Healthcare 4.0 – Managing a Holistic Transformation

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Abstract— Healthcare systems have evolved quickly with the introduction of information communication and technologies (ICT) and the digitization movement. Recently, these systems are going through further transformations to digitalize healthcare services and introduce smartness culminating into what is currently dubbed "Healthcare 4.0". Efforts to introduce Healthcare 4.0 and create effective and smart healthcare services has significantly increased. A Healthcare 4.0 infrastructure will not only make healthcare services smart and highly available, but it will create the necessary framework that will allow healthcare systems to expand their capabilities quickly and efficiently. Unfortunately, much of the efforts to transform and digitalize healthcare systems are isolated and apply different approaches, tools, technologies and models. In addition, there are many integration and compatibility issues across different healthcare systems especially among systems that already exist and proposed new ones. As a result, it becomes increasingly difficult to integrate them or support collaboration across the disjoint healthcare systems to achieve the Healthcare 4.0 vision. We believe that a unified vision and a strategic approach to implementing Healthcare 4.0 is necessary and that long-term planning will help reduce some of the issues and create more systemic capabilities to connect current systems, integrate new ones and add advanced functionalities and smart capabilities. In this paper, we discuss the challenges facing these efforts and the importance of using a strategic approach to manage the healthcare systems transformation and adopt healthcare 4.0.

Keywords— *Healthcare 4.0, smart healthcare systems, digital transformation, digitalization, systems management, strategic management.*

I. INTRODUCTION

Healthcare 4.0 (also referred to as Health 4.0, Health Industry 4.0, and Healthcare Industry 4.0) is a framework to connect, automate and autonomize healthcare services. Its objective is to increase the efficient, effective, affordable, enhanced and personalized healthcare services to the public [1][2][3]. Some of the important benefits of adopting Healthcare 4.0 include the ability to use healthcare data to detect and control infectious diseases faster and more effectively; creating more accurate models for chronic illnesses based on data not only from patient's medical records, but also from life styles patterns, and environmental conditions; facilitating sharing of resources and information among healthcare service providers to optimize utilization; creating powerful data analytics capabilities based on the high volumes of data collected and generated by healthcare systems; enhancing and personalizing patients care; and offering patients high quality healthcare services at affordable costs.

The advances in technology facilitated the development and deployment of a huge variety of healthcare systems benefiting the industry. A quick search in Google Scholar shows scholarly work published in the field increasing significantly in 2020 and 2021. For example using the term "healthcare 4.0" revealed a total of 1,070 publications for all times, while restricting the search to only include 2020 and 2021 shows 801. Using more generic terms like "smart healthcare services" provides thousands of results, yet the most recent results also include mentions of health 4.0 and healthcare 4.0. In addition, we are witnessing rapid increase in digital care capabilities such as online appointment scheduling, automated check in, remote doctor visits, electronic delivery of prescriptions and test requests, and enhanced methods for keeping, securing and tracking patients' records. Other advances are seen in the healthcare supply chain, resource management, resource sharing, smart medical devices, enhanced simulation and visualization tools to assist and support healthcare professionals.

Even beyond the healthcare facilities, Healthcare 4.0 connects people and their devices to the healthcare systems [2][3]. These may be health monitoring devices, smart devices, lifestyle tracking devices, interaction tracking, and mobility tracking. Similar devices in homes, workplaces and vehicles are or can be connected. Collectively, a complete life record for each person is created and updated continuously. All of these are or can be connected using reliable and advanced network technologies to high capacity/performance infrastructures like the health cloud [4] for safe keeping. Furthermore, integrating these services within the larger scheme of a smart city will lead to better access to city resources like transportation systems, energy grids, and other services supporting healthcare facilities.

Despite the benefits of adopting Healthcare 4.0 on a large-scale, the different healthcare service providers do not seem to agree on what exactly is involved and how to effectively develop and deploy a Healthcare 4.0 infrastructure. Major changes were made by healthcare providers in terms of technology adoption and utilization. Unfortunately, many of these efforts are isolated and short-term focused. This leads to having excellent digitalized healthcare services, yet they are difficult to adapt and integrate with new solutions and other healthcare systems easily. Thus, moving to full adoption of a Healthcare 4.0 infrastructure becomes complex, costly and possibly impractical.

Our objective in this paper is to discuss why it is important to approach the transformation efforts to Healthcare 4.0 as a holistic system engineering problem and to have a strategic

long-term vision for the transformation efforts. We argue that adopting a well-designed, highly connected Healthcare 4.0 framework is achievable when a systemic and strategic plan is in place. Thus, we hope that the research and development community in the healthcare fields and the major stakeholders in healthcare systems and services will adopt a wider perspective and collaborate to create a well-defined strategic direction and work on ways to help collect all efforts and create a cohesive smart healthcare system under the Healthcare 4.0 umbrella.

In this paper, we will start by providing a brief overview of current efforts and new technological advances in healthcare services in addition to a brief overview of Healthcare 4.0 in Section II. Section III organizes the different healthcare services attainable by adopting Healthcare 4.0 in groups then Section IV highlights some of the challenges hindering global adoption of Healthcare 4.0. In Sections V and VI we offer our view of how a unified vision and a strategic planning can help address some of the challenges and pave the way for better adoption of Healthcare 4.0. Finally, we conclude the paper and provide some thoughts for future research possibilities in this area.

II. BACKGROUND AND RELATED WORK

A significant amount of recent research and development was invested in identifying the various benefits of using technology to improve the healthcare system in general. Examples include investigating ways to improve connectivity of healthcare systems within a smart city [5]; Reviewing the challenges and solutions for smart healthcare systems development [6]; proposing the integration of different resources and technologies such as IoT (Internet of Things) and cloud computing to manage healthcare big data [7]; discussing the improvements in capabilities of healthcare systems in detecting and controlling diseases using IoMT (Internet of Medical Things), AI and blockchain [8]; and using deep learning for making decisions and recommendations in smart healthcare systems [9]. More recently work on Healthcare 4.0 also picked up pace and researchers and the industry are pouring their resources in this direction. Several examples were mentioned in the introduction highlighting the advances of technology that contributed to this direction.

Healthcare 4.0 aims to create a comprehensive, well connected set of smart services for the healthcare industry and support the various needs of quality healthcare services [1][3][10][11][12]. Healthcare 4.0 is enabled by several recent and innovative software, hardware, and communication technologies like IoT [13], medical Cyber-Physical Systems (MCPS) [4], health fogs [14][15], health clouds [16], and mobile communications [17]. Big data analytics provide cutting-edge instruments to recognize healthcare trends and relationships, patterns, and insights [18] leading to improved healthcare services, decision making processes, and strategic planning [19]. Blockchain enables trusted interactions and secure ledgers for healthcare applications [20][21] and the abstractions under the Internet of Services (IoS) [22] represent everything as a service with uniform interfaces [23]. Another area of advances in modeling, simulation and digital twin technologies are also becoming an integral part of Healthcare 4.0 and support various smart capabilities for is applications [24][25][26]. Healthcare 4.0 adopts its design principles from the Industry 4.0 principles [27] and these are [28][29][28]: interoperability, virtualization, decentralization, real-time processing ability, service orientation, and modularity. Recently, there is growing interest in developing healthcare applications to reap the benefits of Healthcare 4.0. as illustrated by the contributions in [28][29][30][31][32][33]. Furthermore, the authors in [3] study the benefits of Healthcare 4.0 on healthcare system engineering. Overall, the research directions are solidifying the benefits of adopting a more advanced technologies to build smarter, more efficient healthcare systems.

When looking at areas of applications for Healthcare 4.0, we find the efforts covering various areas of the healthcare system such as monitoring, diagnostics, pharmaceuticals, facilities management and the supply chain. Many technologies are being used to advance these application areas of healthcare services. One important application area is healthcare monitoring and the use of sensor technologies [9][34][35][36][37][38][39][40][41] to automate the process. Another aspect is diagnostics technologies where smart healthcare applications can help in gathering data, analytics, and visualization to assist the physicians and improve the diagnostics [42][43][44][45][46]. There are also technologies to improve intensive care units (ICUs) operations [47][48] and medication delivery [49]. These include applications that monitor the patients' condition and make instantaneous decisions for automated responses to changes in these conditions and methods to improve ICU operations and reduce the length of stay in the ICU [50]. Another aspect is creating a highly connected communication capability that will automatically identify and connect with the appropriate healthcare personnel in case of emergencies [51]. Elderly care and aging issues are another area where technology is very helpful [52]. For example, providing applications that will assist in in-home care [53], remote physician consultations and the use of smart algorithms to schedule visits, delivery of medications and other supplies. Simulation, modeling, and optimization technologies are used to improve healthcare management [54] and supply chain operations [55]. The healthcare industry has benefited greatly from all these efforts and as we plowed through the COVID-19 pandemic, these have proven their applicability and effectiveness. However, the general theme across the board is that we have disconnected smart systems, data sources, and applications that should have been approached for connectivity and make them all fit under the Healthcare 4.0 umbrella.

III. HEALTHCARE 4.0 APPLICATION DOMAINS

We believe that the Healthcare 4.0 vision is well understood and appreciated by everyone. Therefore, aiming to accomplish this vision is beneficial, realistic and doable. There are various areas in healthcare where Healthcare 4.0 can be adopted to improve the services and create better integration. Under a Healthcare 4.0 infrastructure, resources will be more efficiently used and shared; data will be collected continuously and globally forming a rich medium for analysis and research; Equipment, supplies and other necessities will be more efficiently distributed and used; and intelligent capabilities will be more cost effective as they will serve a global infrastructure rather than a single organization. Most needed technologies are available and various healthcare organizations have adopted many of these especially when the COVID-19 pandemic started. However, there is an obvious lack of a unified vision to how and

where Healthcare 4.0 can be applied. The efforts are generally fragmented and various groups (researchers and practitioners) are working on different aspects in silos and many of them repeat others' work in the process.

A highly effective Healthcare 4.0 infrastructure must unify these efforts and provide the means to bring all people, resources and technologies together to achieve this. This will open up huge opportunities to adopt advanced hardware, communication and software technologies to create a global smart healthcare system. To achieve this, it is important to look at the different demands of healthcare services and organize them. We can view these services based on the different aspects of operations such as diagnostics, preventive care, resources and professionals in the field. The categorization helps identify the specific needs of each group of services in terms of achieving the Healthcare 4.0 vision.

1. **Diagnostics** is first concern in patient care and arriving at an accurate diagnostic with the lease invasive methods is critical. Healthcare 4.0 applications can support activities like analyzing symptoms and correlating them with other factors like life style and environmental factors to find answers. The ability to collect, organize and analyze historical diagnostics data, preferably on a global scale, can help healthcare professionals make more informed decisions for new cases and applications using data analytics and smart algorithms are helpful.

2. **Prevention** is an elusive goal that healthcare professionals are chasing. Healthcare 4.0 applications can use various data sources like historical patients' data, environmental and life style factors associated with these patients, and data on diseases and their signs, symptoms and treatments. Smart analytics tools can help sift through the data, identify relationships and provide the healthcare professionals with better insights on how diseases start and the factors that increase or lower the chances of developing them thus providing a strong basis to create vaccines, preemptive policies and guidelines for prevention. This is best achieved with access to large repositories of data, optimally a global repository.

3. **Treatment** is also an important area where the availability of data is extremely helpful. With historical data on treatment protocols and their results, Healthcare 4.0 applications can analyze this data and provide detailed information on their effectiveness and success rates. Applications can also provide the healthcare professionals with tools to compare different protocols. Furthermore, the data can be the basis for simulation software that allows professionals to adjust available treatments or add new ones and project their effectiveness before even prescribing them to patients.

4. **Public Health** can be drastically improved using Healthcare 4.0 applications as they can provide methods to intelligently identify public health threats and ways to mitigate them. One of the major problems is building and maintaining the people's trust so they would be more accepting of public health policies and guidelines. The Healthcare 4.0 infrastructure will provide consistent access to global data and provide transparency in the processes healthcare professionals use to create such policies and guidelines. In addition, it will be possible to collaborate with other systems like the weather, transportation, environment monitoring, etc. to enhance living conditions and support the healthcare activities.

5. **Resources** like facilities, equipment, research facilities and computing capabilities are crucial for any system. In healthcare many are critical to the core functionality of the system. Healthcare 4.0 applications can support various needs to secure, distribute, maintain and optimally use these resources. Smart supply chain applications can improve equipment acquisition, provide effective scheduling for resources allocation, help different facilities share and exchange resources, and allow healthcare professionals to have access to all the resources they need, locally and remotely. Healthcare 4.0 applications can also help in the process of designing and building new facilities, creating new tools, and monitoring the health and performance of their facilities and equipment.

6. **Healthcare professionals** are the core of healthcare systems. Physicians, nurses, pharmacists, researchers, and all others supporting the systems are essential, yet there is never enough of them. Therefore, finding ways to optimize their work, enhance their working conditions and encourage others to join them is necessary. Healthcare 4.0 systems can provide services to achieve these goals. For example, they can offer smart scheduling and adaptive assignments of the professionals; provide healthcare specialists with a collaboration infrastructure to help them work together, share ideas, data and resources and provide their services to various locations in an optimized manner; and it can offer ways to automate some of the mundane and routine tasks these workers do so they can focus on the more important and demanding tasks.

IV. CHALLENGES OF ADOPTING HEALTHCARE 4.0

Looking at the various domains of healthcare services, it becomes clear that there are many challenges to address to achieve the Healthcare 4.0 vision. These challenges have slowed down the adoption of a global Healthcare 4.0 infrastructure and made the process complex, expensive and in some cases impractical (if not impossible). Here we discuss some of these major challenges.

1. **Privacy**: As seen in the examples, a high percentage of Healthcare 4.0 applications rely on data, lots of data. This data includes patients' records, healthcare workers' records, information about people in other organizations like the insurance companies, suppliers, caterers, and research centers. Many consider collecting and keeping such data invasive and are hesitant to consent to its collection and use. Recently, when some healthcare organizations in some counties created tracking apps for COVID-19 cases and vaccination records, some refused to use them because they did not know who and how the data will be used. We can also see this problem when considering patients' electronic health records (EHR), where questions on who should/should not have access, what type of access is allowed to different users and how owns these records. Healthcare 4.0 applications could not function properly without appropriate data privacy policies and measures. These policies must also be communicated clearly with all users.

2. **Security**: It has been a major issue with practically any distributed application. The problem intensifies, when we also include vast amount of people's private data like in healthcare applications. Securing Healthcare 4.0 applications is a massive endeavor, especially when we consider global deployment. The recent increase cybersecurity attacks and data breaches is proof

that security measures and techniques still have room for improvements to provide better protection. The importance of securing Healthcare 4.0 applications and data further intensifies as these applications could have direct impact of the wellness and livelihood of humans.

3. **Access Control**: some consider this part of the security challenge; however, it is a major problem on its own. Even when you have a highly secure system, you still need to control access to the different components and data in the system. Banks for example keep ledgers of customer transactions that practically no one in the bank, including top executives can alter. Thus, well defined access policies were set and enforced to achieve this. In healthcare, the problem is a lot more complex because we are dealing with different entities that need to view and alter health records/data. For example, a patient is usually considered the owner of their EHR, yet, they are not allowed to change these records. Some doctors need to change these records, yet, it is not always known which doctors should have access and weather this access should be continuous or temporary. Expand this situation to a global scale and access control issues intensify.

4. **Interoperability and integration**: The Healthcare 4.0 infrastructure cannot be built from scratch. Current technologies, applications and systems should be integrated with new components under the Healthcare 4.0 umbrella. Most current systems are built independently from each other; thus, issues of compatibility, interoperability and connectivity arise when trying to integrate some of them together. In addition, new components and systems will need to be designed to interoperate with current systems. This will restrict how new systems are designed and may lead to performance problems or will force new systems developers to forgo better ways of implementation in favor of interoperability with current systems.

5. **Global connectivity**: Healthcare 4.0's vision is to create a global infrastructure encompassing all healthcare systems around the world. This statement alone is a problem. Finding ways to establish connectivity and rules of engagement is not difficult technically. However, it is very difficult when considering political, governance and legislative constraint. Countries have their own rules and regulations on software systems and what is considered acceptable in one country may be illegal in another. As a result, it becomes difficult to find common ground that will allow for various systems in different countries to connect and interoperate across the borders.

6. **Ownership and responsibility**: If resources are to be shared within the Healthcare 4.0 infrastructure, we face the issue of managing ownership of resources and responsibilities of all parties involved. Once more, this is not much of a technical challenge, but still extremely hard to achieve. Agreements on who pays for what, how the finances will be managed, and who is responsible for maintenance, repairs and replacements of systems components and equipment must be developed. For example, if a large healthcare facility owns some very expensive and highly sophisticated equipment that can be shared with others, it will be necessary to clearly define the usage terms and enforce them. Healthcare 4.0 applications will need to include such rules and requirements.

7. **Intellectual property and protected content**: Healthcare 4.0 calls for openness, collaboration and resource sharing, yet not everything can be left open, accessible or sharable. Patented content, technologies, and designs to one organization cannot be shared with other organizations. It may be possible that one entity allows others to access their proprietary information/resources, however there will have to be clear mechanisms to protect this content. Healthcare 4.0 applications must provide these measures and provide assurances among collaborators regarding their shared content. Unfortunately, this is not only a technical challenge, but it is also a human challenge. Ethical behaviors cannot be enforced by an application and opportunities to misuse special knowledge are always present. This is one of the main reason different healthcare organizations would refrain from being part of a larger collaborative and resource sharing framework.

8. **Human factors**: Is another issue that does not particularly complicate the Healthcare 4.0 applications from the technical perspective; yet they could easily render them unusable. The major issues arise from how humans view and understand technology and their perception and acceptance of its invasive nature. Healthcare 4.0 applications rely heavily on constant monitoring and recording of health conditions, daily activities, interactions with others, and proximity information. A lot of people view this type of monitoring and data collection to be invasive and in many cases unnecessary. As a result, getting people to accept and use Healthcare 4.0 applications becomes an extremely difficult task. To further complicate the problem, having systems collect and use such data, also raises questions about who will have access to and/or use this data, how it will be used, where it will be stored, among many other questions. Since the COVID-19 pandemic started, we have seen these questions arise extensively with different governments and organization instituting (or tying to institute) applications that could track users to record test results and vaccination information, conduct contact tracing, and enforce quarantines. For some societies, this was acceptable, while for others it was considered an invasion of privacy. The Healthcare 4.0 vision requires a lot of similar capabilities to be active and in use which we expect will be facing the same issues. Furthermore, the human factor also includes the politics and governance issues, which can easily intensify this problem, Finally, we also need to deal with the willingness to collaborate and exchange knowledge and resources among healthcare professionals around the world. In this case, questions regarding intellectual property, exclusive access, unique solutions, etc. arise and humans and organizations are not always willing to share.

9. **Lack of vision**: Healthcare organization around the world have moved aggressively to adopt technology and transform their business model for more effective healthcare services and reduced costs. For several decades, the move to digitizing healthcare information through the use of healthcare information systems, EHRs, digital transcriptions of diagnostics and lab results, computerized equipment and monitoring devices, among other technologies. Unfortunately, the efforts, as positive and effective as they are, do not have a unifying vision. The current state of healthcare systems is disjoint and the achieved results are localized to specific systems and specific organizations. Some larger healthcare organizations started creating a more strategic approach to achieve better digital transformation and include smart healthcare applications, yet,

these too are localized within these organizations. Thus, intensifying the different adoption, integration and collaboration issues. The digitalization of healthcare systems to achieve a global Healthcare 4.0 infrastructure and smart healthcare applications requires a broader view of the global needs to make significant impact. The localized planning at the organizational level needs to be augmented with considerations of what others are doing, how to work with others, how technology is evolving, what can be incorporated, and how to make use of current advancements and solutions to move forward. A long-term strategic vision is a must to unify the efforts and make it possible to achieve full scale healthcare systems transformation.

Overall, current work in the field has addressed some aspects of these challenges and ongoing research and development efforts will continue to find more solutions. In addition, solutions for the technical challenges seem to be moving forward at a much faster pace than the non-technical challenges. Furthermore, the lack of vision has become a major concern as more solutions in the digitalization efforts are introduced by separate entities and are mostly incompatible and extremely difficult to integrate with others.

V. MANAGING THE HEALTHCARE 4.0 TRANSFORMATION

There are many challenges to overcome when considering creating a global Healthcare 4.0 infrastructure. These include challenges in implementing and using the technologies and addressing scientific issues like collecting accurate data]. There are also technical challenges concerning the design, development and deployment of healthcare systems using these technologies. In the previous section (IV), we outlined several of these challenges. Many of these can be addressed via improvements in the use and adoption of new technologies and keeping integration and interoperability as a main requirement, while some require more human interventions.

Technical challenges are being addressed in various ways such as developments in tele-medicine, supply-chain, use of IoT and MCPS, and incorporating intelligence. Blockchain [57] is shown to help with UAV path planning during a health crisis [58]; creating trusted medical records [59]; securing remote patient monitoring [60]; creating a tele-surgery framework [61]; and protecting electronic health records [62]. Other technical challenges include systems and applications integration, data sharing, collaboration, and human factors [63]. Somework is ongoing on prominent issues like privacy [64][65][66][67]; collaboration capabilities and tools [63][67][68]; experience in medical research coupled with technology aspects [69][70]; and high performance computing and communication capabilities [67][70][71][72][73][74]. Challenges of privacy, security, energy and communication limitations are discussed in [71]. On the other hand, the human factor plays a strong role in making, or breaking, the Healthcare 4.0 vision. Ethics, equity, and human factor issues were discussed in [56][63][64][65][69]. Politics, governments, private/public sector involvement, intellectual property protection, and public trust are also important.

The human factor is extremely important because software/systems acceptance is in their hands. If patients decide that an automated home monitoring system is invasive to their privacy, they will refuse to use it. If innovators in the healthcare system are not willing to share their work in the name of protecting intellectual property, it will be hard to foster a collaborative knowledge/resource sharing infrastructure. Moreover, the high disparities in governing organizations and countries make it hard to find common grounds where everyone can give and take to achieve the vision. We can see that solving problems in this realm is not something we can address with technological solutions; thus, we are no considering them heavily in the discussion. We will focus more on the technology aspects of Healthcare 4.0.

We will discuss the transformation efforts in terms of technology adoption, introductions of new software systems and the integration of different technologies to create a holistic Healthcare 4.0 infrastructure. In this regard, we need to make sure that current and new healthcare systems will integrate and operate together as one large system. Therefore, the transformation steps must be well studied and managed and highly coordinated across healthcare service providers and supporting services as in pharmaceutical companies, equipment manufacturers, suppliers and the supply chain activities.

To make the move for a healthcare 4.0 infrastructure, we need to look at it as a large-scale and long-term strategic venture. It is a huge project that involves a very large number of stakeholders, an increasingly growing scope and unlimited possibilities and risks. In strategic planning, the first step is always creating a direction that focuses efforts and rallies stakeholders towards a common goal. The Healthcare 4.0 vision is what we want to achieve, which we believe is the one aspect all healthcare providers, supporters and users need to agree on. The common goal is to have a globally accessible, highly effective, optimally operated and cost-effective healthcare infrastructure. As part of that vision, we also need the people involved (the general public, patients, healthcare professionals, organizations leaders, and governing bodies) to agree on the benefits of the Healthcare 4.0 vision and understand the demands and consequences of adopting it.

With a general agreement on the vision (hopefully) in place, we need to also have a well-defined, overarching long-term set of objectives to move us towards that vision. These objectives should help individual healthcare organizations to plan their transformation within the context of the main objectives. Individual healthcare facilities and organizations achieved various levels of connectivity and automation that can lead to the larger objectives for Healthcare 4.0. However, as discussed earlier, these efforts do not have a common goal that guides them to better alignment with other efforts in other organizations.

A holistic view requires addressing (1) current solutions in use in the healthcare sector; (2) Solutions under investigation and/or development; and (3) future solutions. Unlike a traditional system development project, this project has already taken off, thus using traditional project planning methods may not be the best thing to do. Different parts of this project are traveling in different directions and there is no way to determine if it will be possible to diverge all efforts into a unified direction. So, our task now is to find ways to align the efforts and provide ways to help everyone move in the same direction.

The most difficult part is aligning existing healthcare solutions with the Healthcare 4.0 vision. For current solutions, healthcare entities will need to review them and identify

applications and technologies that can be adapted to integrate with new Healthcare 4.0 solutions. Unfortunately, many existing solutions may be inflexible or very expensive (in terms of cost and/or time) to adapt. In this case, it is usually recommended to phase them out as they reach the end of their life cycle. In general, this is one of the most challenging areas for organization and key to why they may not be willing to agree on or work towards a unified Healthcare 4.0 infrastructure.

Healthcare application in the development phase are somewhat easier to address; however, it all depends on how far these are in the development cycle. Some that are closer to completion may also be extremely difficult and expensive to change. However, it is possibly worth the effort. Projects in the early stages of development or still under research and analysis can be easily adapted to conform with the Healthcare 4.0 vision.

Therefore, the master plan for achieving the Healthcare 4.0 vision must include the efforts to transform and adapt current solutions, redirect developing solutions and envision new solutions to create in the future on the same infrastructure. Although this seems difficult and expensive, on the long run, we envision that it will reduce the costs of developing and introducing new healthcare services under the Healthcare 4.0 umbrella because having a unified vision will eliminate duplicate efforts, streamline innovation, provide better ways to find and use appropriate technologies and make it possible to find, recruit and share the talents needed.

We need to consider currently available resources and rely on well-established technologies, while working on enhancing and integrating Healthcare 4.0 functionalities and capabilities. For example, we already have a robust and well-developed communications infrastructure facilitating communication and integration for many types of distributed systems and collaborative applications. The base medical infrastructure and resources including healthcare professionals, hospitals, pharmaceutical industry, insurance, transportation systems, medical equipment are in place. However, the great disparity in access and utilization of such resources around the world is one major aspect to be addressed in this project. We need to develop technologies and solutions that will enhance available resources and provide equitable access to them. In addition, we have super computers and the cloud/fog infrastructures that support various healthcare applications for managing health records, improving diagnostics, and supporting research. We need to make it easier to utilize such resources to develop more applications and advanced solutions for large-scale deployment within a unified Healthcare 4.0 infrastructure. These resources need to also be effectively used to handle the abundant amount of data collected and generated in the healthcare industry.

The Healthcare 4.0 project is the ultimate example of an agile development project. There is a huge "wish list" of features and capabilities to accomplish. The problem is, the content of this wish list is scattered, incompatible, belongs to various independent entities, and has a lot of duplicate and conflicting requirements. One of the major aspects for any healthcare organization to consider is to consider what is on this wish list before creating their own. A strategy to organize and prioritize a shared wish list that incorporates all the requirements for a complete Healthcare 4.0 infrastructure can help improve the

transformation, reduce duplication of efforts and wasting resources in the process, and improve interoperability across systems for better integration.

VI. THINK BIG WIN BIG

As we highlight the potential benefits of a highly effective Healthcare 4.0 infrastructure, we acknowledge the challenges we need to address. Yet, we believe the benefits outweigh the costs of addressing these challenges. Technically, we have most of the resources and capabilities needed, yet we need more done on the planning and managerial side. There are no unifying vision or strategic objectives leading to the realization of Healthcare 4.0. Stakeholders are not collaborating to correct the issue and many are reluctant to do so. Yet, this is practically the best way. The main challenge is that there is no one way to develop and deploy healthcare technologies and applications. Thus, everyone is doing it their way. The lack of a holistic view, organized approaches, and large-scale coordination is making the progress slow and tedious and over the long run, very expensive. Research communities in the field along with industries need to initiate conversations on how to accept the vision, unify the efforts, employ standardized methods for interoperability and integration, and identify ways to support connectivity and collaboration across healthcare applications and systems within a healthcare organization and across multiple (hopefully global) organizations.

Thinking big and having a strategic plan to create a comprehensive healthcare 4.0 framework is the best way to improve all healthcare services and offer effective healthcare services and health crises management. Many have proposed different ways to integrate current healthcare technologies and new ones under a holistic Healthcare 4.0 umbrella. The research has shown that it is not impossible to achieve this goal and that many pieces of the Healthcare 4.0 infrastructure are here and more can be developed in the future. All we need to do is find a way to get stakeholders to agree on some form of collaboration and standardization to facilitate integration across organizations and countries. We need a really good plan and visionary project managers to make it happen. The transformation efforts need to be coordinated to avoid problems, facilitate global collaboration and provide realistic development, integration, and deployment of such infrastructure. However, there are great differences in how everyone sees this happening.

We need to take a few steps back and look at the global healthcare industry as a whole and figure out how to put together the different parts to make Healthcare 4.0 happen. In a way, all stakeholders need to keep in mind others' contributions to the field when they want to add their own. They also need to change the way technology is adopted in the healthcare systems. A long-term consideration is required when making immediate technology adoption decisions to make it possible to introduce and integrate new technologies as they become available. Provisioning for the future is important for a sustainable Healthcare 4.0 infrastructure. It is clear that we cannot anticipate technology advancements and how new healthcare applications will be, but we can still provision for the possibilities and ensure continuity in the development and adoption of such technologies under the same Healthcare 4.0 infrastructure.

VII. Conclusion

We a unifying vision and a long-term strategic plan to achieve the Healthcare 4.0 vision on a global scale. We believe that current advancements and future work will gradually build the total Healthcare 4.0 infrastructure, however, we must ensure that this incremental approach to achieving the vision will actually work. IT infrastructures need to be further enhanced and equipped with capabilities to connect with and operate within the Healthcare 4.0 infrastructure. Current and emerging technologies, intelligent applications, automated systems and advanced medical equipment must be designed with connectivity and interoperability in mind. Software development efforts should adopt standardized approaches for designing and implementing software solutions that will allow different software and services to be integrated. In addition, the digitalization of the healthcare infrastructure, systems and data must continue with explicit support for collaboration, safe data sharing, and efficient resources utilization. The Healthcare 4.0 vision is achievable through a unified effort to complete one huge continuously evolving project encompassing various healthcare services and applications. Stakeholders need to be aware of this and plan accordingly. Finally, and most importantly, people need to be aware of and understand the requirements and implications of adopting Healthcare 4.0 applications. They need to accept some of the imposed demands of these applications on their personal lives and be capable of managing and protecting their personal data, while being proactive in providing the needed information for Healthcare 4.0 systems to do their jobs. We would like to view our work here as a start for the research and development communities around the world to start work on establishing some level of agreement on what the Healthcare 4.0 vision is and finding ways to create transformation plans that keep collaboration at the center of them. It is time to step out of the silos and work together, coordinate the efforts, share valuable resources, and move forward under the same set of objectives to achieve the Healthcare 4.0 vision.

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