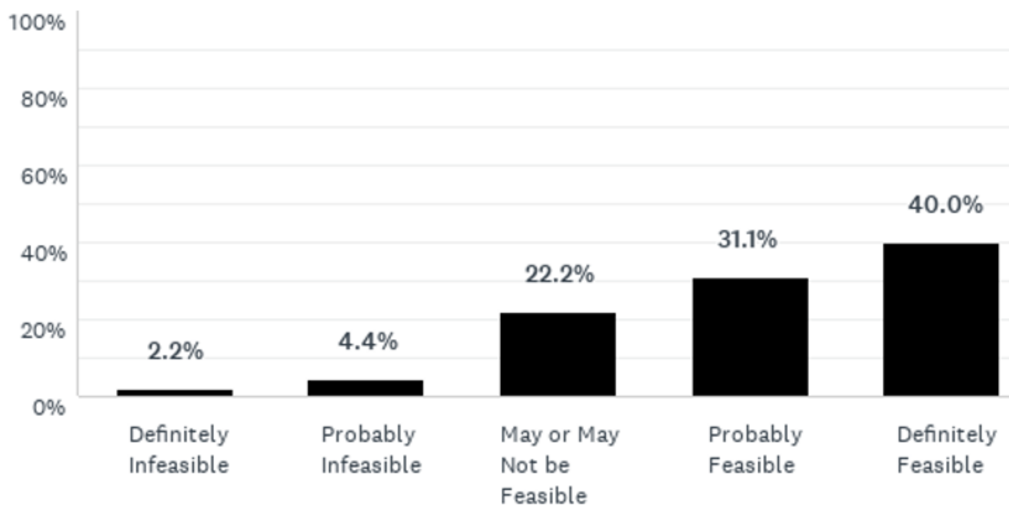
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
15) Analysis provenance and traceability of results	
Importance result:	Important
Feasibility result:	Undetermined feasibility



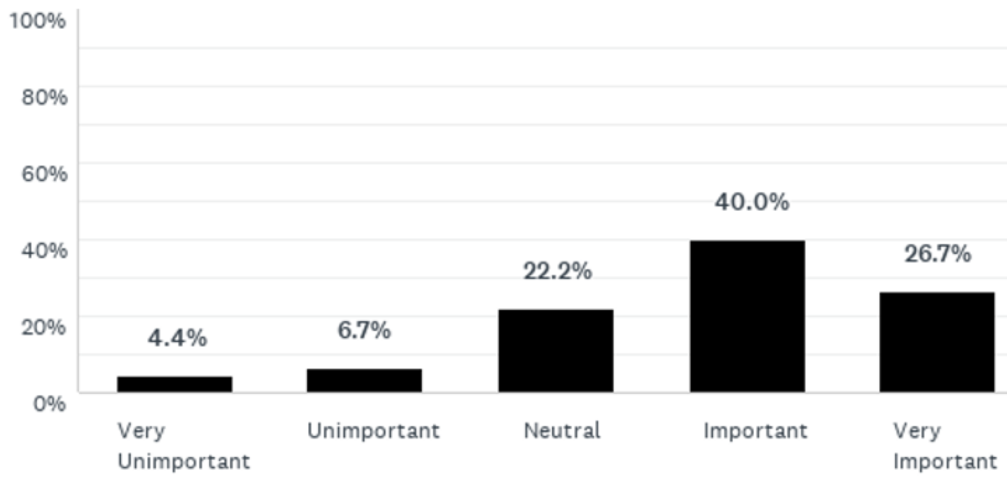


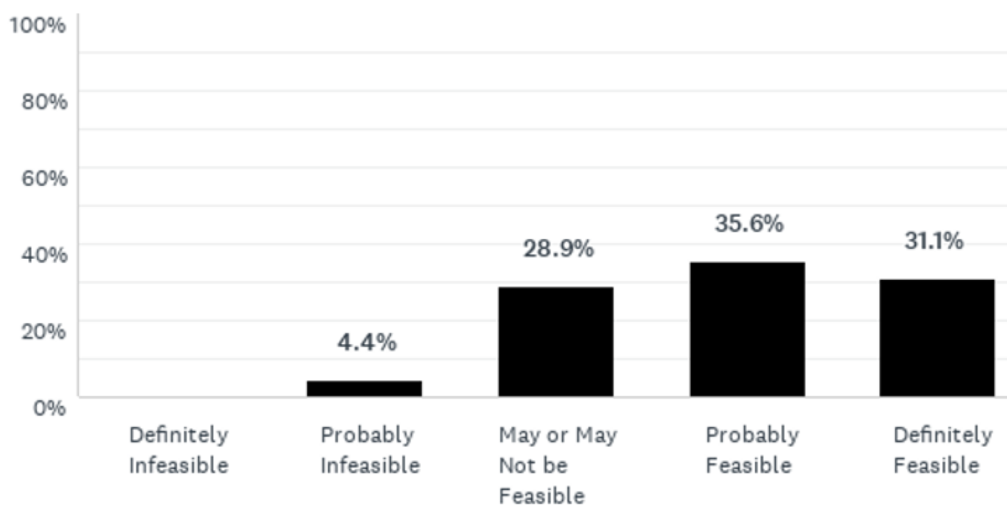
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
16) Application programming interface (API) with labs that offer genetic or precision testing	
Importance result:	Important
Feasibility result:	Undetermined feasibility



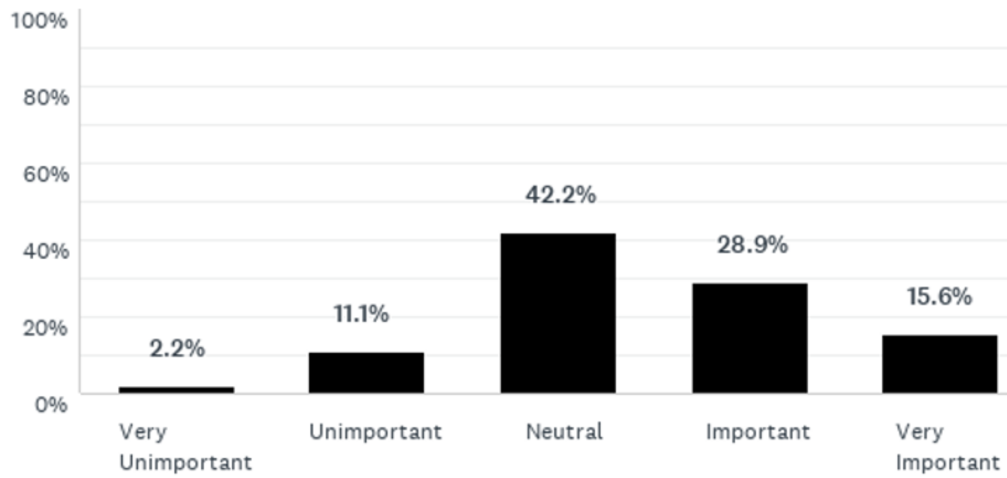


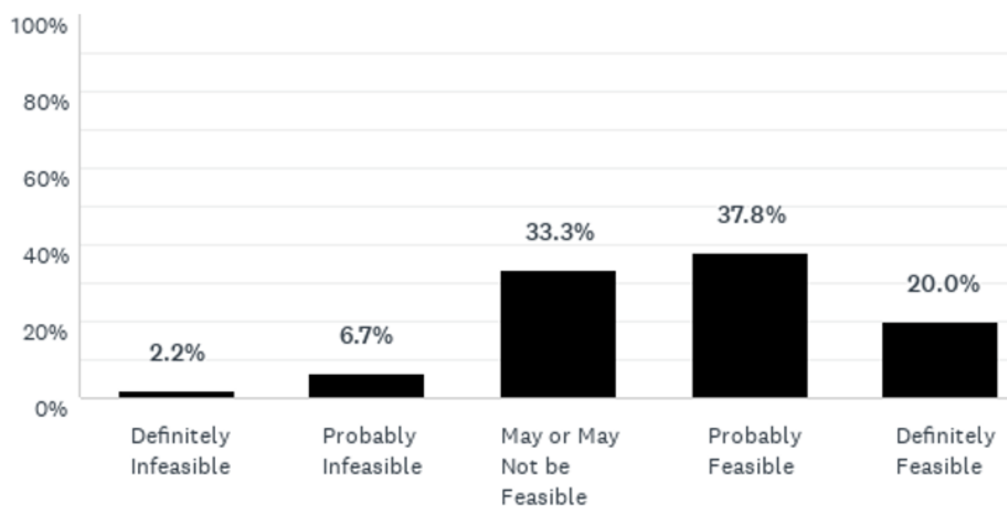
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
17) Artificial intelligence and machine learning to detect the severity of diseases using computed tomography (CT) images	
<u>Importance result:</u>	Undetermined importance
<u>Feasibility result:</u>	Undetermined feasibility



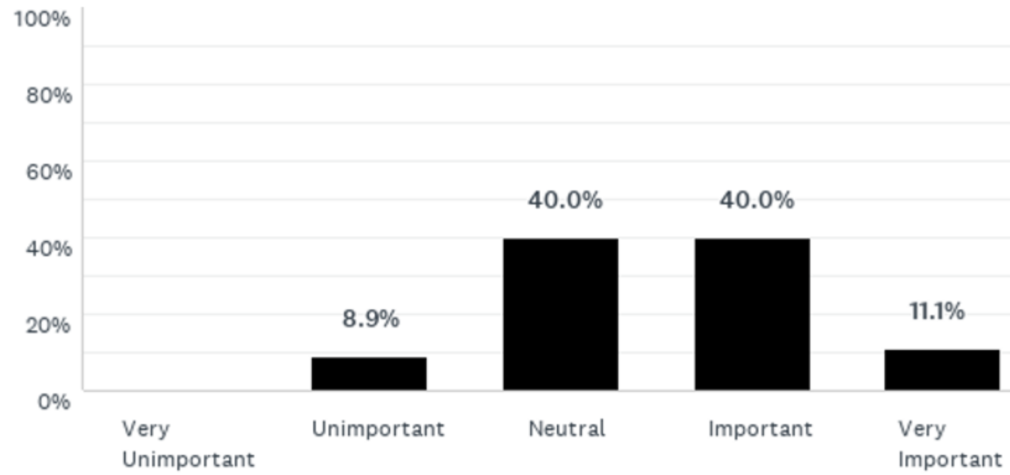


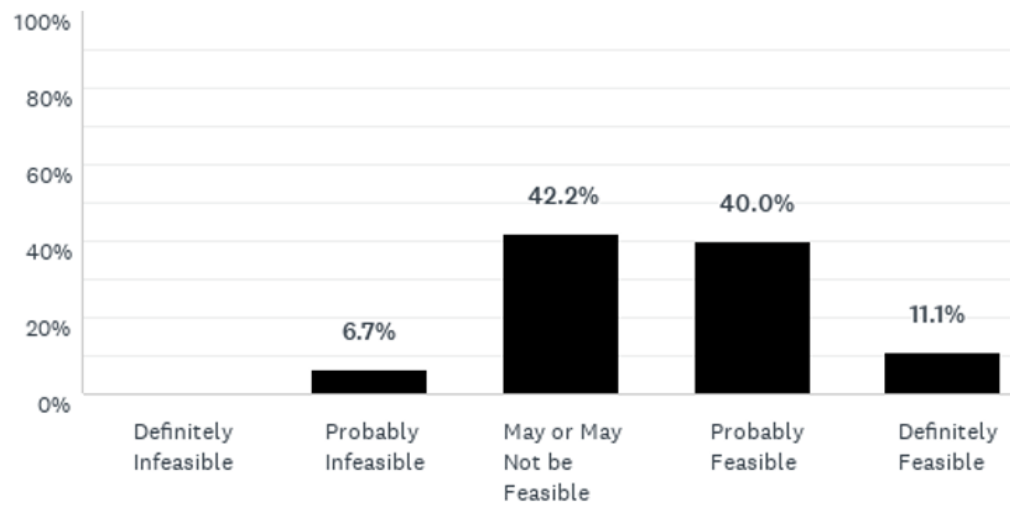
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
18) Artificial intelligence chips (also called artificial intelligence hardware or artificial intelligence accelerators)	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



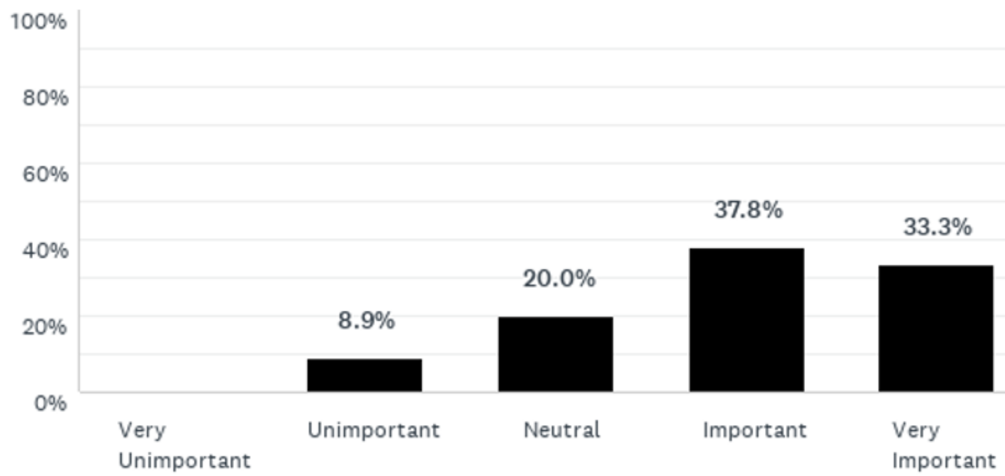


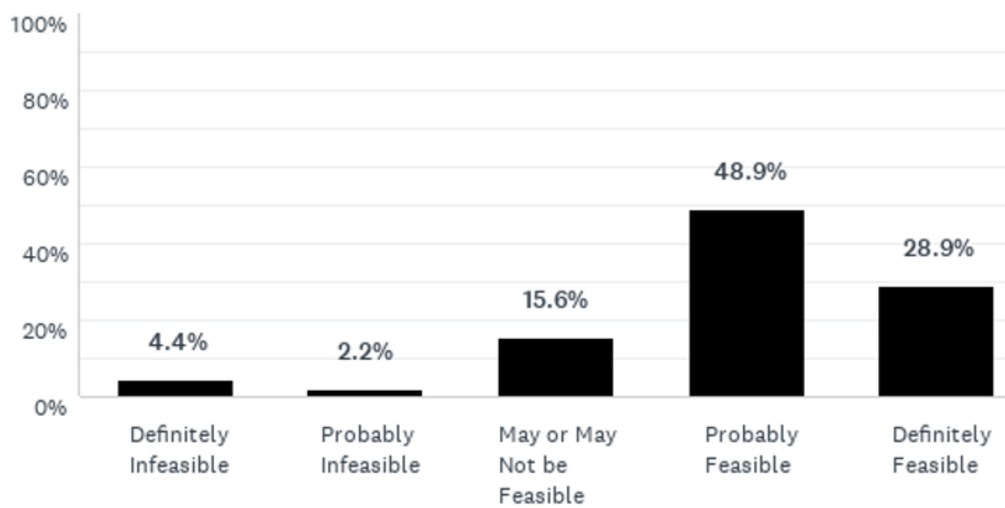
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
19) Artificial intelligence in drug discovery using simple molecular docking and virtual screening approaches	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



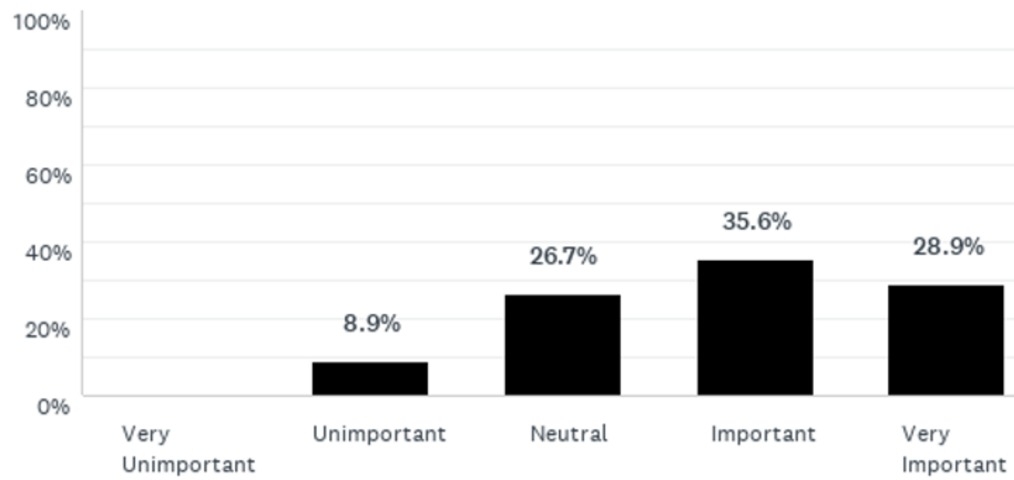


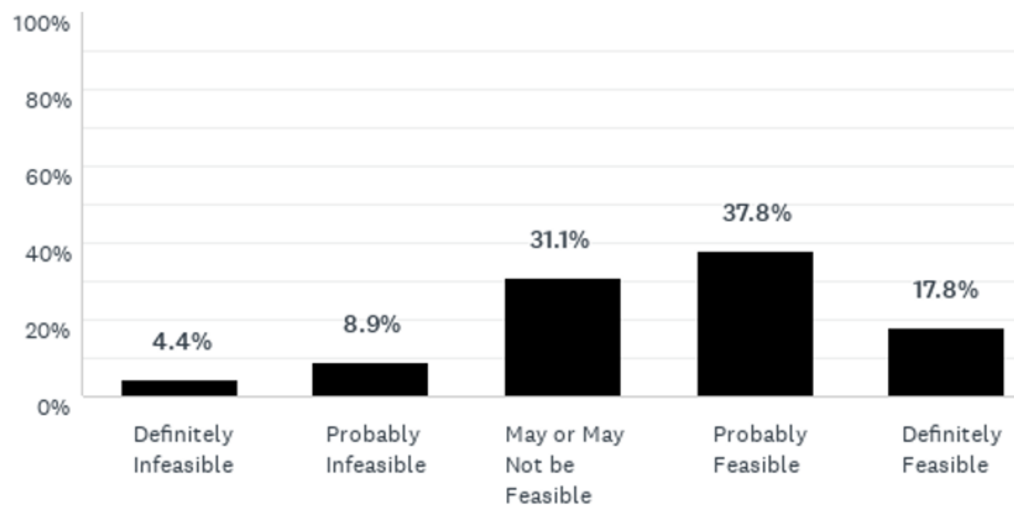
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
20) Artificial intelligence in next generation sequencing technologies	
Importance result:	Undetermined importance
Feasibility result:	Feasible



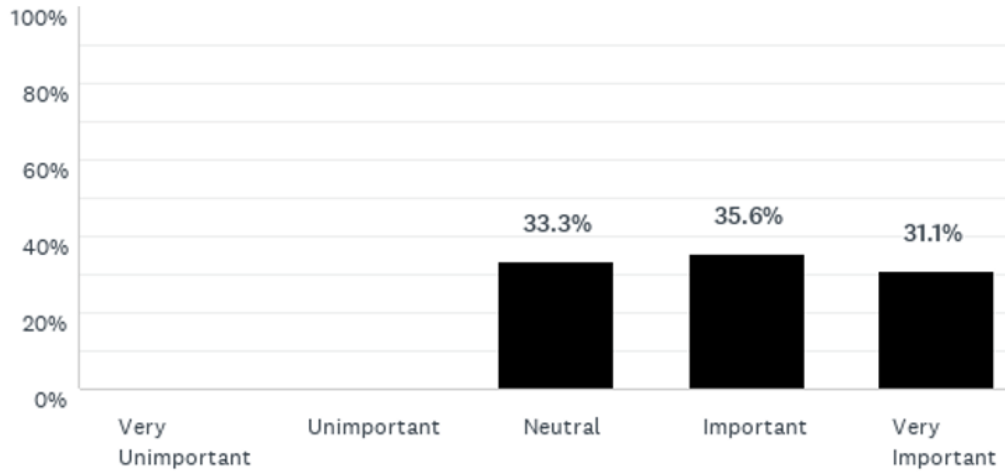


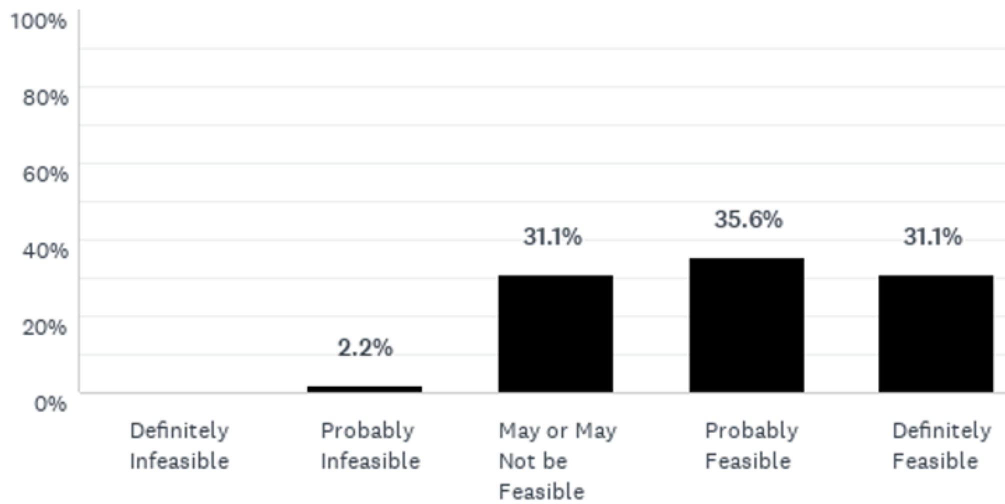
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
21) Artificial intelligence in solving protein structures and understanding their role in different pathway mechanisms	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



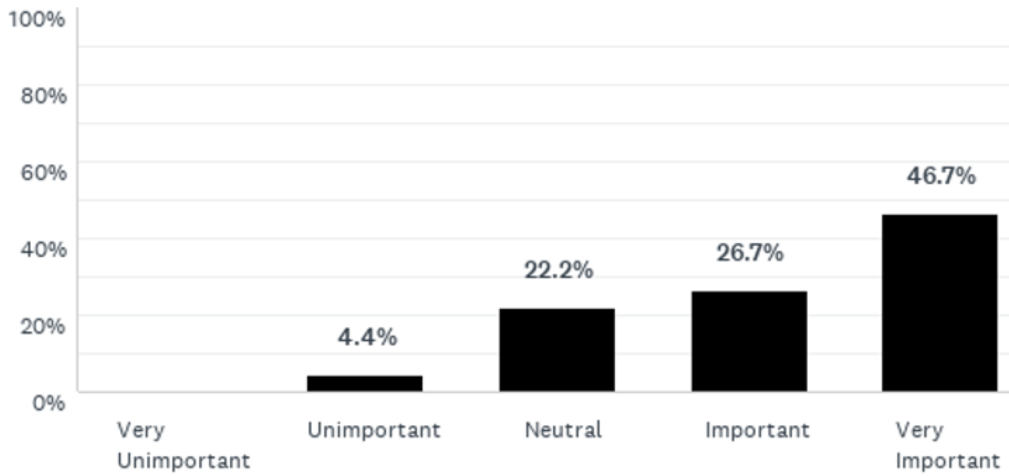


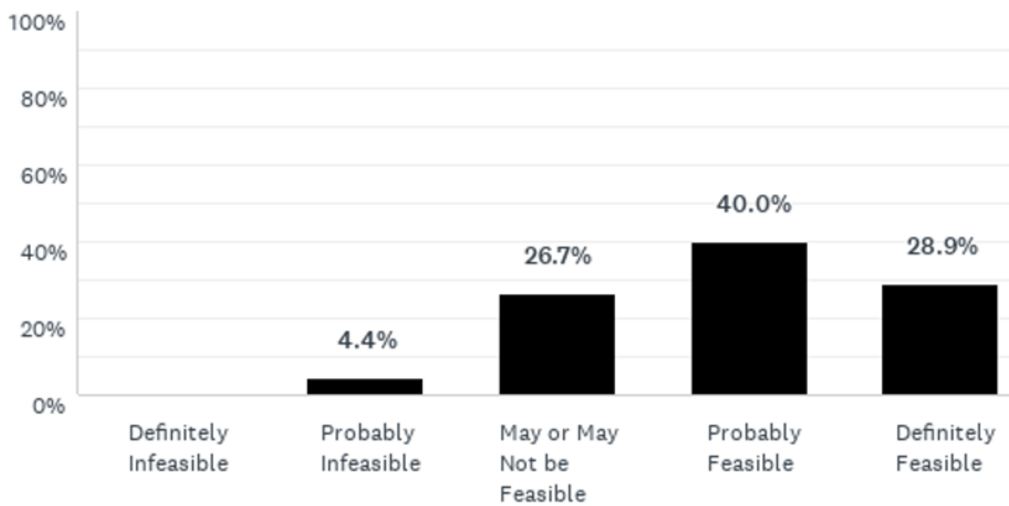
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
22) Artificial intelligence platforms	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



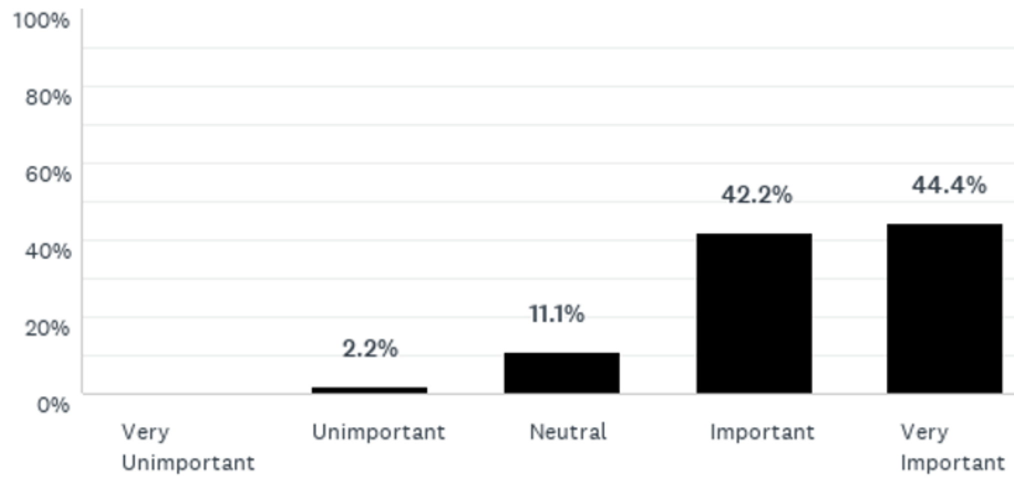


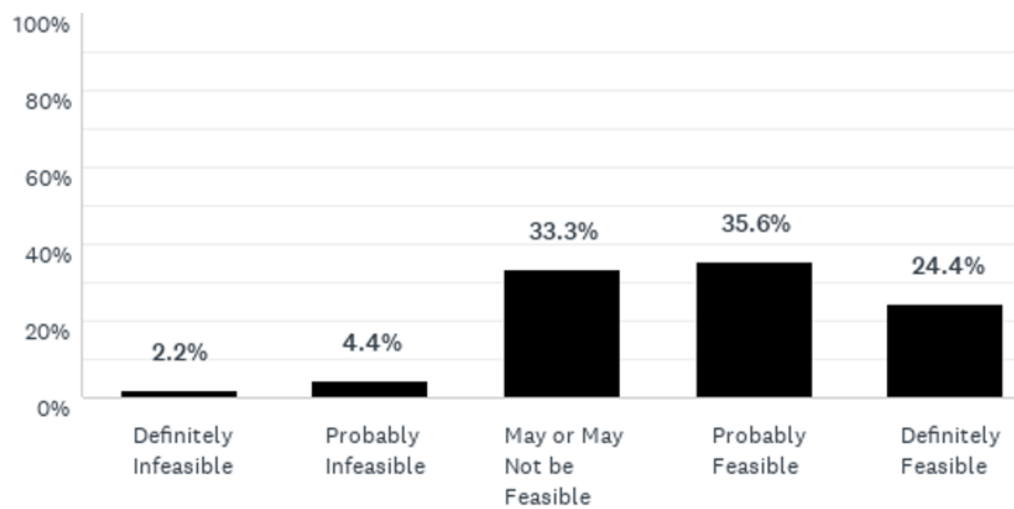
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
23) Automated event detection and reporting systems for drug reaction, medication dispensing, etc.	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



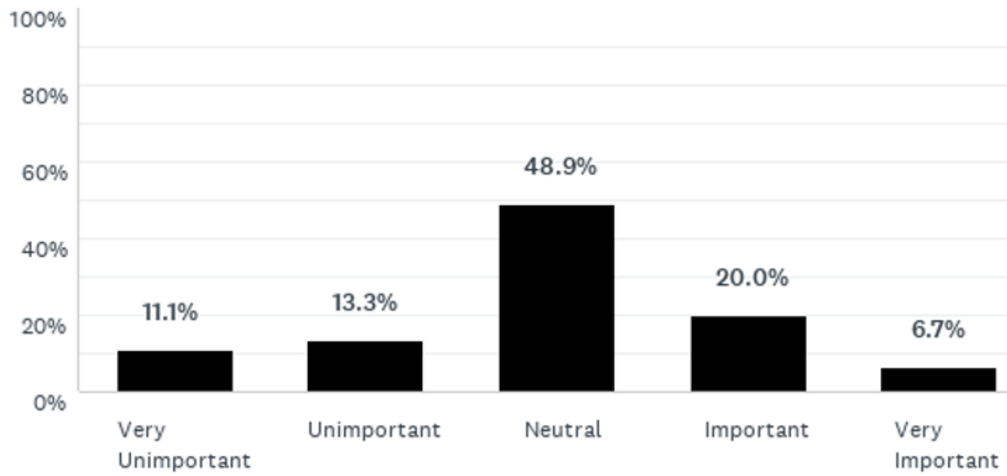


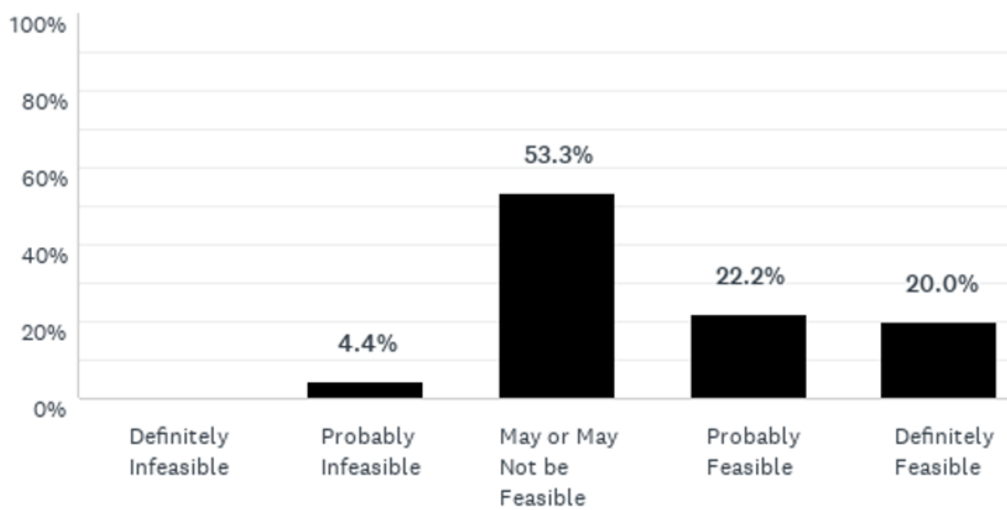
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
24) Big data platform - large scale analytics support incorporating whole-view data for a patient (e.g., clinical, biometric, sequencing, population health, etc.)	
Importance result:	Important
Feasibility result:	Undetermined feasibility



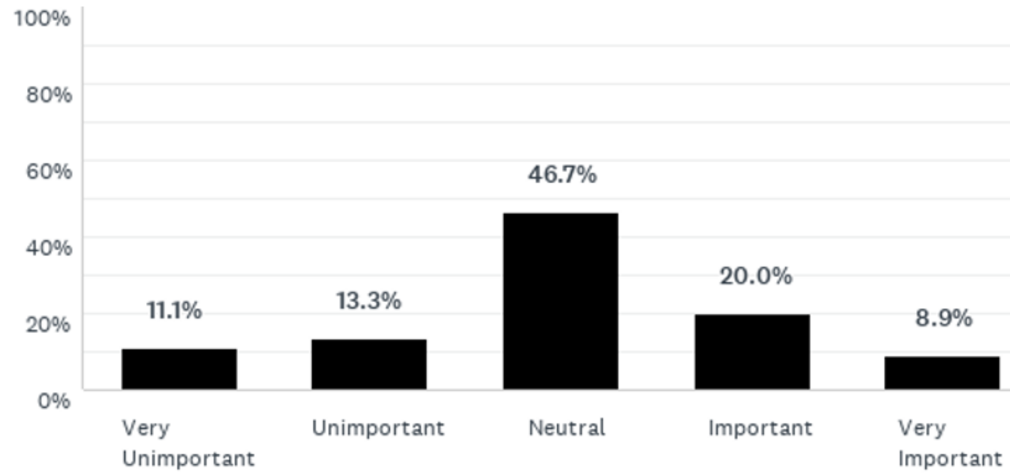


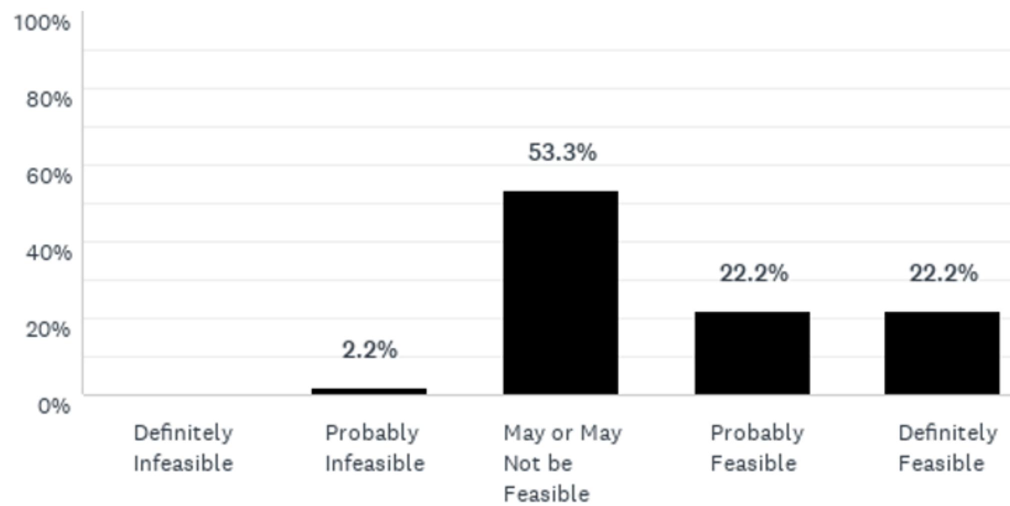
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
25) Blockchain specialist	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



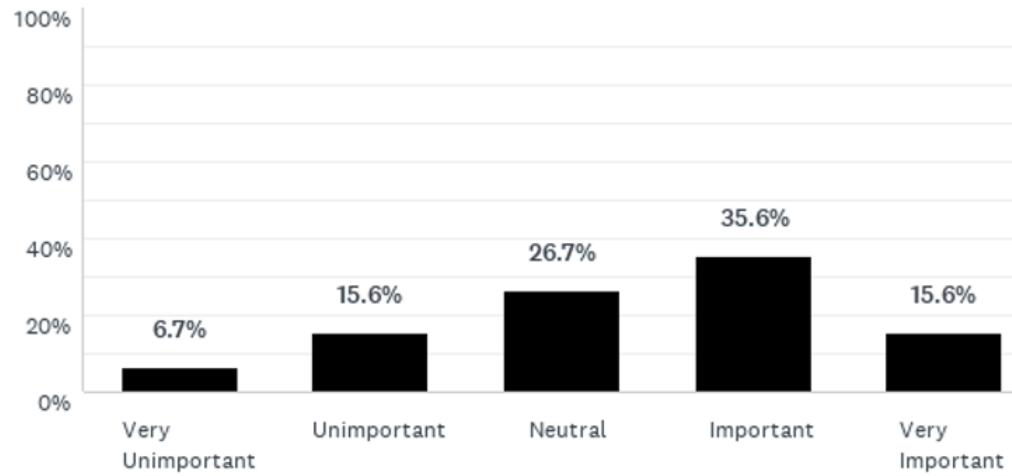


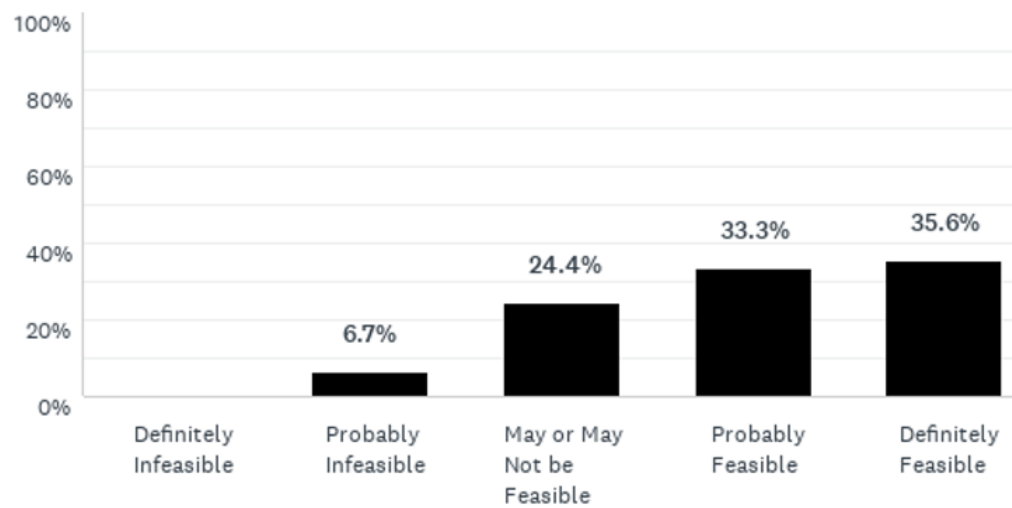
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
26) Blockchain technology	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



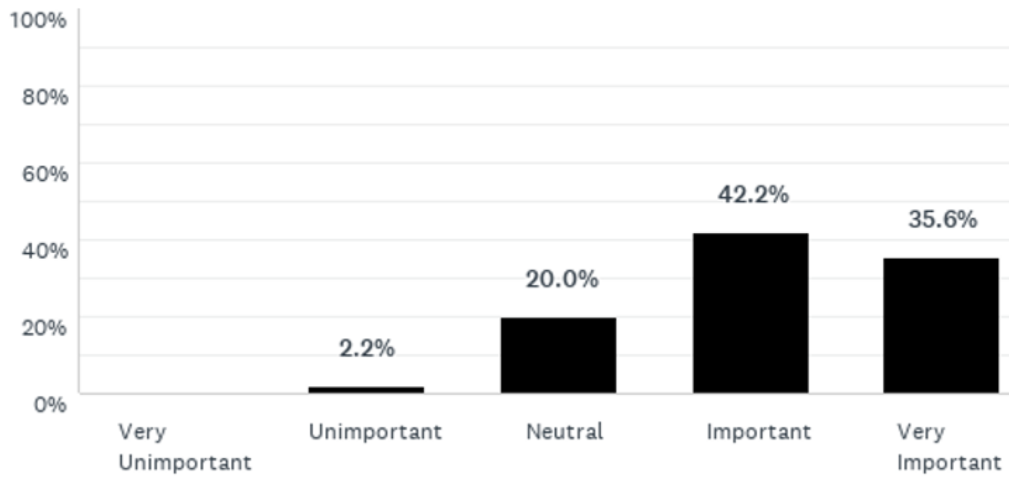


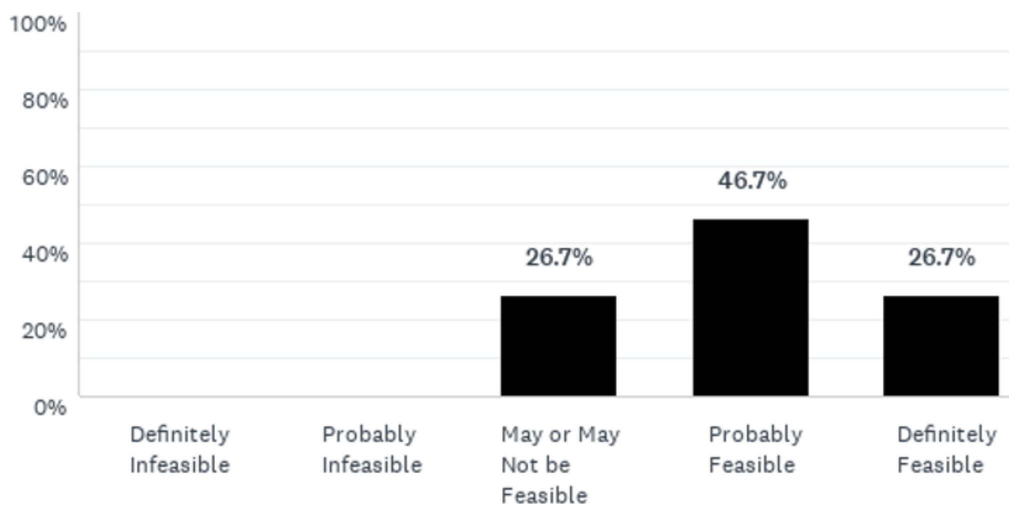
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
27) Chatbots or other tools that streamline patient outreach by not requiring a clinician	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



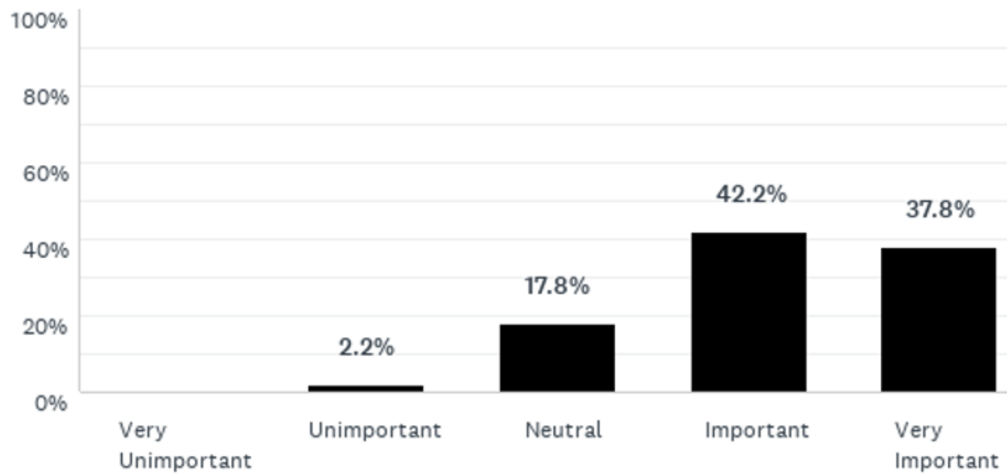


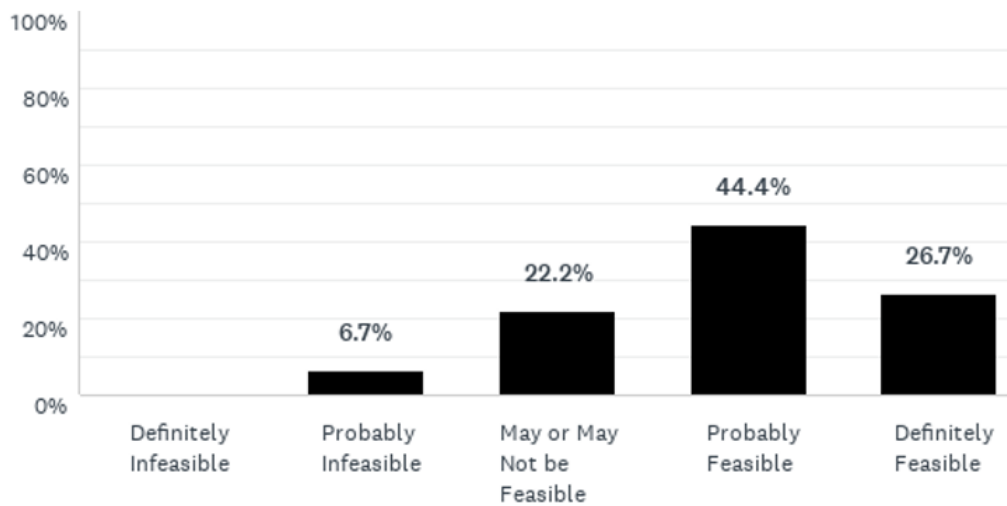
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
28) Clinical bioinformatics in which clinical and bioinformatic aspects can be used with artificial intelligence and machine learning	
<u>Importance result:</u>	Important
<u>Feasibility result:</u>	Undetermined feasibility



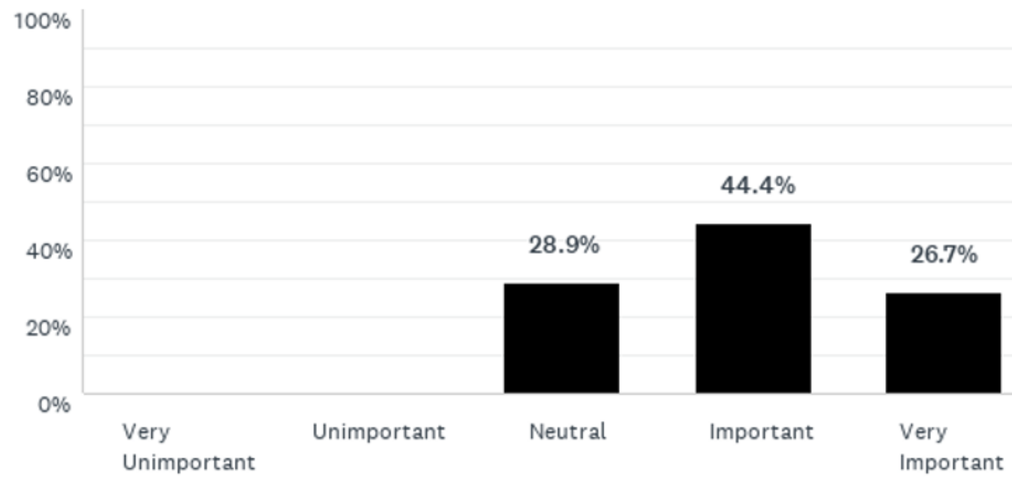


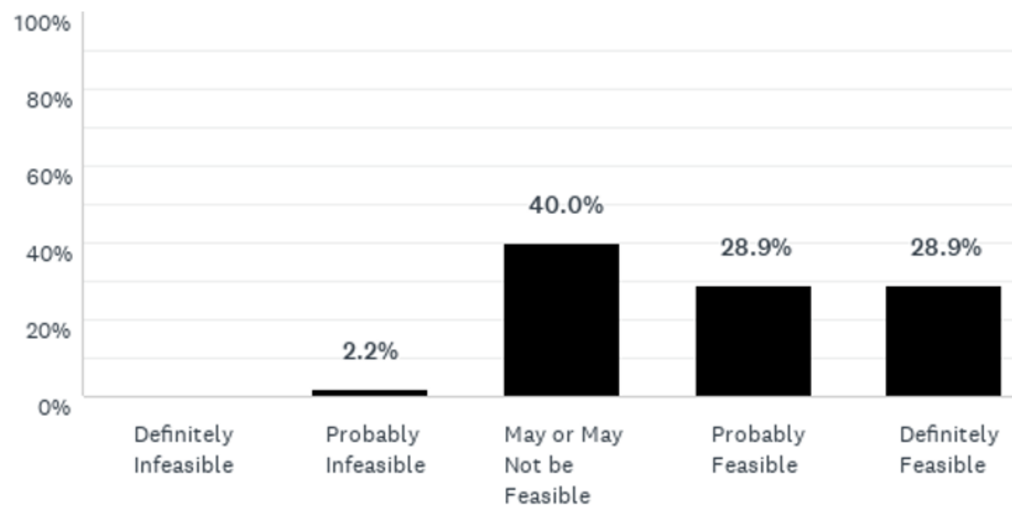
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
29) Clinical decision support customizability	
<u>Importance result:</u>	Important
<u>Feasibility result:</u>	Undetermined feasibility



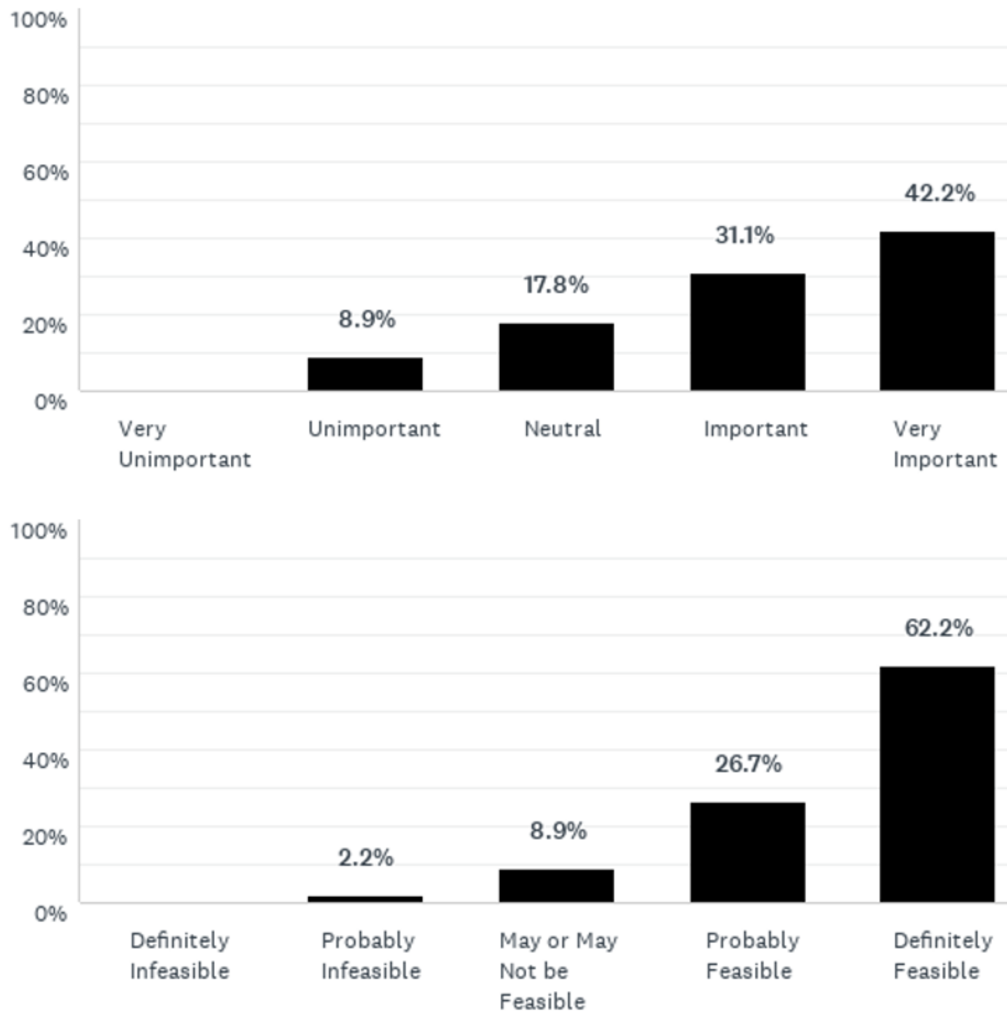


IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
30) Clinical trials infrastructure built in	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility

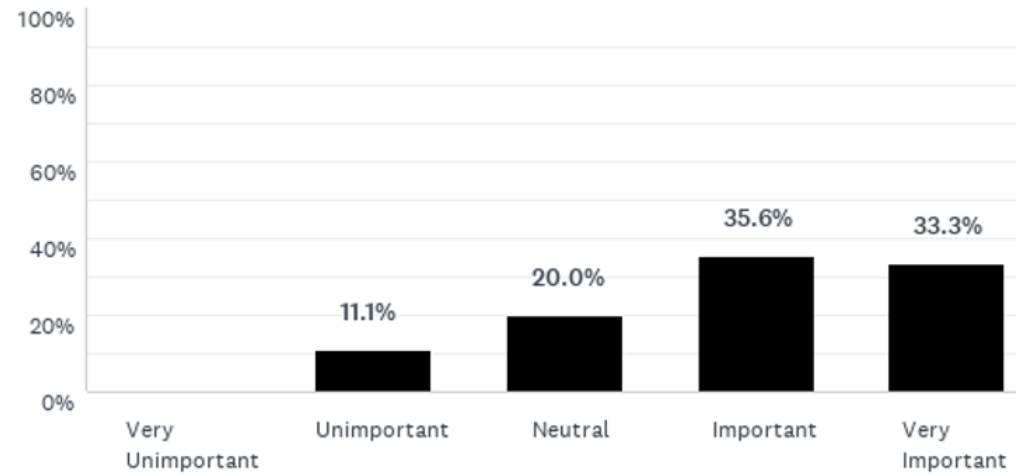


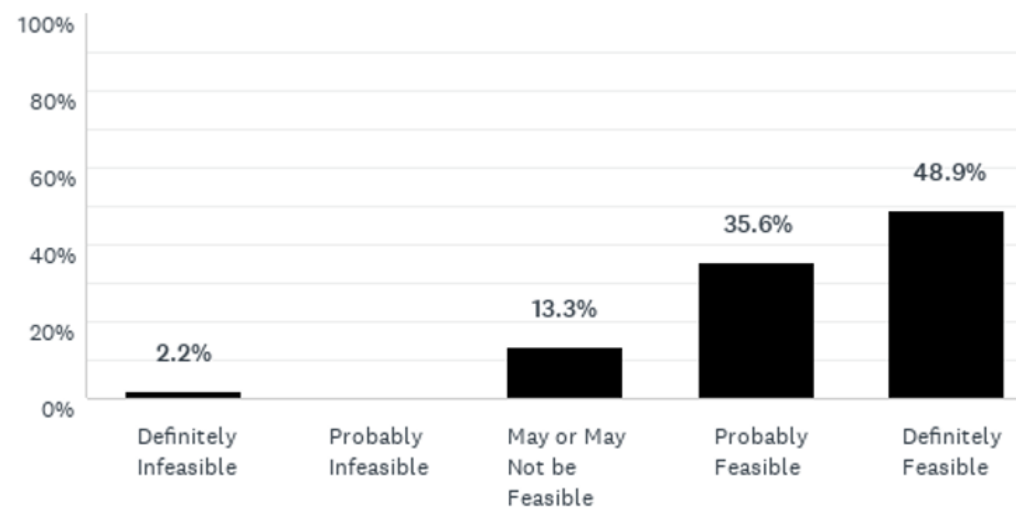


IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
31) Cloud computing	
Importance result:	Undetermined importance
Feasibility result:	Feasible

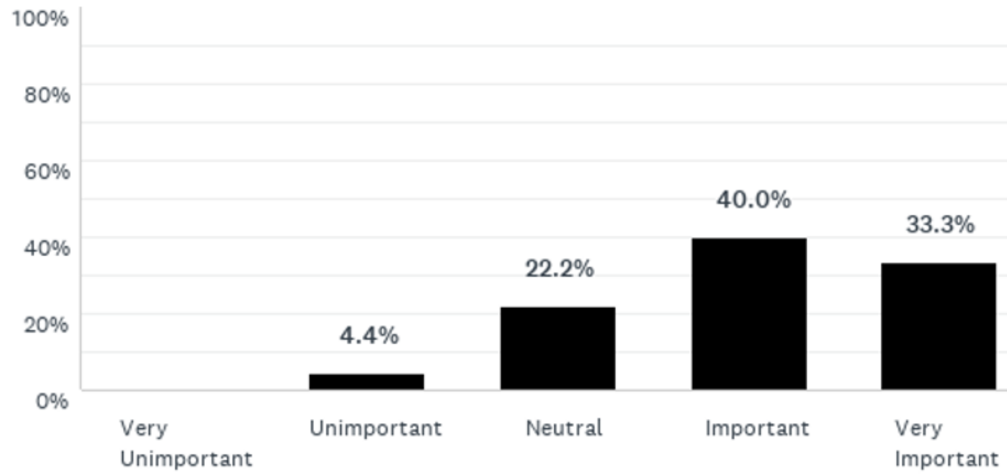


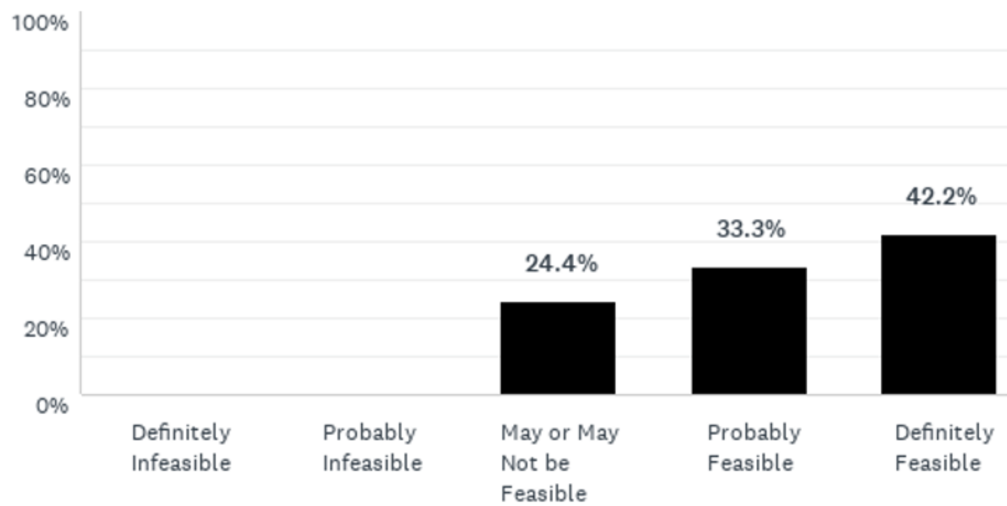
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
32) Cloud services specialist	
Importance result:	Undetermined importance
Feasibility result:	Feasible



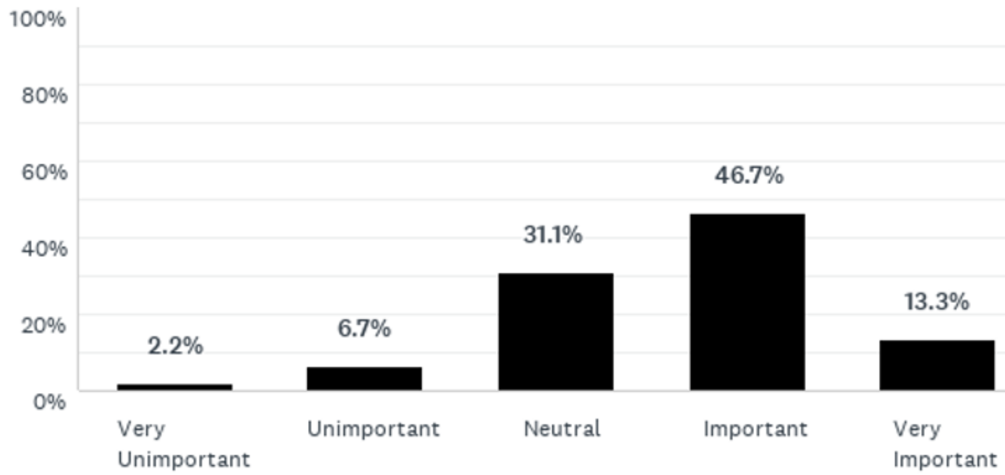


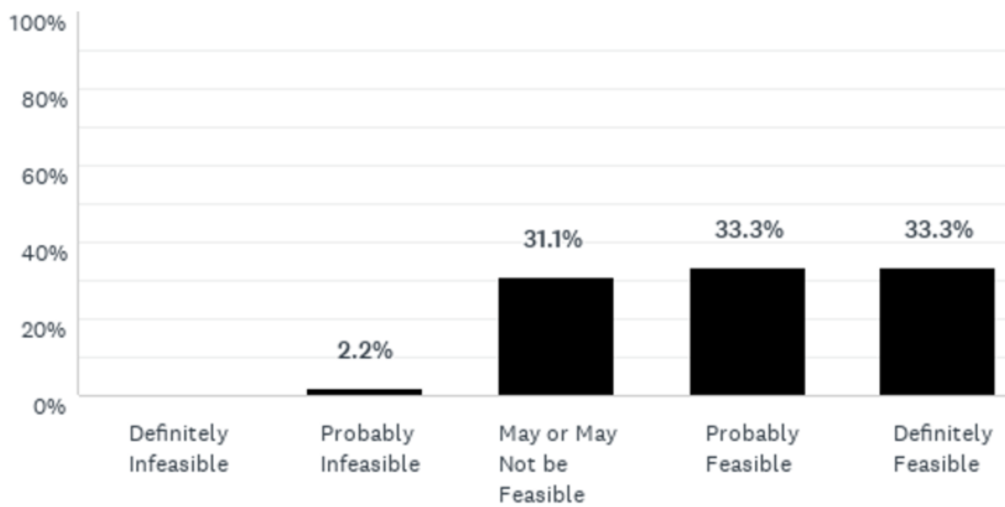
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
33) Computational biology	
Importance result:	Undetermined importance
Feasibility result:	Feasible



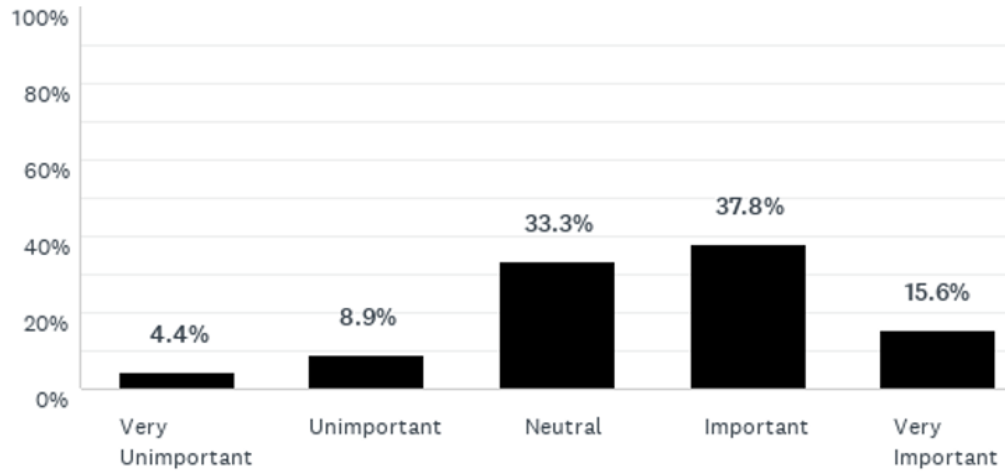


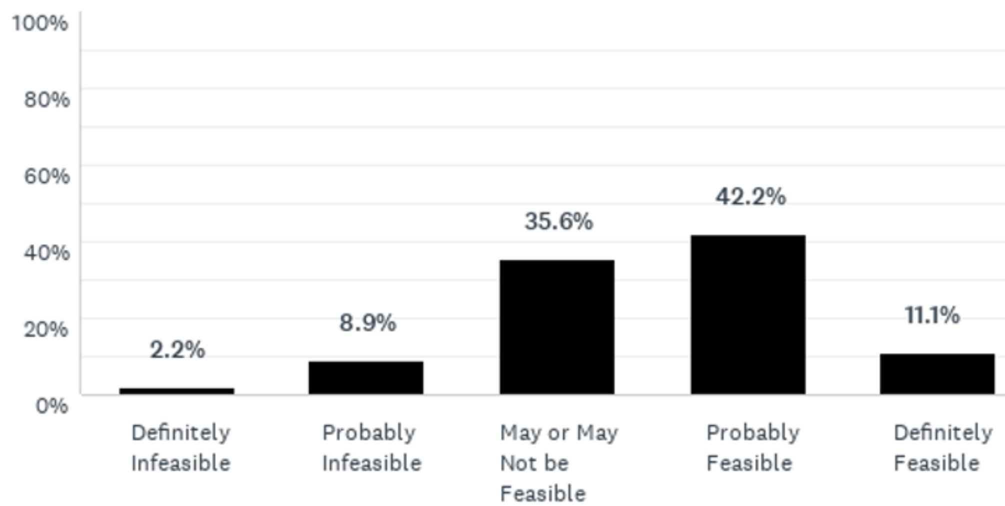
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
34) Computer vision	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



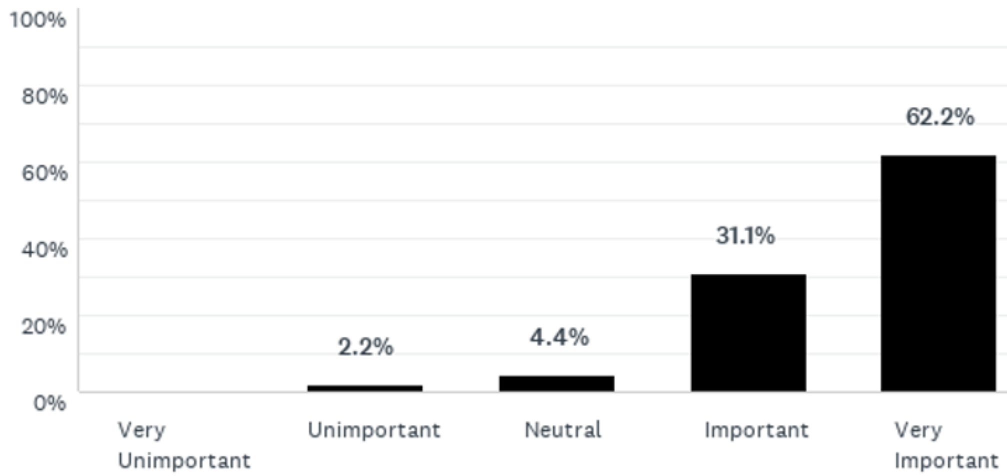


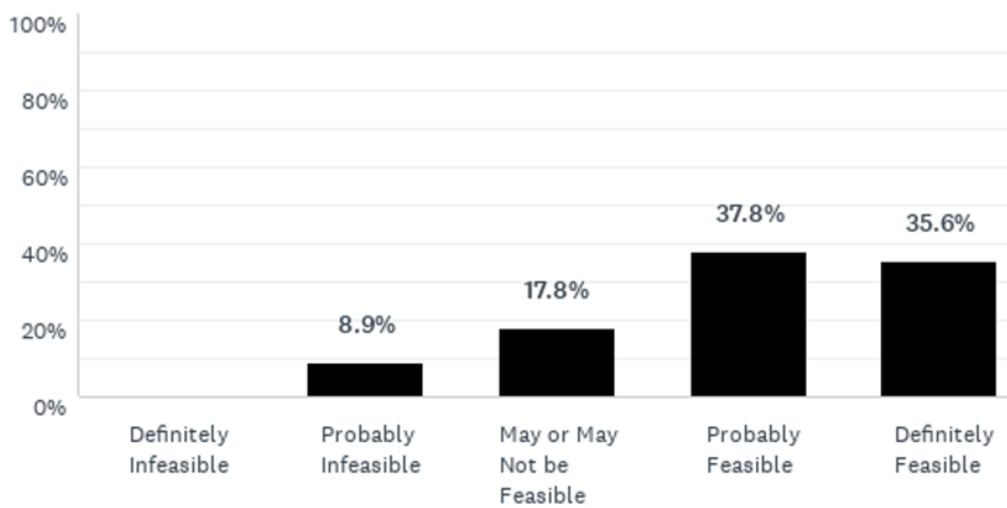
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
35) Conversational artificial intelligence	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



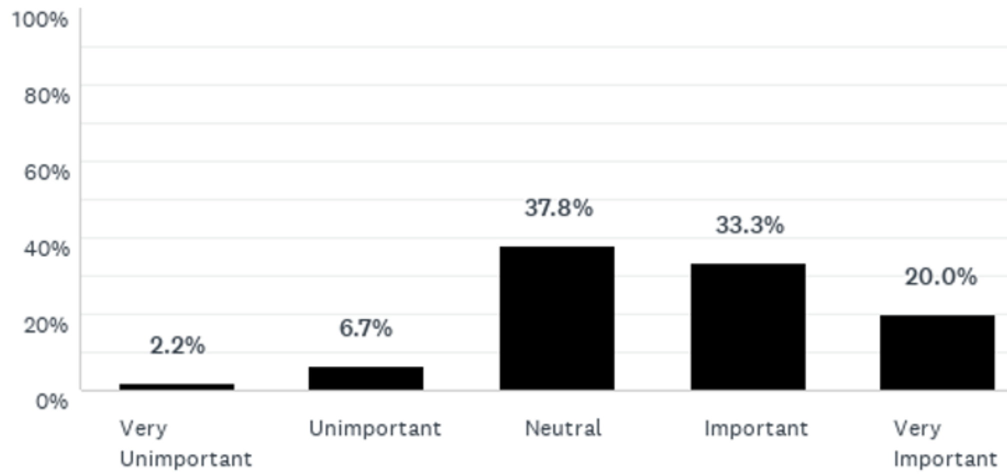


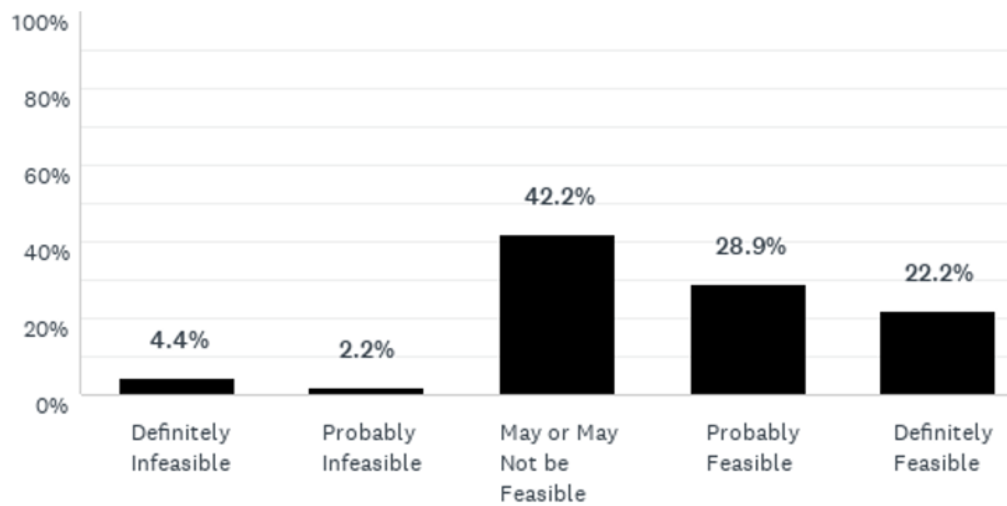
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
36) Data capture for patients in different populations to avoid bias based on location, sex, social determinants of health, or chronic conditions	
Importance result:	Important
Feasibility result:	Undetermined feasibility



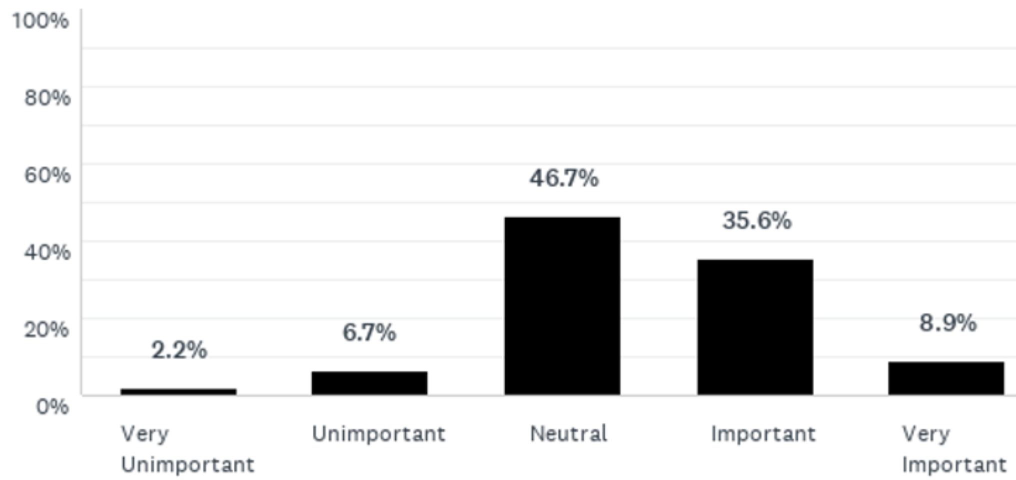


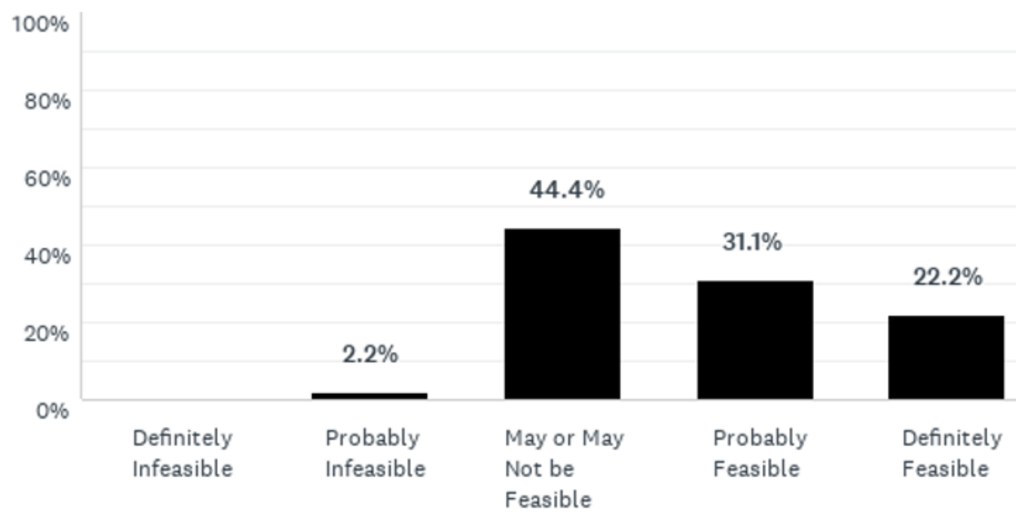
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
37) Data lakes that can be federated	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



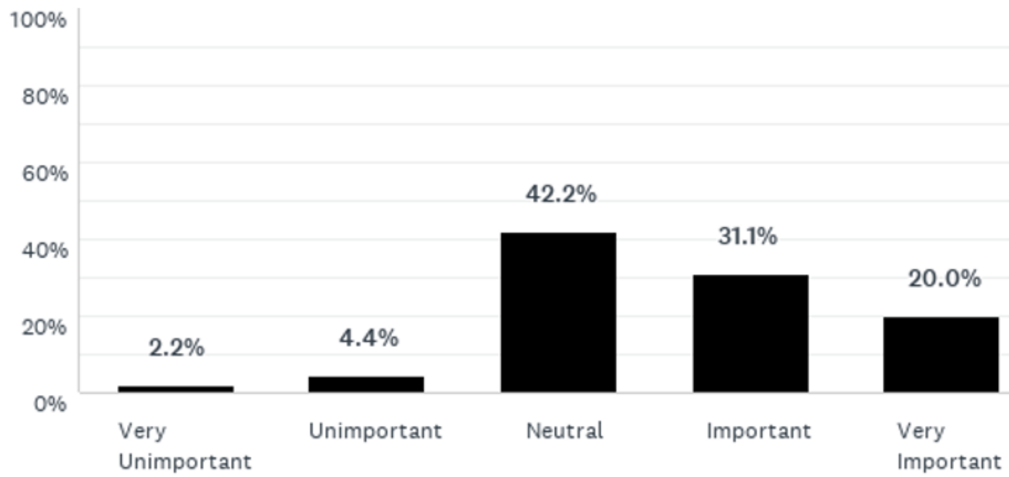


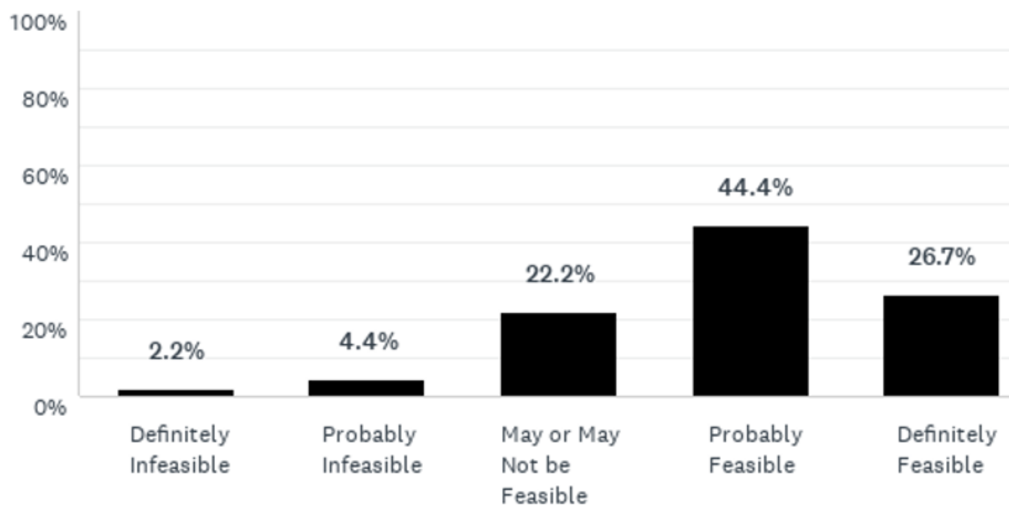
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
38) Drools and CQL developers	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



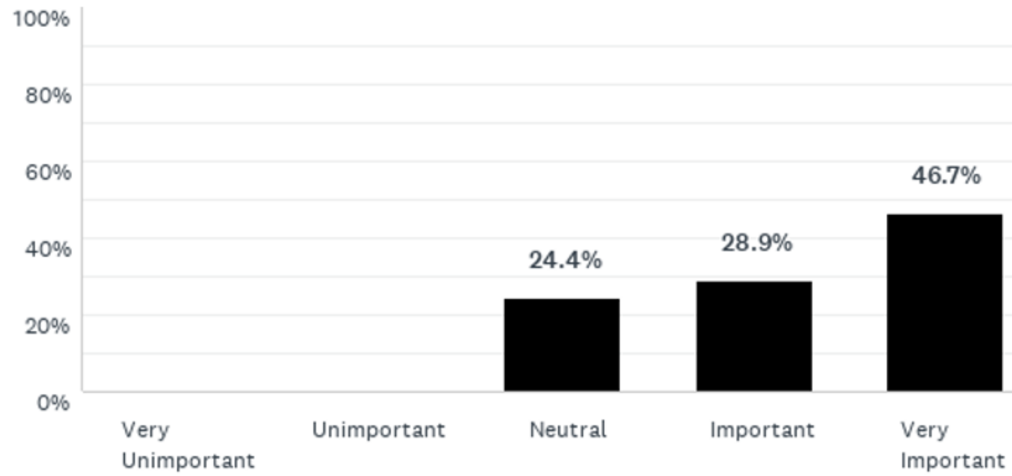


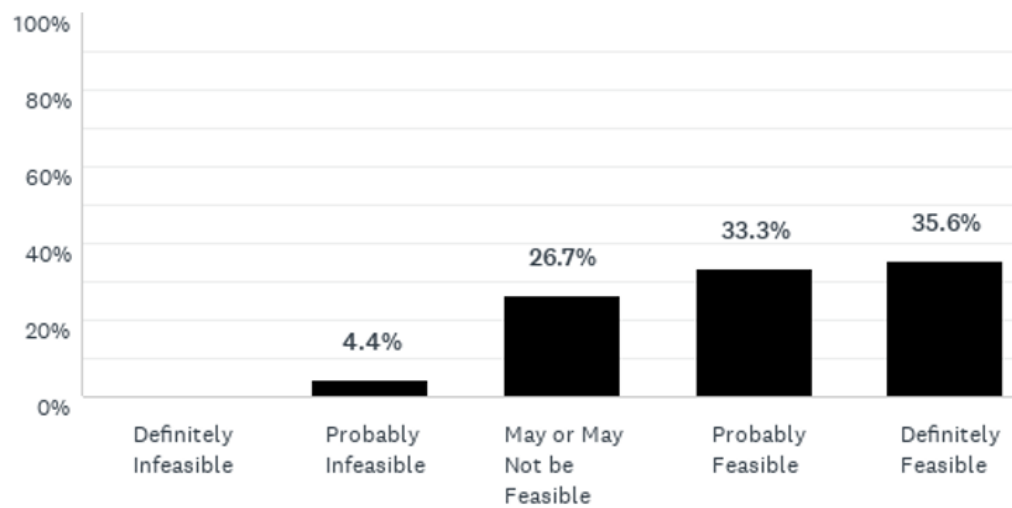
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
39) Edge computing that allows local processing of medical data (e.g., smart watch)	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



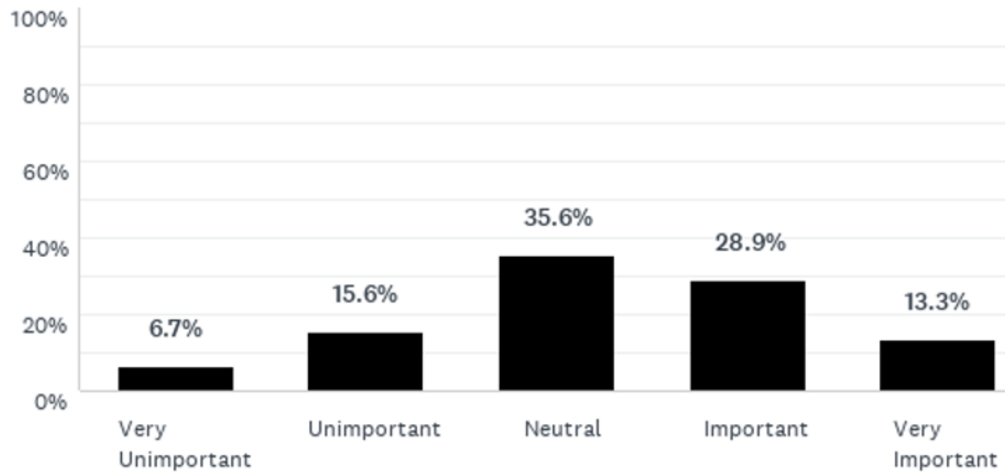


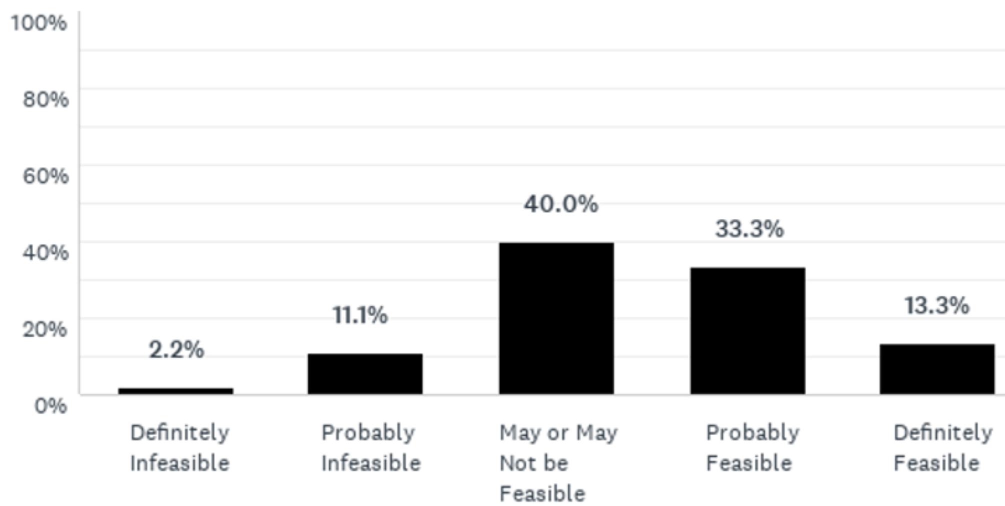
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
40) Enhanced ability to capture and use patient provided information to incorporate patient preferences into treatment plan and capture patient reported outcomes	
Importance result:	Important
Feasibility result:	Undetermined feasibility



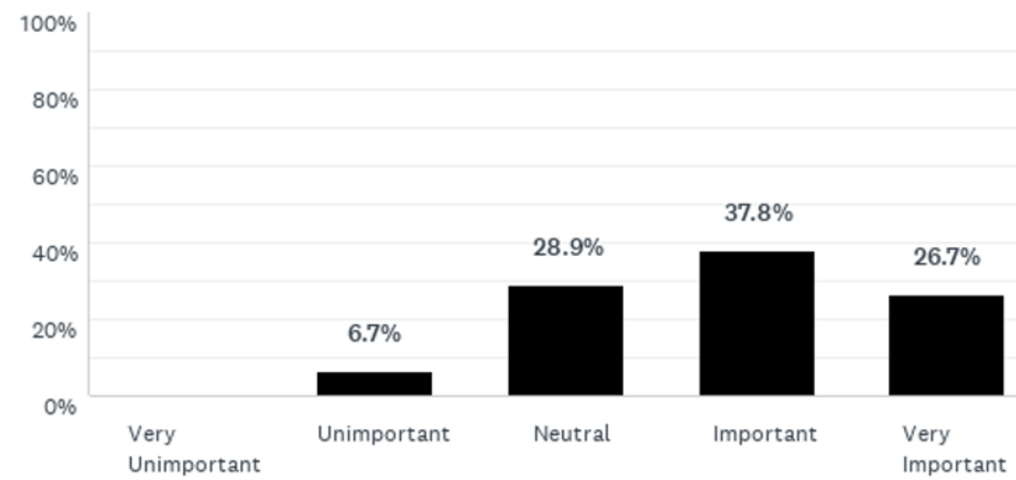


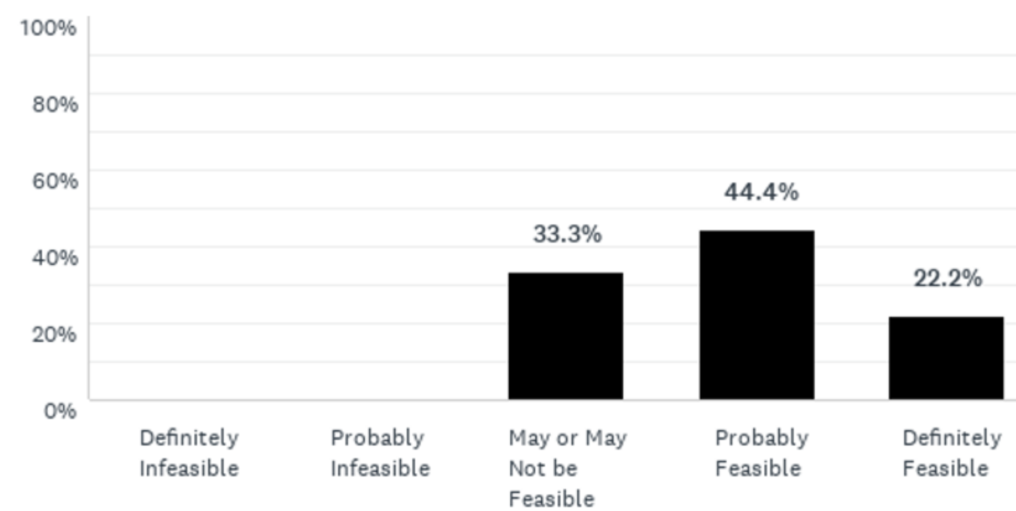
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
41) Expertise in conversational artificial intelligence	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



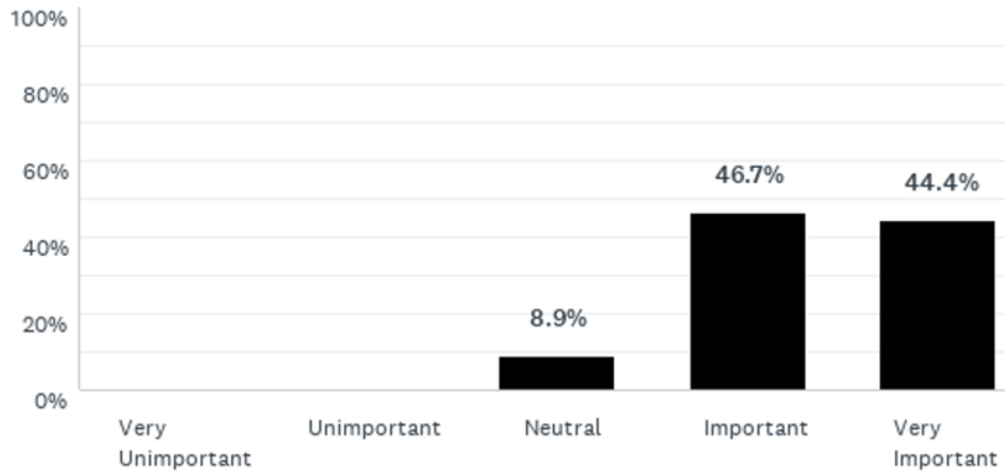


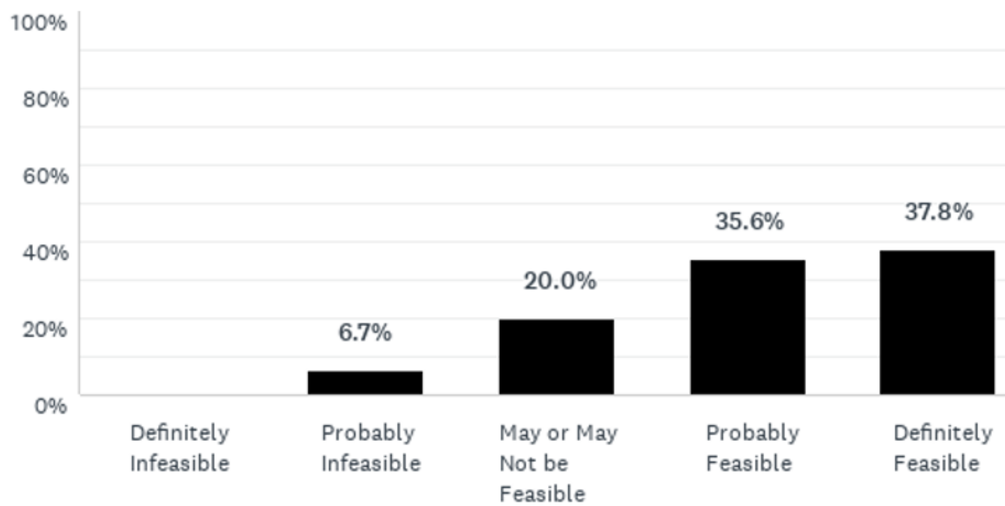
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
42) Federated data analytics	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



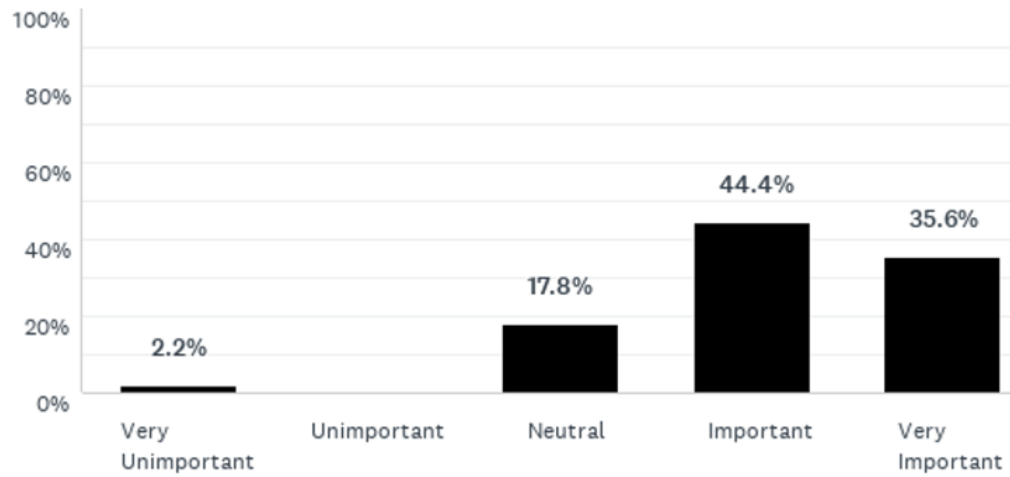


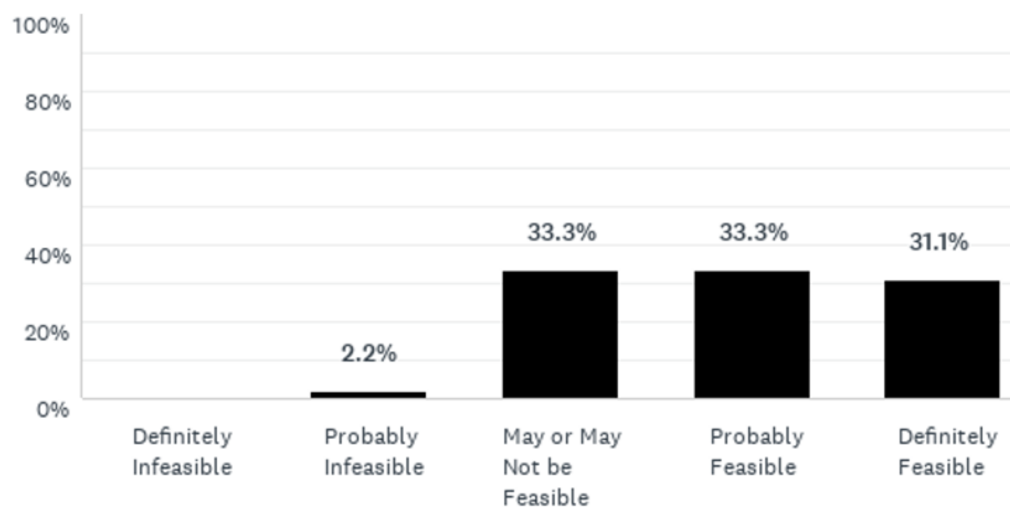
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
43) Integration of EHR, genomic, and pharmacologic platforms	
Importance result:	Important
Feasibility result:	Undetermined feasibility



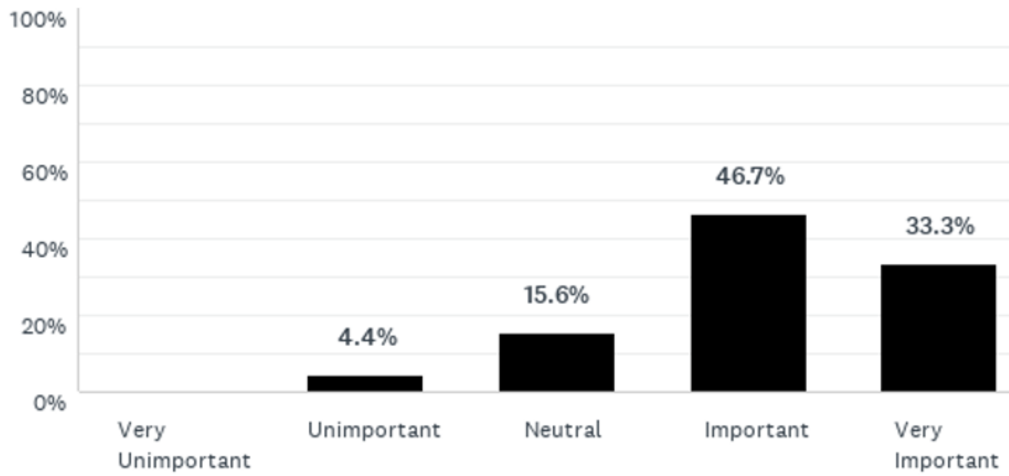


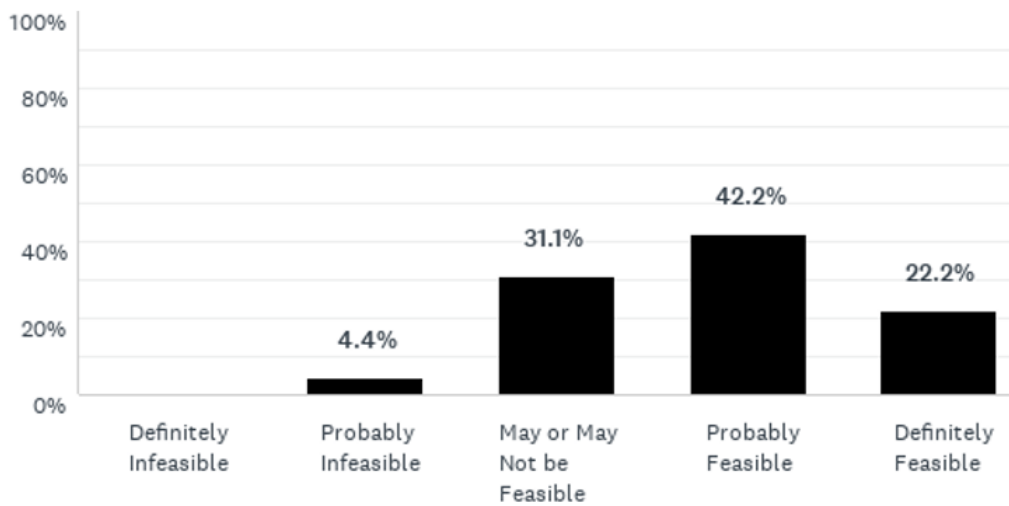
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
44) IT infrastructure connected to a data warehouse for health services research and economic estimates for the impact of personalized medicine (e.g., emergency department admissions and expenses related to adverse drug events before and after the introduction of a pharmacogenetic program to screen all adults for FDA related drug-gene interactions)	
Importance result:	Important
Feasibility result:	Undetermined feasibility



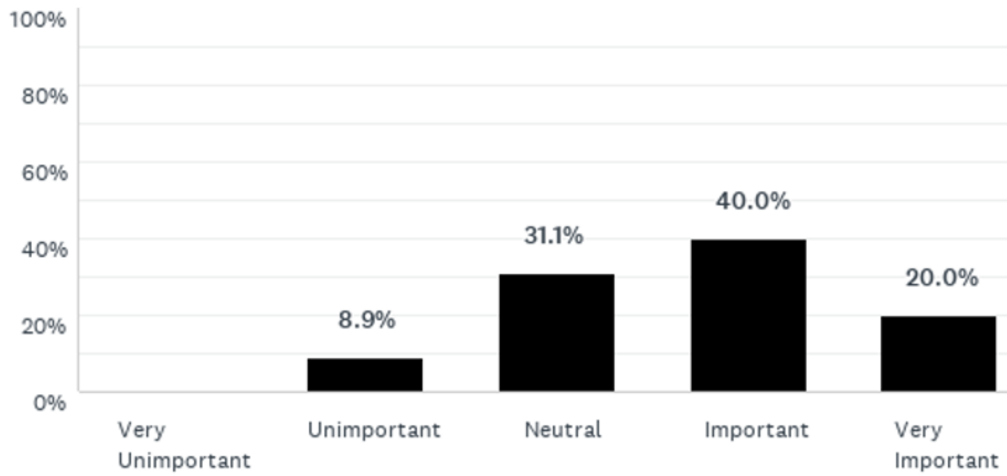


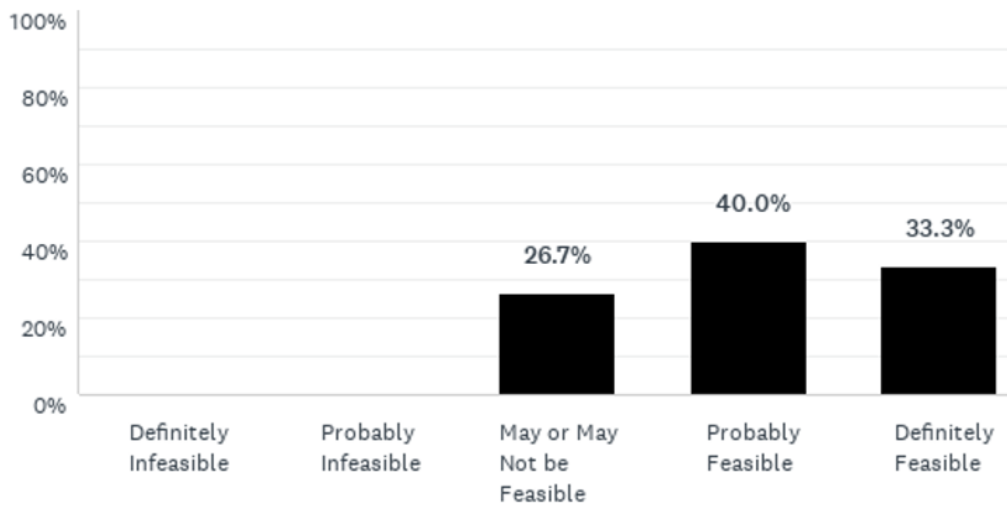
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
45) IT infrastructure to capture real time events (e.g., emergency department admissions related to adverse drug events)	
Importance result:	Important
Feasibility result:	Undetermined feasibility



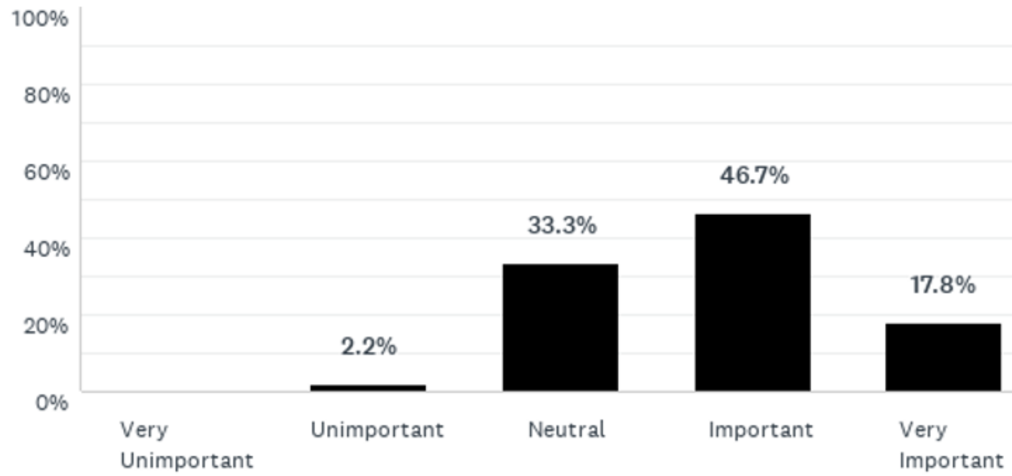


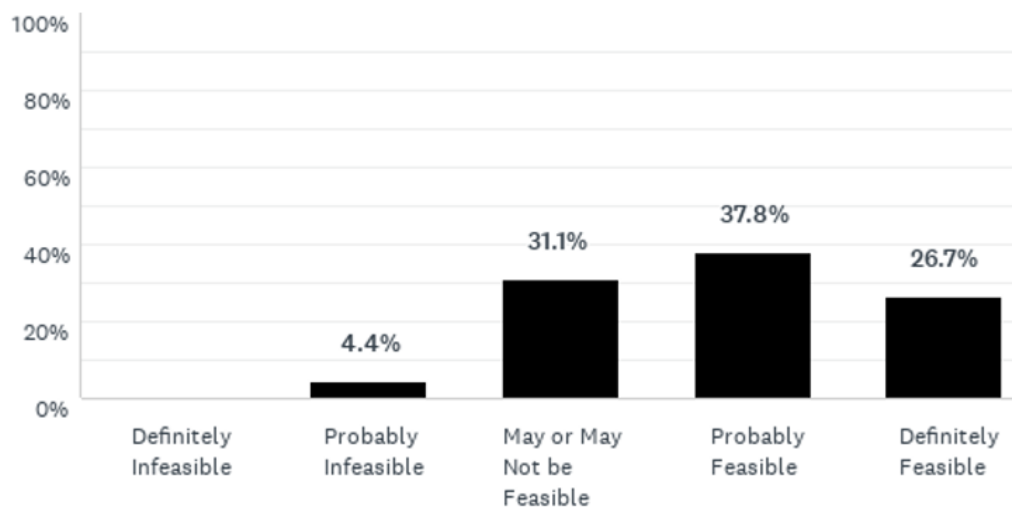
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
46) Knowledge graphs	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



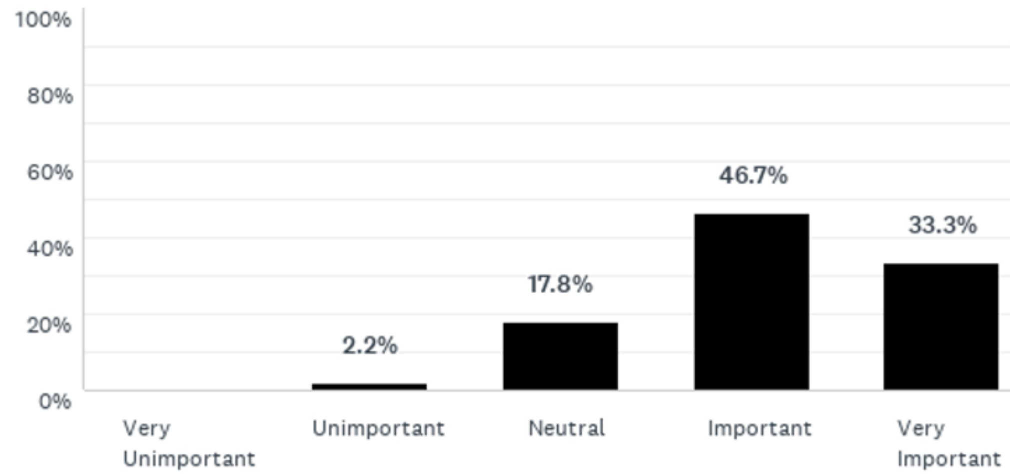


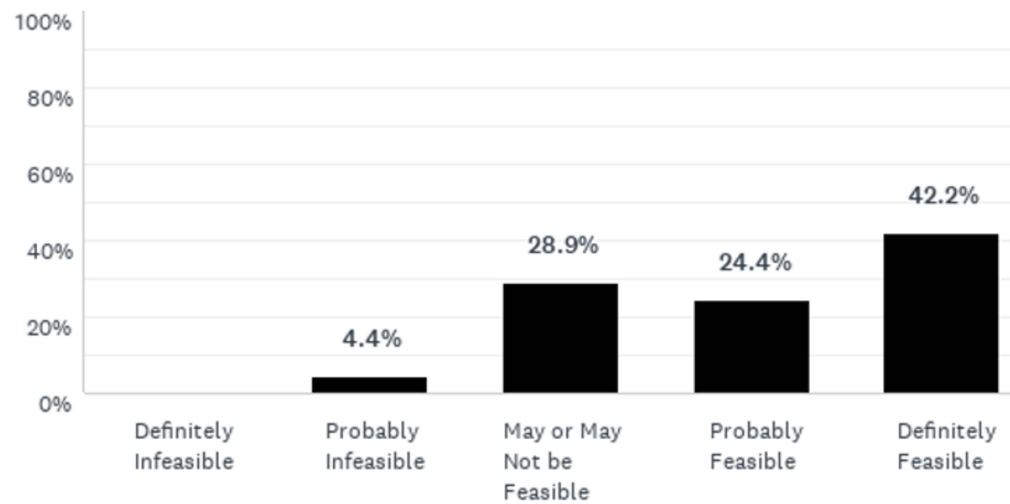
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
47) Mobile device data and metadata	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



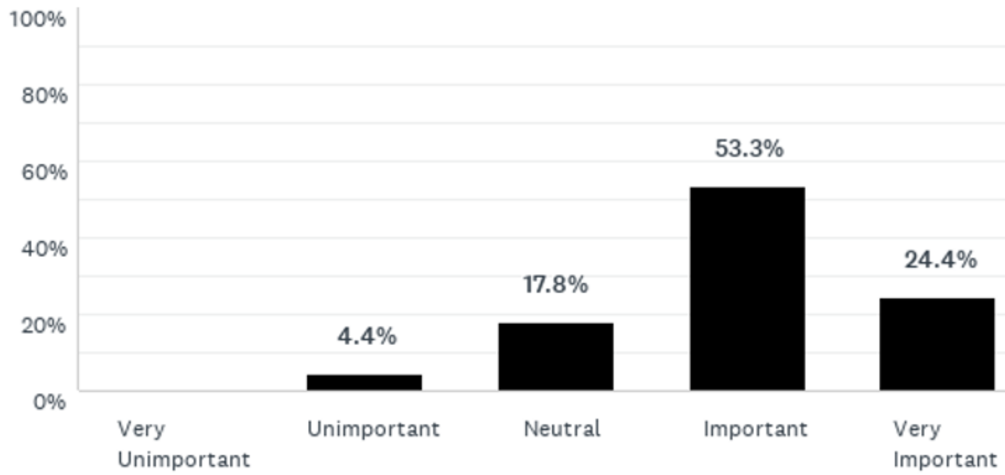


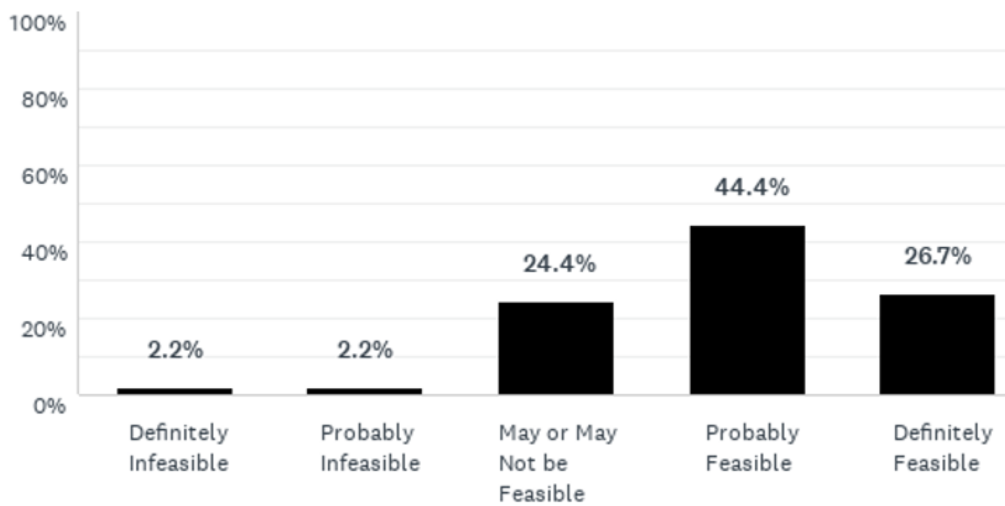
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
48) Multimodal clinical data repository	
Importance result:	Important
Feasibility result:	Undetermined feasibility



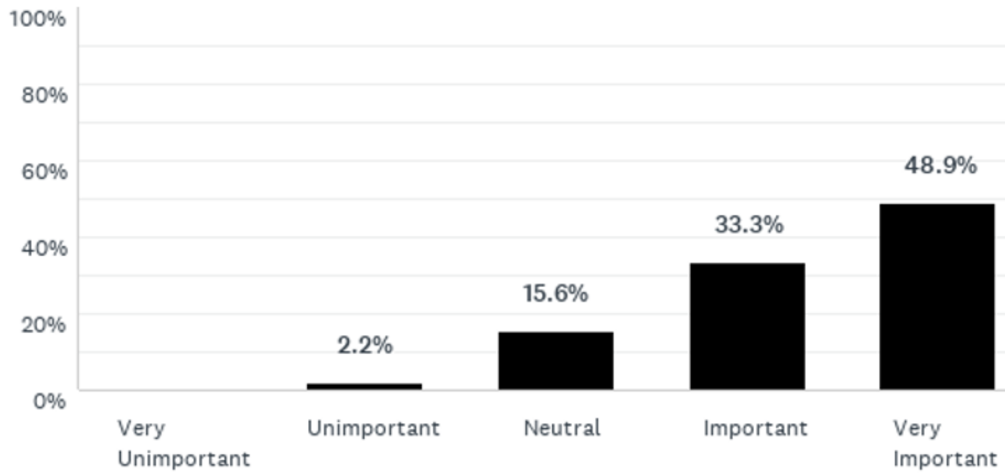


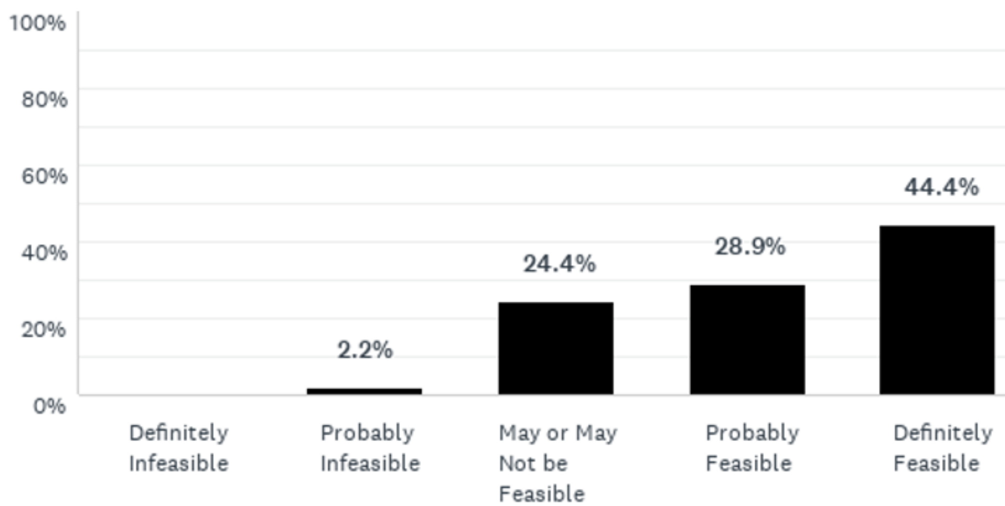
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
49) Native interoperability and application programming interface (API) connectivity between EHR, electronic case report form (eCRF), and biobank databases	
Importance result:	Important
Feasibility result:	Undetermined feasibility



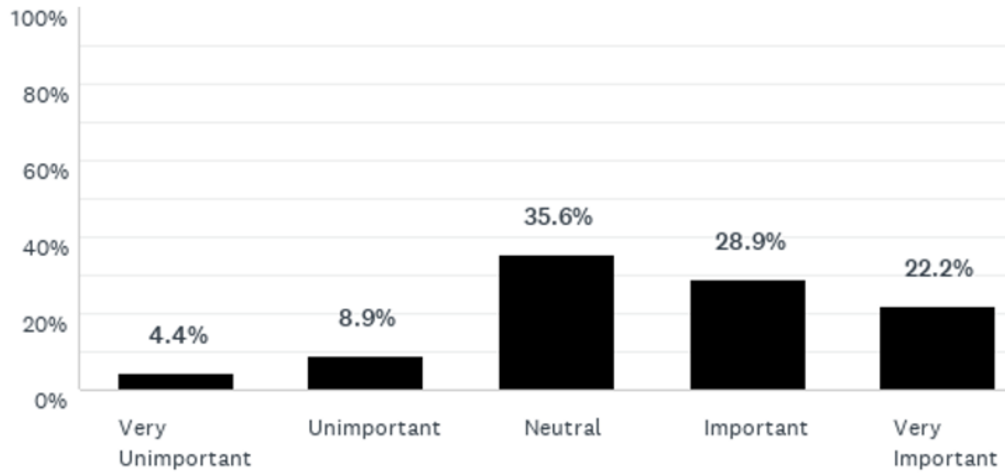


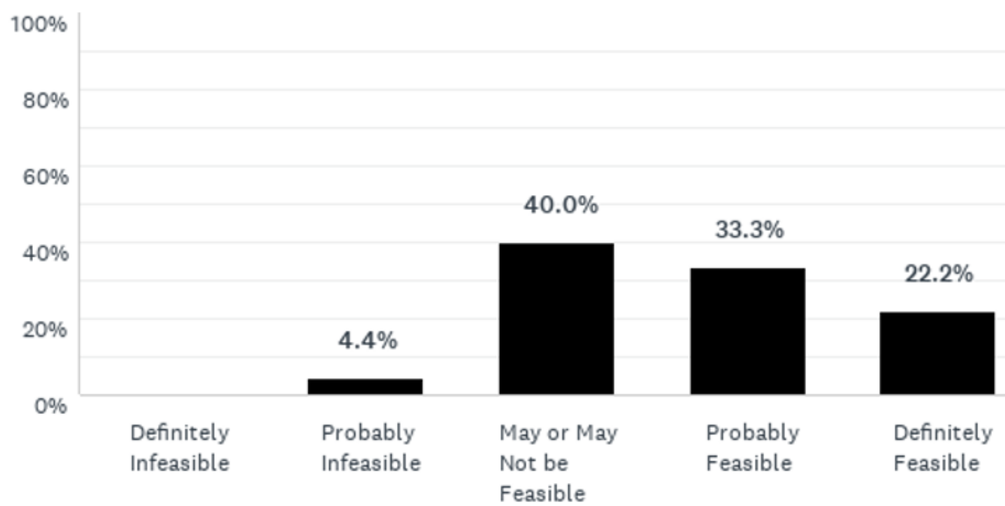
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
50) Natural language processing	
Importance result:	Important
Feasibility result:	Undetermined feasibility



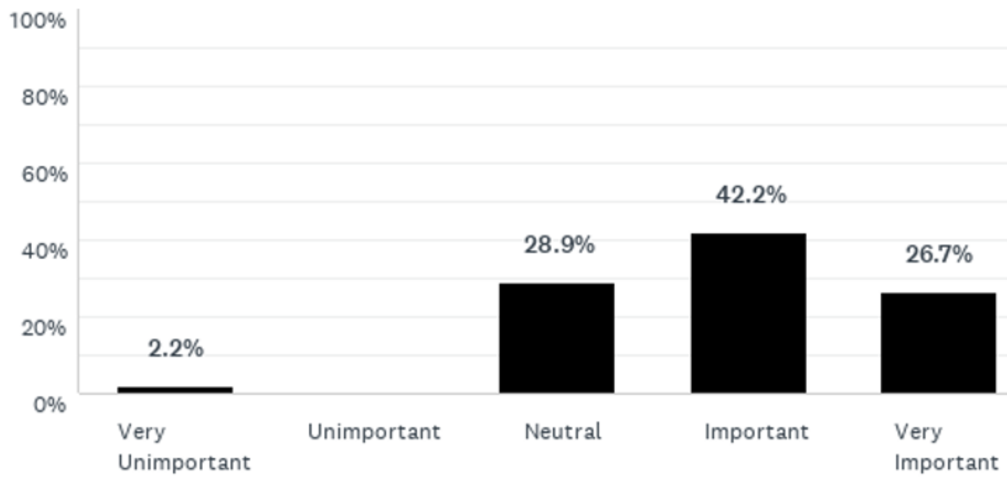


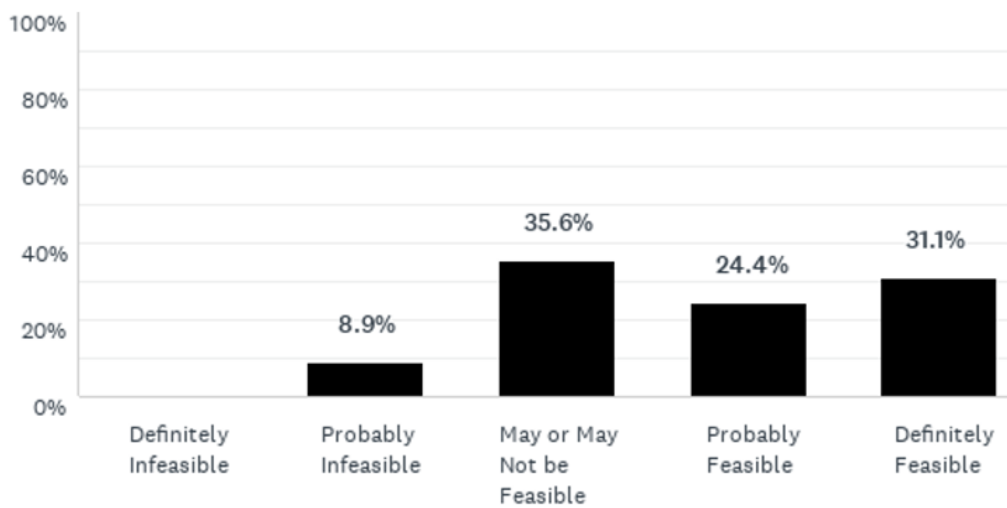
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
51) Pathway software to enable the understanding of mechanisms (e.g., Elsevier Pathway Studio)	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



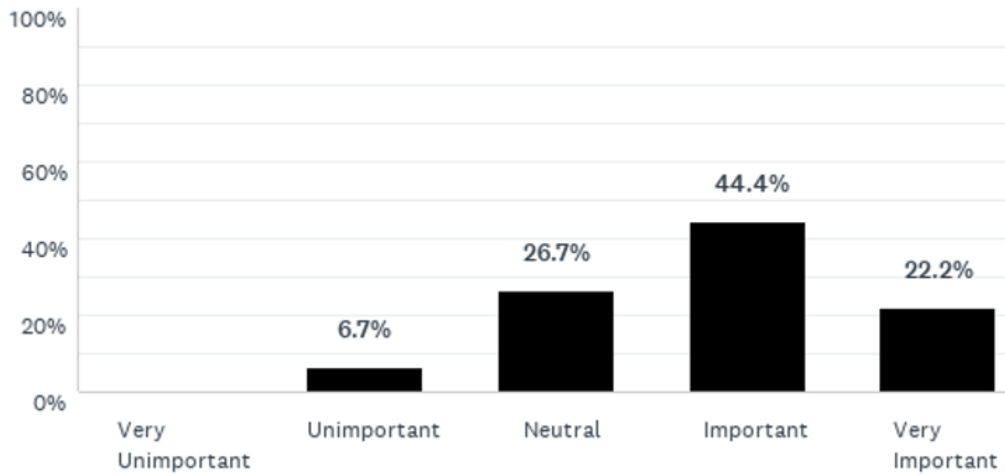


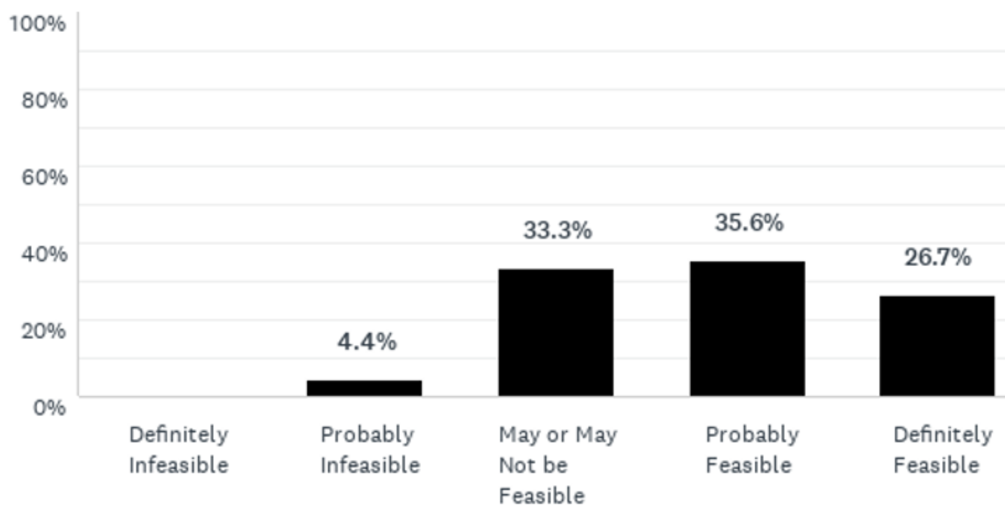
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
52) Platform integration across devices	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



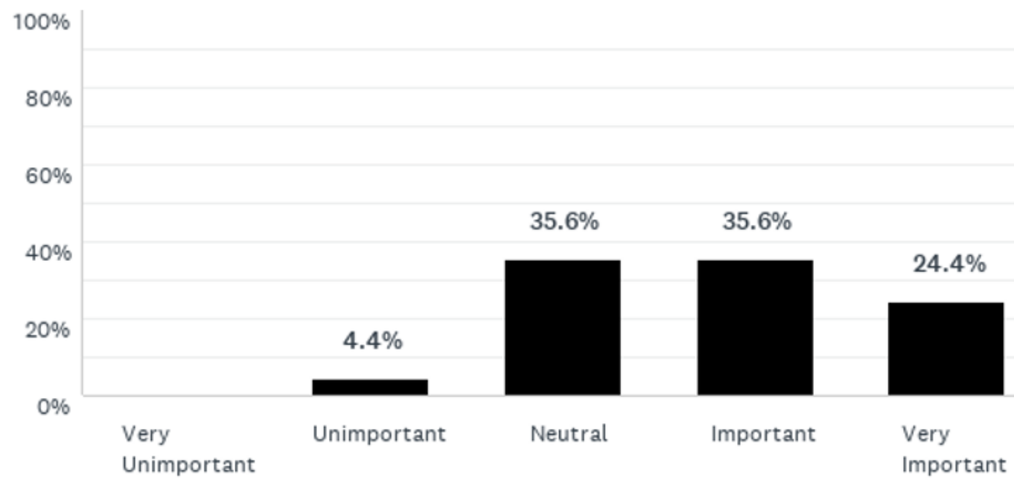


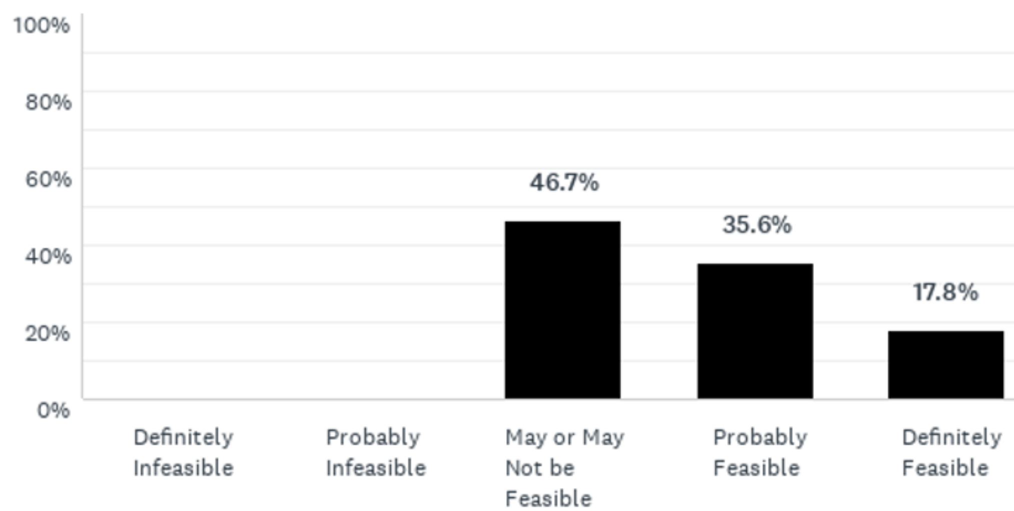
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
53) Semantic modeling	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility



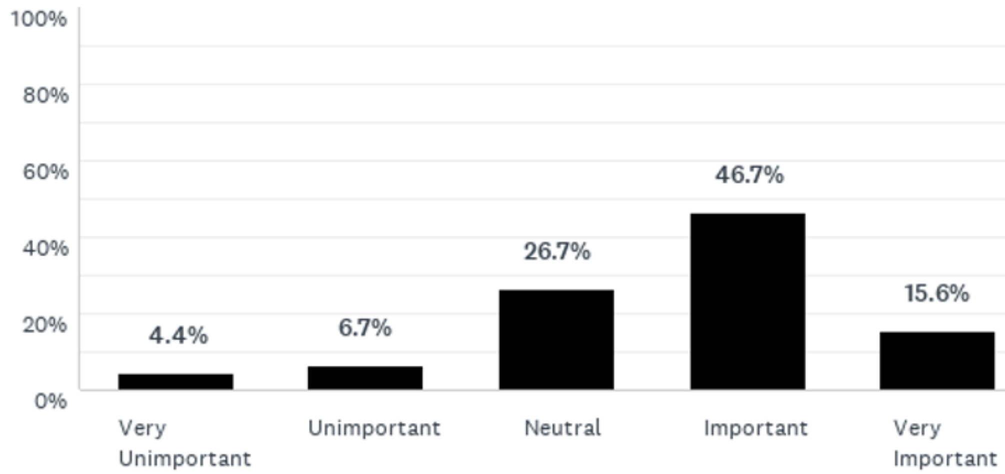


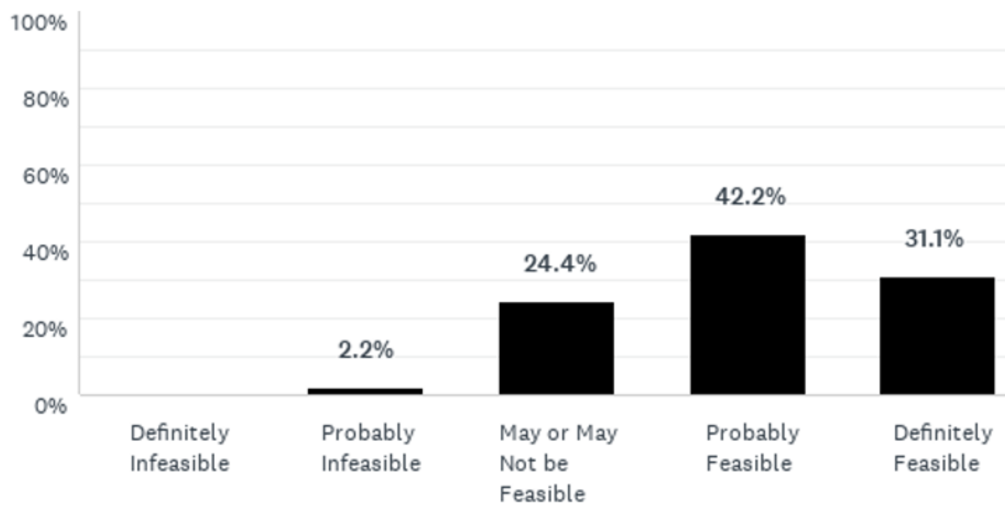
IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
54) Temporal reasoning	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility





IT Capabilities and Resources That Were Rated in Round 2, but Are Considered To Have Undetermined Importance, Undetermined Feasibility, or Both	
55) Terminologists	
Importance result:	Undetermined importance
Feasibility result:	Undetermined feasibility





Additional IT Capabilities and Resources That Were Collected During Round 2
1) 3D printing
2) Application programming interface (API) development by EHR vendors
3) Clinical decision support architect
4) Collaborative teams that include experienced physicians working with engineers and data scientists
5) Computer vision expertise
6) Contract specialist among providers, researchers, vendors, and the government
7) Data standardization experts
8) Development of quantum computing solutions
9) Fast healthcare interoperability resources (FHIR)
10) Fast healthcare interoperability resources (FHIR) clinical decision support tool
11) Fast healthcare interoperability resources (FHIR) genomics standards for discrete results, data alignment, and storage
12) Genomic nomenclature converting tools across multiple IT platforms
13) Genomics laboratory information system that stores sequencing data and can translate results into an understandable narrative for the provider
14) Healthcare virtual and augmented reality
15) Human factor engineering - taking clinician and patient personas into account
16) Increased number of full-time equivalents (FTEs)
17) Interoperability across different platforms (e.g., EHR, genomic data, etc.)
18) Interoperability experts
19) Knowledge about deep learning
20) Knowledge about EHR integration options that minimize alert fatigue and provide precision recommendations
21) Knowledge management with clinical and IT personnel
22) Machine learning capability

Additional IT Capabilities and Resources That Were Collected During Round 2
23) More sustainable genomic nomenclature (e.g., Human Genome Variation Society nomenclature)
24) Nanotechnology
25) No code and low code machine learning solutions
26) Open source commercial software
27) Patient data and educational resources outside the EHR
28) Pilot testing capabilities
29) Pilot testing environment
30) Predictive analysis
31) Preparation for clinical decision support that scales to thousands of rules
32) Preparation for precision medication that leverages molecular (e.g., DNA) findings
33) Program manager for precision medicine initiative execution
34) Real world data literacy
35) Scientific publication access
36) Software engineering
37) Someone that has knowledge of both clinical informatics and bioinformatics
38) Someone with expertise to create precision clinical decision support
39) Substitutable medical apps and reusable technology (SMART) on fast healthcare interoperability resources (FHIR)
40) Supercomputer management
41) Task force to implement new technologies
42) The necessary subject matter experts across a variety of disciplines (e.g., integration, genomics, data science, data architecture, etc.)
43) Translational knowledge engineering
44) Transnational knowledge base (e.g., CPIC guideline)
45) Use case design