Telemedicine: A Future Scenario Analysis

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Margaret Cusack

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

Rider W. Foley, Department of Engineering and Society

Introduction

The COVID-19 pandemic sparked the increased usage of telemedicine as an alternative to in-person doctor visits in the United States. This proliferation was primarily due to telemedicine being used so non-COVID-related appointments could take place without patients potentially exposing themselves to COVID-19 in medical facilities. Telemedicine (or telehealth) is defined as "the practice of medicine over a distance, in which interventions, diagnoses, therapeutic decisions, and subsequent treatment recommendations are based on patient data, documents and other information transmitted through telecommunication systems" (WMA General Assembly, 2020, p. 1). These telecommunication systems are non-public facing, meaning only intended parties can join, and include phone calls, video calls, emails, and text messages (Bonvissuto, 2020). The current state of telemedicine is a very important one for analysis because the use of telehealth skyrocketed during the COVID-19 pandemic, however, as the emergency stages of the pandemic passed, it is clear that the technology has the potential to remain a widely-used tool and should therefore be analyzed for problems and future capabilities.

With so many recent changes to the healthcare landscape in terms of telemedicine, it is important to ask the question of what the future holds for telehealth given its rapid proliferation and the uncertainty surrounding the possibilities for telehealth technologies. The purpose of this study is to address this question through scenario construction. Scenarios are "structurally different stories about how the future might develop" and are meant to challenge assumptions while still being plausible and relevant for decision makers (Rialland et al., 2009, p. 3). "By developing and exploring scenarios we are searching for trends, events or driving forces that may lead to a future radically different from the situation today" (Rialland et al., 2009, p. 9). This allows organizations to think proactively about what they would do if specific things were to happen and what would need to be true for other situations to occur (Rialland et al., 2009). This thesis will construct and analyze detailed and divergent future scenarios to raise awareness of the risks, decisions, constraints and opportunities which could be encountered within the future of telemedicine in the United States.

Case Context

Before the COVID-19 pandemic, telemedicine was often seen as a last resort option because of patient and provider reservations as well as limited telemedicine appointment coverage and reimbursement by insurance companies (Bestsennyy et al., 2021). Pre-pandemic, only 4% of the US population had ever used telehealth services (Murez, 2021). However, once COVID-19 became a public health emergency, patients and doctors were looking to limit non-emergent contact and insurance providers relaxed restrictions on telemedicine to allow patients to continue receiving the care they needed (Murez, 2021). At the peak of the pandemic, telehealth vendors reported getting a year's worth of traffic each month (Kaplan, 2020) and "in April 2020, overall telehealth utilization for office visits and outpatient care was 78 times higher than in February 2020" (Bestsennyy et al., 2021, p. 1). At the end of the public health emergency and in the months to follow, telemedicine utilization in the US has stabilized to 38 times higher than the pre-COVID-19 baseline and, on average, its use ranges from 13 to 17 percent across different medical specialties (Bestsennyy et al., 2021).

Looking to the future of the technology, if telemedicine remains an option for patients, the Mayo Clinic anticipates it will result in increased access to medical providers, cost reductions, and increased medical reach to people in underserved communities (Temesgen et al., 2020). It is also important to consider some of the risks of the rapid growth of telemedicine.

There are many risks associated with medicine in general such as malpractice, assurance of pay, and misdiagnosis (Nittari et al., 2020). All of these risks would still be present in telehealth interactions but are not projected to increase from in-person visit levels. However, there are added risks associated with telehealth, including, privacy risks, legal risks that come with telehealth across borders, and data protection risks (Nittari et al., 2020). This context of the current state of telemedicine as well as the future considerations will ultimately aid the selection of important variables to consider in scenario construction.

Foresight Framework

The STS framework used to analyze the changes happening surrounding telemedicine is Voros's Generic Foresight Process Framework. Foresight frameworks "provide a structure that allows expansion of perspectives to seek new possibilities as external changes evolve over time, to imagine futures that generate new strategic or policy options, and to decide on action to take today to prepare for and work towards a preferred" (Conway, n.d., p. 1). Foresight will be used to generate and analyze the possible futures for telemedicine.

The future of telemedicine can be assessed through Voros's Generic Foresight Process Framework. The framework has four key stages: inputs, foresight work, outputs and strategy (Voros, 2003). The input stage is the information gathering phase. The foresight work stage is broken into three parts: analysis, to see what seems to be happening; interpretation, to see what's really happening; and prospection, to think about what might happen. The outputs stage is for assessing the tangible and intangible products of the foresight stage. These outputs are used in the strategy stage to inform decisions (Voros, 2003). The first step of using this framework to assess futures of telemedicine, will be to use the current state as the starting point for the inputs stage. During the foresight stage, alternative futures can be generated and these can be used in the outputs and strategy stages to consider which futures are optimal and what intermediate steps would need to be taken with telemedicine in order to reach those goals.

Research Question and Methods

The research question being answered in this paper is: Where could telemedicine use in the United States be going? This question was answered through the creation and interpretation of a diverse and detailed set of future scenarios. The steps taken to create scenarios were adapted from Neda Nazemi's (2019) paper and included: i) identifying key variables that affect telemedicine and their future projections, ii) consistency analysis to assess the logical consistency of the projections, iii) scenario analysis with Python code, iv) selecting a set of scenarios for further analysis, v) driver variable analysis.

In order to create a wholistic list of variables and their future projections, literature review of several sources was conducted to understand which aspects of telemedicine were the most important and the current state of each of those aspects. After understanding the current-state-of-affairs, I theorized two or three future projections that reflected improvements or regressions from the current state. Table 1 outlines the final set of variables, future projections and current state.

Table 1. Set of Variables and Future Projections

Variable	Future Projection	Current State
Insurance Company Willingness to Pay	1- Insurance companies primarily reimburse for in-person visits 2- Insurance companies set their own policies	During the COVID-19 pandemic, many states required insurance providers to cover telehealth visits (Weiner, 2021). Currently, at the end of the emergency stages of the pandemic, many states are keeping this

	for reimbursement causing inconsistent coverage across companies 3- Mandate for every insurance company to reimburse telehealth visits to the same level as in-person visits	requirement, some are still unsure and it is yet to be decided whether telemedicine should be covered the same as in person visits. "Currently, less than half of states mandate parity for remote care" (Weiner, 2021, p.1).
Patient Willingness to Engage	1- Less than current state willingness to engage 2- Greater than current state willingness to engage	Patient willingness to engage with telehealth has improved since pre-pandemic times (Bestsennyy et al., 2021). Patients were most willing to engage during the peak of the COVID-19 pandemic, however, perceptions and usage have dropped slightly since then. "Around 40 percent of surveyed consumers stated that they believe they will continue to use telehealth going forward—up from 11 percent of consumers using telehealth prior to COVID-19" (Bestsennyy et al., 2021, p.1)
Doctor Willingness to Engage	1- Less than current state willingness to engage 2- Greater than current state willingness to engage	At the peak of the pandemic, around 32 percent of appointments occurred via telehealth. Since June 2020, utilization has stabilized with 13-17 percent of appointments occurring via telehealth across specialties (Bestsennyy et al., 2021). "58 percent of physicians continue to view telehealth more favorably now than they did before COVID-19, though perceptions have come down slightly since September 2020 (64 percent of physicians). As of April 2021, 84 percent of physicians were offering virtual visits and 57 percent would prefer to continue offering virtual care" (Bestsennyy et al., 2021, p.1).
Efficient and Secure Telemedicine Technologies	1- Technologies have more cybersecurity risks and usability challenges 2- Technologies become more secure and user-friendly	During the peak of the COVID-19 pandemic, the US government stopped restricting videoconferencing services that do not meet Health Insurance Portability and Accountability Act (HIPAA) privacy standards (Weiner, 2021). Many of those platforms are a lot more user-friendly. Now, hospitals are returning to HIPAA-compliant services, there is a push to add easier-to-use features (Weiner, 2021).

		There are also several privacy considerations when using telehealth platforms. Specifically, intruders joining video conferences, inadequate encryption of communications or ransomware attacks (Jalali et al., 2020).
Barriers to Use (access to internet, age, ethnicity, first language, technology literacy)	1- Barriers to use become greater for minority groups 2- Barriers to use are reduced for minority groups	In 2021 roughly 72% of rural Americans have broadband internet access at home (up from 63% in 2016) (Vogels, 2021). Studies have shown that people of older age, Black race, Hispanic ethnicity or primary language Spanish, and primary insurance being Medicaid or Medicare were all significantly associated with less telemedicine visits (Ye et al., 2020). Currently, healthcare institutions are working to help patients who are technologically limited. One tactic being used to do this is hiring digital health navigators who help patients with such steps as logging onto platforms, positioning their cameras, and otherwise becoming comfortable with telehealth" (Weiner, 2021, p.1).
Research and Development	1- No new telehealth research and development pursued 3- New telehealth research and development consistently being pursued	There was 3X the level of digital health investment in 2020 than in 2017 (Bestsennyy et al., 2021). Moreover, "total venture capital investment into the digital health space in the first half of 2021 totaled $14.7 billion, which is more than all of the investment in 2020 ($14.6 billion) and nearly twice the investment in 2019 ($7.7 billion)" (Bestsennyy et al., 2021, p.1).
Out-of-state doctor patient relationships	1- No states allow out-of-state doctor patient relationships 2- Some states allow out-of-state doctor patient relationships 3- All states allow out-of-state doctor patient relationships	During the COVID-19 pandemic, most states relaxed the licensing rules so doctors could treat patients out-of-state via telemedicine (Weiner, 2021). Pre-pandemic, licensing required many forms and large fees. Currently, at the end of the emergency stages of the pandemic, nearly half of US states are reversing the eased licensing rules and doctors are being forced to drop patients. More states are projected to follow (Weiner, 2021).

The next step in creating scenarios was to preform consistency analysis for the future projections of variables. To do so, a matrix was created with the additive consistency score of each pair of future projections (Appendix A). The consistency score was chosen with deductive logical reasoning about the likelihood of the two future projections occurring together. The consistency scoring system, drawn from Neda Nazemi's (2019) paper, can be seen in Table 2.

Table 2. Consistency Scoring System

Additive Indicator	Explanation	Multiplicative Indicator
-2	Impossible to exist together	0
-1	Unlikely to exist together	0.5
0	No impact between projections	1
1	Likely to exist together	2
2	Must exist together	3

The consistency matrix was used as the input for the next step in selecting scenarios which was to perform consistency analysis using Python code, see Appendix B (Lampert, 2022; Nazemi et al., 2020). In the code, both the additive and multiplicative consistency were calculated for each possible combination of projections of variables. Additive consistency is calculated by summing the additive indicators for each pair of future projections in a scenario, whereas, multiplicative consistency is calculated by multiplying the multiplicative indicators for each pair of future projections in a scenario. Calculating multiplicative consistency helps to call attention any scenarios where any pair of future projections could not possibly exist together due to multiplication by zero.

The code returned 288 scenarios reflecting every different combination of the future projections of the variables along with their respective additive and multiplicative consistencies. For this research, it was optimal to narrow down to less than 10 consistent but diverse scenarios for analysis. First to eliminate the least plausible (consistent) scenarios, any with an additive consistency less than or equal to 4 were removed or any with a multiplicative consistency less than or equal to 16 were removed. This left 36 scenarios which were narrowed down using diversity analysis.

The goal of diversity analysis was to identify a set of plausible and distinct scenarios for further analysis. The process consisted of manually choosing ten scenarios that seemed distinct and representative of the trends observed in the 36 consistent scenarios while also prioritizing scenarios with higher consistency scores. Next, the harmonic mean of the relative distance to the other scenarios was calculated and 5 scenarios were selected. The summary statistics of the 5 scenarios can be seen in Table 3 below. All scenarios have no inconsistencies as well as positive and high additive and multiplicative consistencies which means all scenarios are plausible. The distance to selected percentages are high with low deviation meaning the scenarios are diverse.

Table 3. Scenario Summary Statistics

	Scenario 1: Best-case	Scenario 2: Worst-case	Scenario 3: No Mandates	Scenario 4: Doctor Pushback	Scenario 5: Effort to Improve
Additive Consistency	18	16	9	8	6
Multiplicative Consistency	147456	65536	288	144	64
Number of Inconsistencies	0	0	0	0	0
Distance to Selected (%)	44	59	46	48	51

In Table 3, scenario 1 is titled ‘best-case’ and scenario 2 is titled ‘wort case’. Scenario 1 is the best-case scenario because all of the future projections of improvements from the current states seen in Table 1, meaning that they are moving towards idealistic telehealth integration in the United States. Conversely, scenario 2 is the worst-case scenario because all future projections are worse than the current state, meaning that they are regressing back to a pre-COVID-19 situation where telemedicine was not utilized to its full potential.

Going back to the 36 consistent scenarios, the next step was to identify any of the seven variables that are driver variables. In this context, driver variables are any variable that often moves with the majority of variables within the consistent scenarios. This means that when in specific scenarios a driver variable reflects either an improvement or deterioration from the current state, the majority of other variables follow the trend of improvement or deterioration as well. In order to find the driver variables, all 36 consistent scenarios were examined to see which variables, if any, were moving in a different direction (towards or away from best/worst-case) than the majority. For variables 1 and 7 there are three future projections as can be seen in Table 1. For both of these scenarios, projections one and two were considered to be deteriorations and projection three was considered to be an improvement. This is because, for both variables, projections one and two are worse than the current state and reflect a regression to pre-COVID-19 telehealth practices. Counts of the number of times each variable differed from the majority within the 36 scenarios can be seen in Table 4.

Table 4. Driver Variable Analysis

Variable	Number of Times Variable Direction Differed from Majority
1. Insurance Company Willingness to Pay	14
2. Patient Willingness to Engage	4
3. Doctor Willingness to Engage	6
4. Efficient & Secure Technology	5
5. Barriers to Use	1
6. Research & Development	5
7. Out-of-state Doctor Patient Relationships	15

Results

It is clear that there are several directions that telemedicine could take in terms of the important variables with some of the most likely scenarios having most variables moving together for better or worse than the current state driven by barriers to telehealth use and patient willingness to engage. Barriers to use and patient willingness to engage were identified as driver variables. Barriers to use is the strongest driver because it only differed from the majority in one of the 36 consistent scenarios and it was a scenario with low consistency scores compared to the other 35 scenarios. Patient willingness to engage is also influential because it only differed from the majority four out of 36 times and those four scenarios low consistency scores compared to the other scenarios. Although having efficient and safe technology as well as continued research and development have the next lowest number of appearances meaning they are still important, the scenarios where these were different had higher consistency scores than patient willingness to engage. Therefore, they are not classified as driver variables.

The diversity of possible paths that telemedicine can take over the coming years can be observed through the following discussions of the five consistent and diverse scenarios chosen in the previous section. Each narrative will offer a glimpse of US under each scenario in 2030 and explore how it was influenced by driver variables. The summary of selected scenarios' variable conditions is outlined in Table 5.

Table 5. Summary of Scenarios

Variable	Summarized Future Projection	Scenario 1: Best-case	Scenario 2: Worst-case	Scenario 3: No Mandates	Scenario 4: Doctor Pushback	Scenario 5: Effort to Improve
Insurance Company Willingness to Pay	1- Low Reimbursement 2- Conditional Reimbursement 3- Reimbursement Mandated	3	1	2	3	2
Patient Willingness to Engage	1- Low Willingness to Engage 2- High Willingness to Engage	2	1	2	2	1
Doctor Willingness to Engage	1- Low Willingness to Engage 2- High Willingness to Engage	2	1	2	1	1
Efficient & Secure Technology	1- Security & Usability Problems 2- Secure & Accessible Technology	2	1	2	2	1
Barriers to Use	1- Greater Barriers to Use 2- Reduced Barriers to Use	2	1	2	2	1
Research & Development	1- No New R&D 2- Consistent R&D	2	1	2	2	2
Out-of-state Doctor Patient Relationships	1- No States Allow 2- Some States Allow 3- All States Allow	3	1	1	2	1

In the following paragraphs, a set of narratives will attempt to communicate the selected futures of telemedicine in a way that would be helpful to decision makers. These futures are created using deductive reasoning and hold everything external to be constant between 2022 and 2030. The narratives depict one possible pathway that is logical with the scenarios' variables and future projections, however, there are many different possible situations or variations not mentioned that still align with the conditions.

Scenario 1: Best-Case Scenario

Under scenario 1, the best-case scenario, every aspect surrounding telemedicine has improved since 2022. Improvement means that telehealth use is growing and it is being used in an ideal way. There are mandates for equal insurance reimbursement for in-person and telehealth appointments as well as action that allows out-of-state doctor patient relationships to occur. The states that are currently reversing the ease of restriction allowing out-of-state relationships during the COVID-19 pandemic have reversed again meaning the licensing currently required for these relationships was either removed or became easier to acquire to the point that it is common practice for doctors to receive it. There is also continued research and development which has lowered barriers to use and made telemedicine technology more efficient and secure. Platforms have been developed with the ease of use of platforms like Zoom but security features that are HIPPA compliant. All of these aspects have made it so patients and doctors are highly willing to use telemedicine. Research has also explored how telemedicine can be used more often for more doctor specialties by working creatively to manage the parts of appointments that can be virtual and those that cannot. Overall, in scenario 1, the whole process of telehealth is widely used and understood as well as efficient and effective.

Scenario 2: Worse-Case Scenario

Under scenario 2, the worst-case scenario, every aspect surrounding telemedicine has worsened. Since 2022, some variables have returned to pre-COVID-19 practices where there is low insurance reimbursement and out-of-state doctor patient relationships are too much work because of the costly and hard to acquire licensing required for doctors. Due to no new research and development investment, there has been no innovation that has made telemedicine technology easier to use, more secure, or more inclusive to minority groups. There were events where security was breached on promising new platforms which discouraged more work to be done in the area. As a result, patients and doctors became discouraged and have in turn abandoned telemedicine as anything other than a last resort option.

Scenario 3: No Mandates

Scenario 3 is similar to scenario 1 with the only differences being that there is conditional insurance reimbursement and that no states allow out-of-state doctor patient relationships without the expensive licensing. Conditional reimbursement means that each insurance company can decide the level of reimbursement they give to different types of visits. Even though these variables are not the best-case for the future, patients are still interested in using telehealth likely because many insurance companies, although they can decide on their own, chose favorable telehealth reimbursement policies and those that did not became less popular. Moreover, insurance companies/plans popular among minority groups, including Medicare and Medicaid, have attractive reimbursement policies which contributes to the lower barriers to use. Lastly, in the states that still require a license to treat patients out-of-state, it is more attractive to get a license because of patient uptake of telemedicine services and policy revisions that make it easier to acquire licensing. This contributes to increased doctor and patient usage of telemedicine as well. Neither insurance reimbursement nor the availability of out-of-state doctor patient relationships are driver variables which can also explain why all other variables improved since 2022 while these did not.

Scenario 4: Doctor Pushback

Scenario 4 is similar to the best-case scenario except there is low doctor willingness to engage with telemedicine and only some states allow out-of-state doctor patient relationships.

This scenario resulted from changes in doctors' perception of telemedicine or that telemedicine became a burden to them. They are also discouraged that in some places they cannot treat out-of-state without a license which remains hard to acquire. Given there is still continued research and development it could occur further into the future that changes happen which reverse the doctor attitudes and make them more willing to engage with telehealth. Moreover, neither doctor willingness to engage nor the availability of out-of-state doctor patient relationships are driver variables so the reduced barriers to use and high patient willingness to engage are likely propelling this scenario towards a best-case situation.

Scenario 5: Effort to Improve

Scenario 5 is similar to scenario 2, the worst-case scenario, with the only differences being that there is conditional insurance reimbursement as well as continued research and development. In scenario 3, there is also conditional reimbursement which favors patients, however, in this scenario it does not. This means that many insurance companies decided not to cover telehealth visits or not cover them to the same extent as in person visits. This contributes to the increased barriers to use and to low patient willingness to engage with telemedicine. Even though there is still research and development, it is not helping reduce barriers to use or making the technology more efficient or safe to use which is contributing to low willingness to use all around. Looking farther into the future from this scenario, either the research and development will be successful in improving the technology and therefore improves some of the variables or the research and development will continue failing and eventually stop altogether creating a scenario more similar to the worst-case. Moreover, given that high barriers to use and low patient willingness to engage are present in this scenario further suggests that this scenario may continue trending towards a worst-case situation.

Discussion

This research ultimately connects to Foresight processes. Scenario construction facilitated the expansion of future perspectives and followed the four stages of Voros's foresight framework. In this research, the inputs stage included literature review to identify important variables and future projections. The foresight work stage occurred through consistency, diversity and diver variable analysis. The outputs were the scenario narratives and identified driver variables which could be used in the strategy stage to inform decisions. Furthermore, the outputs provide a structure for decision makers to consider how their actions today can have several tangible and intangible affects for all associated stakeholders down the road.

The results of the driver variable in this research mirror information in a 2021 telehealth utilization survey (Karimi, et al., 2022). The survey found that telehealth utilization was highest among individuals with Medicare and Medicaid, black respondents, and people earning less than $25,000 annually (Karimi, et al., 2022). This shows that people in minority groups are engaging with telemedicine which could suggest lowering barriers to use. Given that this was the strongest driver variable identified in this research, this shift towards telehealth improvement could stimulate improvements in other variables as well.

The nature of this study, however, was limited. The first limitation was that the scenarios were analyzed in a vacuum. The narratives 8 years in the future did not consider any other outside factors that could influence aspects of the scenarios. Furthermore, the consistency matrix and narratives were constructed using deductive reasoning with beginner knowledge of the healthcare system and telehealth. Therefore, there are probably things that would be disproven by subject matter experts. Lastly, only 5 scenarios were analyzed because of time constraints. Given no constraints it would be beneficial to generate narratives for a larger set of scenarios.

If this research continues there are several things that could be done to make it more robust. First, more variables as well as more future projections for all variables would produce more varied resulting scenarios. In this research the set of scenarios analyzed had a lot of overlap whereas if there were more levels in the future projections the scenarios could be more specific and diversified. Another thing missing from this research was the consultation of experts in the field. This would have been helpful in determining variables, consistency scores and narratives for the final set of scenarios. Lastly, the scope of this research was limited to the United States so future research could extend to other countries.

Moving forward, I will use my systems engineering degree to enter the consulting field. Although I will not be focusing on telemedicine or healthcare, the process of exploring and communicating future possibilities will be a skill I use day-to-day. More specifically, my role will be performing technology due diligence for private equity firms to aid in their acquisitions. This research is an example of analyzing a technology through its future potential and limitations which emulates what I will do in my career.

Conclusion

The broader significance of this work shows that considering viable future scenarios and influential variables can be very useful in decision making. Furthermore, it is important to think about all stakeholders and the impact decisions can have on them. This research was conducted at a pivotal moment for telehealth given its recent proliferation by the COVID-19 pandemic. Seeing the many possible futures for telehealth, it is important that decision makers take action now in order to ensure a future that is desirable for the parties involved. First, stakeholders should get together to facilitate reflective discussion on telehealth use since the beginning of the COVID-19 pandemic. This could transition into conversation about where stakeholders would like to see telemedicine go in the future. It is essential to keep patients and individuals from minority groups in these discussions because barriers to telehealth use and patient willingness to engage are influential aspects in determining the future of telehealth. Beyond these initial conversations, other steps to achieve productive future use of telemedicine could be increasing funding that goes into telehealth research as well as continuing to educate doctors, patients, insurance companies, healthcare institutions and governments on telehealth and how they can use the associated technology to their advantage.

References

Bestsennyy, Oleg, et al. *(*2021). *Telehealth: A quarter-trillion-dollar post-COVID-19 reality?* McKinsey & Company. Retrieved February 13, 2022, from https://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/telehealth-a-quarter-trillion-dollar-post-covid-19-reality

Bonvissuto, D. (2020, March). *How Does Telemedicine Work?* WebMD. Retrieved April 14, 2022, from https://www.webmd.com/lung/how-does-telemedicine-work#1

Conway, M. (n.d.). *Foresight approaches*. Foresight Futures. Retrieved February 13, 2022, from https://foresightfutures.net/foresight-approaches.

Jalali, M. S., Landman, A., & Gordon, W. J. (2020, December 16). *Telemedicine, privacy, and information security in the age of covid-19*. OUP Academic. Retrieved February 13, 2022, from https://academic.oup.com/jamia/article/28/3/671/6039104?login=true

Kaplan, B. (2020). Revisiting Health Information Technology Ethical, legal, and Social Issues and evaluation: Telehealth/telemedicine and COVID-19. *International Journal of Medical Informatics*. Retrieved February 13, 2022, from https://www.sciencedirect.com/science/article/pii/S1386505620309382?casa_token=tF6R0B_Xx8oAAAAA%3AKcJNTaiEnuQynUYP7KsWVEn7plhaaKbSYam3-dJDQbwBgWpihCh6O4c98H_vPMKxuvCEQcs.

Karimi, M., Lee, E.C., Couture, S.J.,Gonzales, A.B.,Grigorescu, V., Smith, S.R., De Lew, N., and Sommers, B.D. (February 2022). *National Trends in Telehealth Use in 2021: Disparities in Utilization and Audio vs. Video Services*. Office of the Assistant Secretary for Planning and Evaluation, U. S. Department of Health and Human Services. Retrieved April 14, 2022.

Lampert, Will. (February, 2022). Thesis Code (Version 2.0) [Source Code]

Murez, Cara. (2021). *Health care after COVID: The rise of telemedicine*. US News. Retrieved February 13, 2022, from https://www.usnews.com/news/health-news/articles/2021-01-05/health-care-after-covid-the-rise-of-telemedicine.

Nazemi, N., Foley, R. W., Louis, G., & Keeler, L. W. (2020). Divergent agricultural water governance scenarios: The case of Zayanderud Basin, Iran. *Agricultural Water Management*, *229*, 105921. https://doi.org/10.1016/j.agwat.2019.105921

Nittari, G., Khuman, R., Baldoni, S., Pallotta, G., Battineni, G., Sirignano, A., Amenta, F., Ricci, G. (2020). Telemedicine Practice: Review of the Current Ethical and Legal Challenges. *Telemedicine and e-Health.* Retrieved February 13, 2022, from https://www.liebertpub.com/doi/full/10.1089/tmj.2019.0158

Rialland, A., & Wold, K. E. (2009). Future Studies, Foresight and Scenarios as basis for better strategic decisions. Trondheim; Norwegian University of Science and

Technology.

Temesgen, Z. M., DeSimone, D. C., Mahmood, M., Libertin, C. R., Palraj, B. R. V., Berbari, E. F. (2020). Health Care After the COVID-19 Pandemic and the Influence of Telemedicine. Mayo Clinic Proceedings. Retrieved February 13, 2022, from https://www.mayoclinicproceedings.org/article/S0025-6196(20)30789-8/fulltext#articleInformation.

Vogels, E. A. (2021, October 19). *Some digital divides persist between rural, urban and Suburban America*. Pew Research Center. Retrieved February 13, 2022, from https://www.pewresearch.org/fact-tank/2021/08/19/some-digital-divides-persist-between-rural-urban-and-suburban-america/

Voros, Joseph. (2003). "A generic foresight process framework", *Foresight*, Vol. 5 No. 3, pp. 10-21. Retrieved February 13, 2022, from https://doi.org/10.1108/14636680310698379

Weiner, S. (2021, October 21). *What happens to telemedicine after COVID-19?* AAMC. Retrieved February 13, 2022, from https://www.aamc.org/news-insights/what-happens-telemedicine-after-covid-19

Ye, S., Kronish, I., Fleck, E., Fleischut, P., Homma, S., Masini, D., & Moise, N. (2020). Telemedicine expansion during the COVID-19 pandemic and the potential for technology-driven disparities. *Journal of General Internal Medicine*, *36*(1), 256–258.

https://doi.org/10.1007/s11606-020-06322-y

WMA General Assembly. (2020). *WMA statement on the ethics of Telemedicine*. The World Medical Association. Retrieved February 13, 2022, from https://www.wma.net/policies-post/wma-statement-on-the-ethics-of-telemedicine/.

Appendix A: Consistency Matrix

		Insurance Company Willingness to Pay			Patient Willingness to Engage		Doctor Willingness to Engage		Efficient & Secure Technology		Barriers to Use		Research and Development		Out-of-state doctor patient relationships		
		Low Reimbursement	Conditional Reimbursement	Reimbursement Mandated	Low Willingness to Engage	High Willingness to Engage	Low Willingness to Engage	High Willingness to Engage	Security & Usability Problems	Secure & Accessible Technology	Greater Barriers to Use	Reduced Barriers to Use	No New R&D	Consistent R&D	No States Allow	Some States Allow	All States Allow
Patient Willingness to Engage	Low Willingness to Engage	1	0	-1													
	High Willingness to Engage	-1	0	1													
Doctor Willingness to Engage	Low Willingness to Engage	0	0	0	1	-1											
	High Willingness to Engage	0	0	0	-1	1											
Efficient & Secure Technology	Security & Usability Problems	1	1	-2	1	-1	1	-1									
	Secure & Accessible Technology	-1	0	1	-1	1	-1	1									
Barriers to Use	Greater Barriers to Use	1	0	-1	1	-1	1	-1	1	-1							
	Reduced Barriers to Use	-1	0	1	-1	1	-1	1	-1	1							
Research and Development	No New R&D	0	0	0	1	-1	1	-1	1	-1	1	-1					
	Consistent R&D	0	0	0	-1	1	-1	1	-1	2	-1	2					
Out-of-state doctor patient relationships	No States Allow	0	0	0	1	-1	1	-1	0	0	1	-1	0	0			
	Some States Allow	0	0	0	0	0	0	0	0	0	-1	1	0	0			
	All States Allow	0	0	0	-1	1	-1	1	0	0	-1	1	0	0			

Appendix B: Python Code

```
"""
Created on Sun Mar 26 14:54:30 2017
@author: Neda Nazemi
Edited February 2022 by Will Lampert
"""
import numpy as np
import pandas as pd
from numpy import genfromtxt
import itertools
import csv
import math
import time
import scipy
import os
import json
import copy

np.set_printoptions(precision=2)

"""
Function to save output data in JSON format
"""
def save_to (listORdict,name,path):
    workingdatapath=os.path.join(path, name)
    data = open(workingdatapath, 'w')
    json.dump(listORdict, data)
"""
Function to read back the saved data in Json format as required
"""
def load_from(name,path):
    with open (os.path.join(path, name)) as f:
        return json.load(f)
"""
Loging time
"""
print ("It starts at: ", time.strftime('%X %x %Z'))
Starttime=time.time()
"""
Reading the consistency matrix
-additive format
"""
D_in_array_format = genfromtxt('Consistency matrix.csv', delimiter=',',
dtype="float", missing_values="", filling_values="-5")
M=D_in_array_format
M[0][0] = 1
"""
constructing the multiplicative consistency matrix from the additive
consistency one
"""
M2=np.empty(M.shape) #multipicative consistency metric based matrix
for i in range(M.shape[0]):
    for j in range(M.shape[1]):
        m=0
        if not math.isnan(M[i,j]):
            m=M[i,j]
```

```
        if m==-2:
            M2[i,j]=int(0)
        elif m==-1:
            M2[i,j]=0.5
        elif m==0:
            M2[i,j]=int(1)
        elif m==1:
            M2[i,j]=int(2)
        elif m==2:
            M2[i,j]=int(3)
        else:
            M2[i,j]="nan"


levels = [3,2,2,2,2,2,3]
scenarios = []
num_scenarios = 1
for level in levels:
   num_scenarios *= level


def create_scenarios(index, scenario):
   if index == len(levels):
      scenarios.append(scenario)
   else:
      for i in range(1, levels[index]+1):
         newScenario = copy.deepcopy(scenario)
         newScenario.append(i)
         create_scenarios(index+1, newScenario)

create_scenarios(0, [])


#scenario index will tell you which column to use
#Columns will only go for the first six
#colums are for 1-6
#rows are for 2-7
column_offsets = [0]
row_offsets = [0, 0]
for index, value in enumerate(levels):
   if index == 0:
      continue
   if index == 1:
      column_offsets.append(levels[index-1] + column_offsets[index-1])
   else:
      column_offsets.append(levels[index-1] + column_offsets[index-1])
      row_offsets.append(levels[index-1] + row_offsets[index-1])


additive_consistency = []
multipicative_consistency = []

for scenario in scenarios:
   coords = []
   for index1, value1 in enumerate(scenario):
      for index2 in range(index1+1, len(scenario)):
         value2 = scenario[index2]
```

```
        #value1 should be the column, value2 should be the row
        #x is the row, y is the column
        y = value1 + column_offsets[index1] - 1
        x = value2 + row_offsets[index2] - 1
        coords.append((x,y))
   additive = 0
   multiplicative = 1
   for x,y in coords:
      additive += M[x][y]
      multiplicative *= M2[x][y]
   additive_consistency.append(additive)
   multipicative_consistency.append(multiplicative)

w = csv.writer(open("Consistency output_additive+multipicative.csv", "w"))
for i in range(len(scenarios)):
   w.writerow([scenarios[i], additive_consistency[i],
multipicative_consistency[i]])

print ("It is Done!!!")
```