AI & ITS IMPACT TO HEALTH FACILITY DESIGN & PLANNING

December 2024, Version 1.1

ACHA Think Tank

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"It is difficult to think of a major industry that AI will not transform. This includes healthcare, education, transportation, retail, communications, and agriculture. There are surprisingly clear paths for AI to make a big difference in all of these industries."

- Andrew Ng, Computer Scientist and Global Leader in AI

Image: AI Generated

1 Acknowledgments

Credit is due to the following individuals whose leadership, knowledge, skills, and ability made this document possible.

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2　Executive Summary

Artificial Intelligence (AI) is something that has been researched and in continuous development since the 1950's. As increasing computational power has become available, AI has continued to advance at a steady pace at research facilities, universities, corporations, and the military. However, in late 2022, several significant milestones fueled the public's perception of an AI revolution. Headlines and newsfeeds were suddenly filled with generative AI-powered everything: new drug discoveries, self-driving cars that work, advanced robotic automation, language translation, text generation, computer vision, and various kinds of creative content creation of amazing images and videos.

It was the initial launch of accessible tools like: ChatGPT and DALL-E by OpenAI, Midjourney an independent lab, Stabile Diffusion by Stability AI, that really changed things for the masses. (All of these products are still dominant in their respective updated forms at this writing in September 2024.) Since the launch of these products, and other equivalent products, it is now possible for anyone to experiment with and experience the potential of AI.

AI's greatest capabilities are premised on a sales pitch of a vision of the theoretical future, where everything is better, if you just trust the companies selling the tools. What you see now, is but a glimpse of what is about to change the world.

Image: AI Generated

In October of 2023, the American College of Healthcare Architects (ACHA) Board of Regents decided that this AI revolution was dominating every discussion about how it has the potential to change everything. Not only would it change how Architects would program, plan, and design, but it also has the potential to affect the way healthcare will be delivered. Therefore, this topic was identified as something that needed further review and was ideal for the next think tank for 2024. Thus, the ACHA Think Tank: Artificial Intelligence (AI) and its Impacts to Health Facility Design and Planning was formed to study these issues and try to answer these five main questions:

- *What are the near-term and long-term impacts of A.I. on health facility design and planning?*
- *How will A.I. change the process of planning and design?*
- *How will A.I. change the programmatic and planning requirements of health facilities?*
- *What are the roadblocks or constraints that will prevent A.I. from reaching its predicted impact?*
- *Will A.I. result in lower costs, improved outcomes, or improve safety?*

The report will define key terms and concepts related to A.I. and health facility design and planning, explain the methodology and sources used for the report, and preview the main findings and recommendations of the report. The topic of A.I. will also be connected to the convergence of key related fields such as bio-engineering, genetic therapy, robotics, and quantum computing. All these technologies are inter-related to the advancement of AI and will play a major part in this technological transformation of healthcare delivery and health facility design and planning.

AI tools were used to assist as needed to improve the readability of the report. However, it is the full intention of this Think Tank to produce original thought leadership on this topic with original written content not derived from AI sources. Many of the images throughout this report were developed with AI imaging tools and are clearly labeled as such.

On October 7th, 2024, some of this report was presented in session E45, at the Healthcare Design Conference and Expo held in Indianapolis, IN.

3 What Does the Data Tell Us About AI?

"Generative AI", A Re-Introduction of AI to the World

Why are we NOW waking up to AI? Two Words: GENERATIVE AI. In late 2022, significant milestones fueled the public's perception of a new AI revolution. With the quantum-computing that is now possible, Generative AI and it's ability to connect and correlate disparate things together is bringing generative AI-powered everything:

• new drug discoveries, primarily through Individual Specific Genetics
• self-driving cars that are making real-time decisions
• advanced robotic automation
• language translation
• text generation
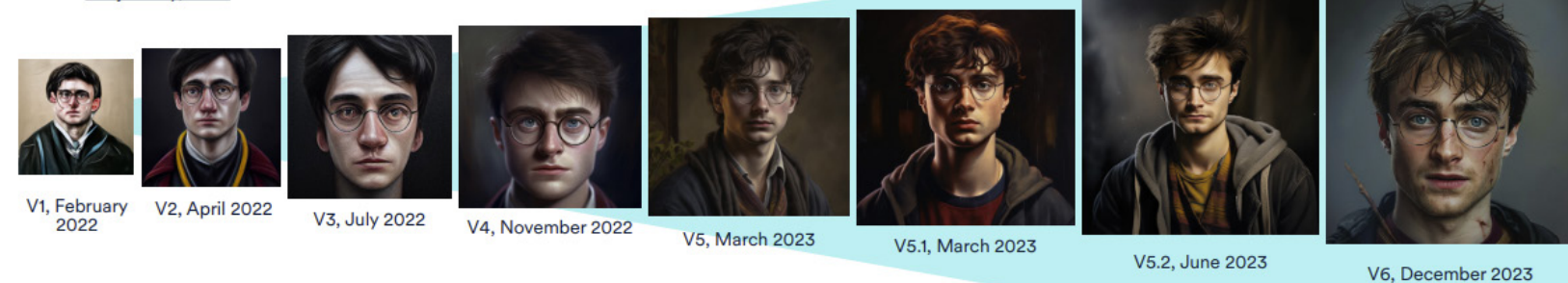• amazing images and videos

ChatGPT and DALL-E by OpenAI, Midjourney an independent lab, Stable Diffusion by Stability AI, changed things for the masses.

> "AI's greatest capabilities are currently premised on a sales pitch of a vision of the future, where everything is better, if you just trust the companies selling the tools. They promise: What you see now, is but a glimpse of what is about to change the world."

What Made Generative AI Feel Revolutionary?

ChatGPT3.5's launch, less than 2 years ago, truly made Generative AI Revolutionary by redefining the capabilities of GenAI Systems…..it offered abilities to write code, compose music, generate proposals, and answer very complex questions. The "learning capability of AI" has been described as "exponential". The ability for AI to generate hyper-realistic images can be visualized in the timeline below from left to right.

Midjourney generations over time:
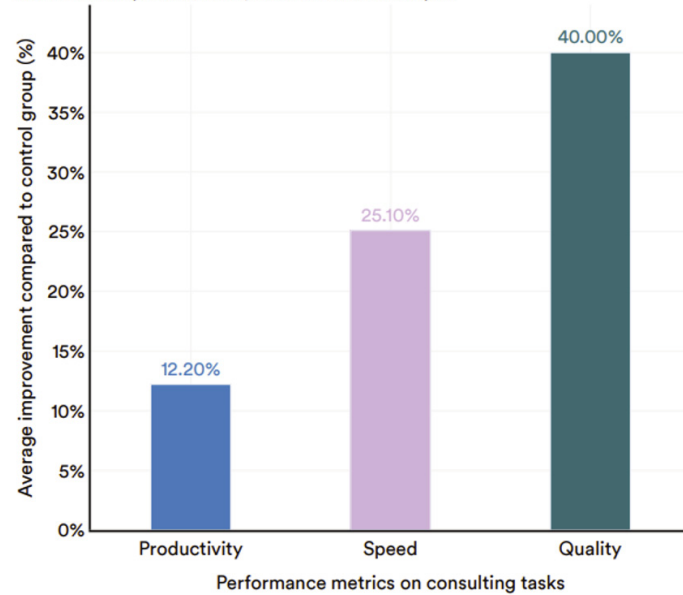**"a hyper-realistic image of Harry Potter"**
Source: Midjourney, 2023

V1, February 2022   V2, April 2022   V3, July 2022   V4, November 2022   V5, March 2023   V5.1, March 2023   V5.2, June 2023   V6, December 2023

Does AI Improve Overall Human Performance? *(Harvard Study)*

Effect of GPT-4 use on a group of consultants
Source: Dell'Acqua et al., 2023 | Chart: 2024 AI Index report

A 2023 Harvard Business School Study (Dell'Acqua et al.) revealed a group of consultants with access to GPT-4* saw:

+12.2% increased productivity
+25.1% increased speed
+40.0% improved quality

*compared to a control group without AI access.

Aside from the capabilities of AI itself, the question has been asked: is human performance improved by AI. In this study, conducted by Harvard, the performance metrics of productivity, speed and quality were evaluated by those who had access to Chat GPT-4 against a control group. In all categories, it was concluded that human performance was augmented positively with the use of AI.

What is the Growth of AI Globally? *(Center for Security & Emerging Tech)*

*"The **United States** leads China, the EU, and the U.K. as the leading source of top AI models. In 2023, 61 notable AI models originated from U.S.-based institutions, far outpacing the European Union's 21 and China's 15. But China is outpacing in AI patents."*

For AI growth on a Global Scale, one may look at Granted AI Patents. China has invested heavily in this "new technology race" and leads the World. However, most AI models are developed by U.S.-Based institutions and firms.

Granted AI patents (% of world total) by geographic area, 2010–22
Source: Center for Security and Emerging Technology, 2023 | Chart: 2024 AI Index report

61.13%, China
20.90%, United States
16.71%, Rest of the world
2.03%, European Union
0.23%, India
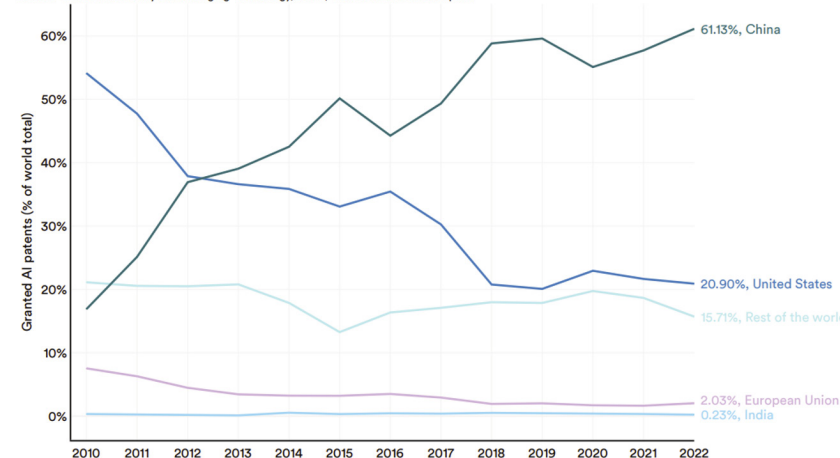
What is the American Reception to AI in Daily Life?
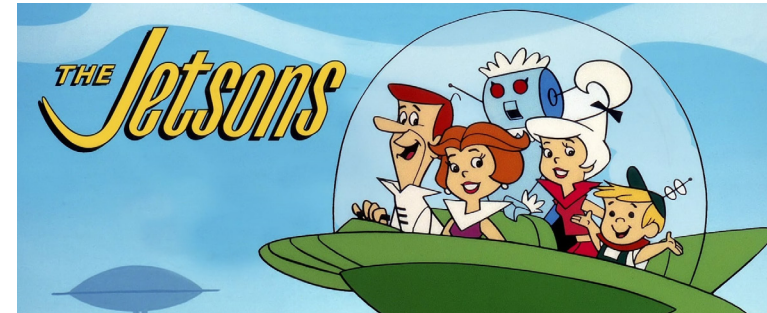
It seems that the "Jetsons" had it right all along! 60-years ago, imagining the future in a way in which personalized, artificial intelligence would assist the human race with the demands of everyday life was a foreshadowing…although it was fantasy decades ago. Items that the "Jetsons" predicted correctly included smarthomes, video calls, sustainability, remote working, wearable technologies, personal assistants and robots, robot vacuum cleaners, self-driving vehicles, smartwatches, food printing, space tourism and particular to Generative AI: an all-knowing computer called "RUDI: Referential Universal Digital Indexer". All-knowing implied that the computer would actually think and reason for itself, to the benefit of its user to provide answers to conduct daily life.
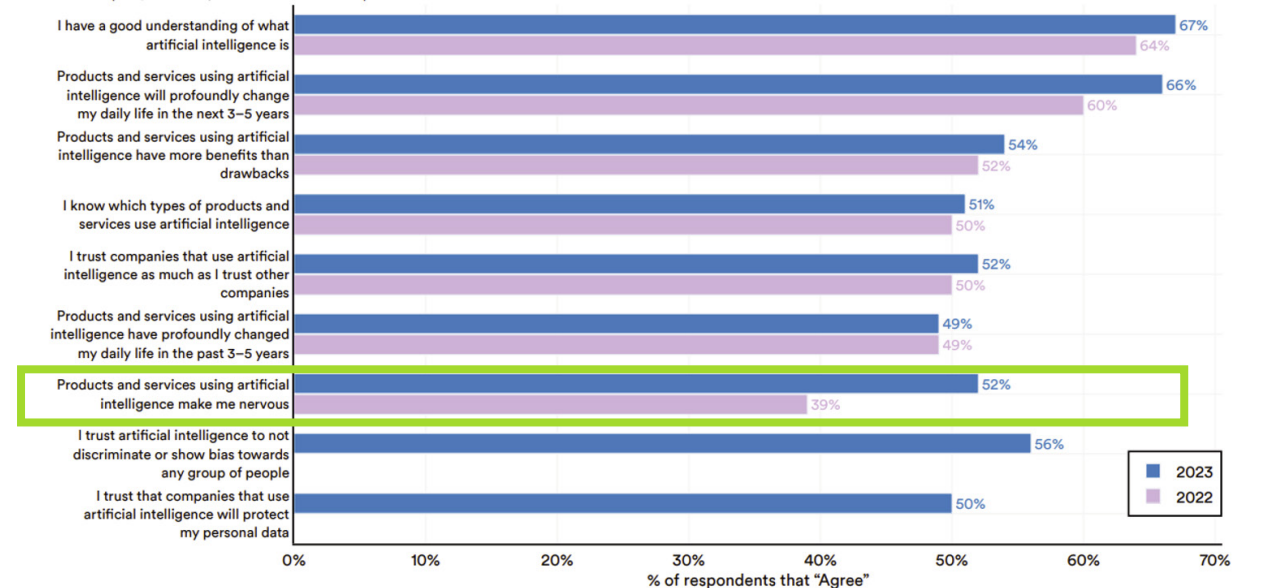
Today, a 2023 Pew Research Center study now shows more Americans are concerned than excited about AI.

What is the Global Reception to AI in Daily Life? *(Pew Research)*

The global reception to AI in daily life is showing a trend that that products and services using AI make them increasingly nervous. This data may reflect that most people worldwide were not fully aware of AI, and its shortcomings. The latter may have been something that became more apparent over time. It could be that future surveys will reverse this trend as AI use increases and improves.

Global opinions on products and services using AI (% of total), 2022 vs. 2023
Source: Ipsos, 2022–23 | Chart: 2024 AI Index report

Statement	2023	2022
I have a good understanding of what artificial intelligence is	67%	64%
Products and services using artificial intelligence will profoundly change my daily life in the next 3–5 years	66%	60%
Products and services using artificial intelligence have more benefits than drawbacks	54%	52%
I know which types of products and services use artificial intelligence	51%	50%
I trust companies that use artificial intelligence as much as I trust other companies	52%	50%
Products and services using artificial intelligence have profoundly changed my daily life in the past 3–5 years	49%	49%
Products and services using artificial intelligence make me nervous	52%	39%
I trust artificial intelligence to not discriminate or show bias towards any group of people	56%	
I trust that companies that use artificial intelligence will protect my personal data	50%	

Is AI Driving Real Business Efficiency Gains? *(McKinsey)*

If you're a business owner, embracing AI is on the rise to promote efficiency. This survey data shows that nearly every business sector is adopting the technology and realizing measurable returns on the investment. Clearly, this is no longer a choice about creating a new competitive advantage. Incorporating AI is now a "stay even" choice for any business to reduce costs and to increase revenue. It may show that choosing to avoid adoption could lead to situations where a business may not be competitive.

Cost decrease and revenue increase from AI adoption, by function,[1] % of respondents[2]
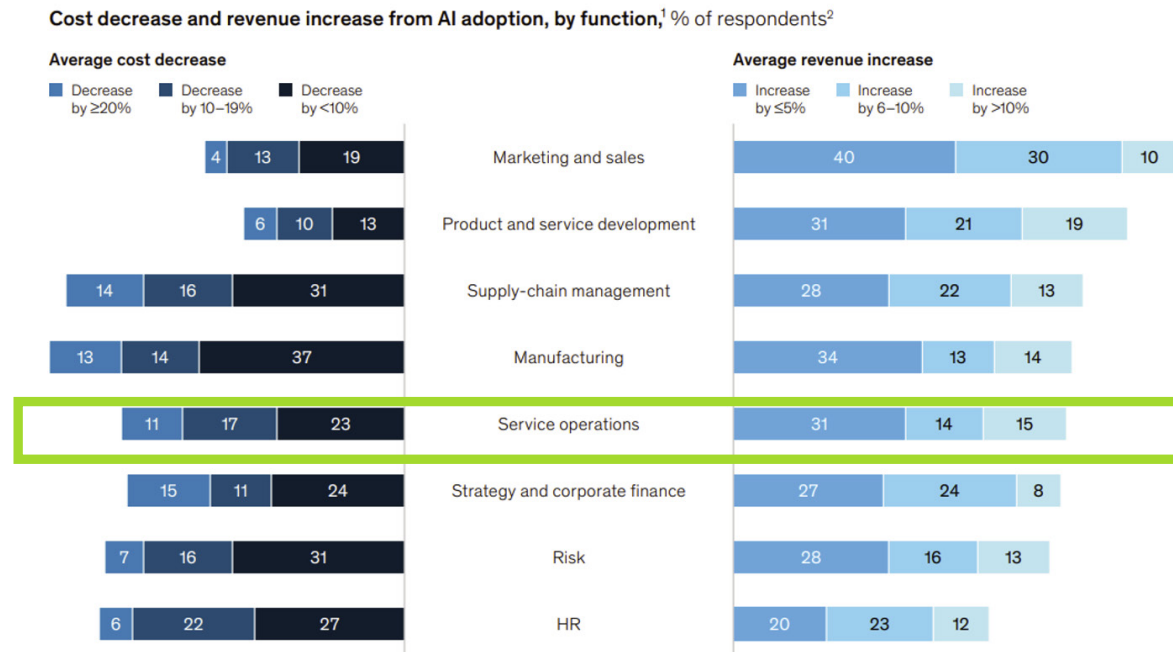
*2023 McKinsey report reveals 55% of organizations now use AI in at least one business unit or function, **up from 50% in 2022, and up from 20% in 2017.***

How is AI Adoption Changing the Workforce? *(McKinsey)*

Change in workforce due to AI adoption, % of respondents
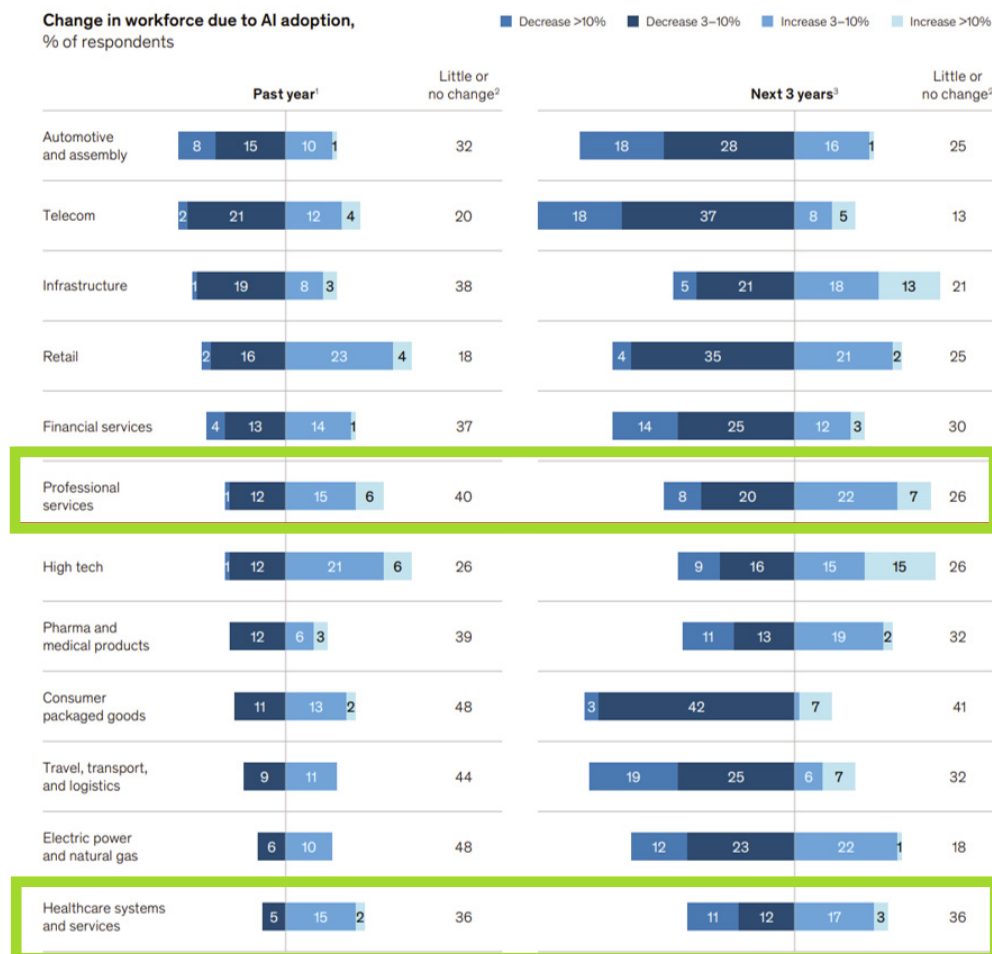
What is the Growth of AI in Medical Diagnosis? *(Stanford)*

There is a major push in AI Technology related to Medical Diagnostics as AI accuracy becomes trusted. For the first time in medical history…it is now possible for an AI to do something human eyes cannot do. The technology shown in this image from "Cleery Health" can look at your cardiac scans shown on the left area, and turns it into a diagram of your arteries as shown on the right side. AI identifies the high-risk plaques in yellow, and low risk plaques in blue. If these high risk plaques burst, platelets stick to it and cause heart attacks. Another example of AI technology is also how a particular version of "ChatGPT4", known as "GPT4 Medprompt" has markedly increased its accuracy in clinical knowledge on the "MedQA Benchmark" which is the gold standard for evaluating medical knowledge with AI systems.
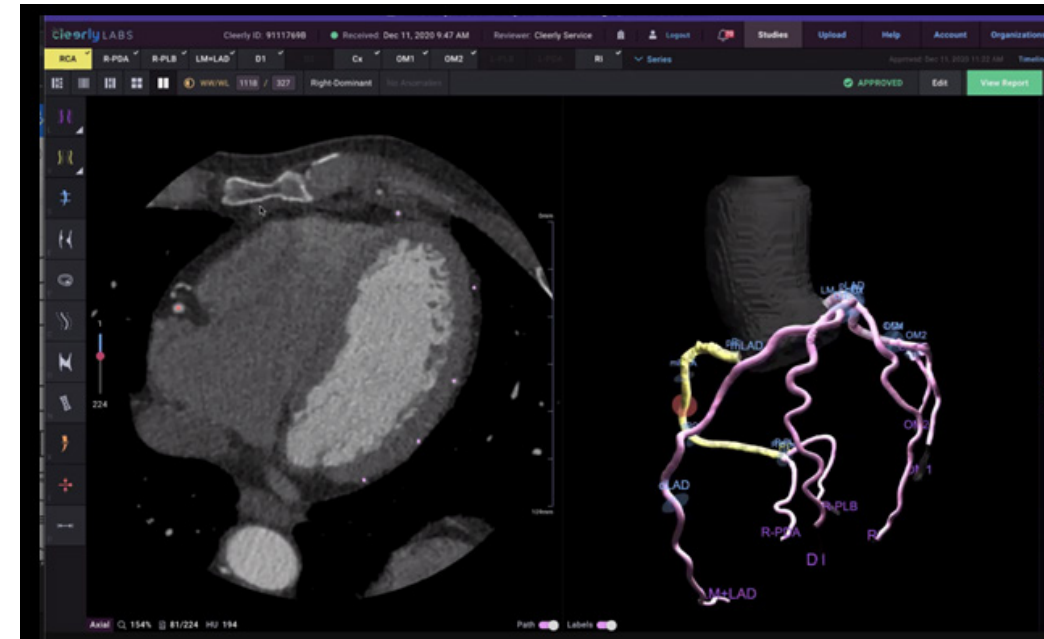
**CT Angiogram:
A Mammogram of the Heart**

• Enhanced by AI (Cleerly Health)
• Not Otherwise Visible by Human Eyes
• Turning the Scan into a Diagram of Arteries
• Disseminating High Risk (Yellow) Plaque from Low Risk (Blue) Plaque

*"On the **MedQA** benchmark, a key test for assessing AI's clinical knowledge. The standout model of 2023, **GPT-4 Medprompt**, reached an accuracy rate of 90.2%, marking a 22.6 percentage point increase from the highest score in 2022." (Stanford AI Index 2024)*

Image: AI Generated

AI adoption is changing the workforce as shown in this survey data. In some categories, the projected growth is so significant that AI will not impact that growth as much as others.
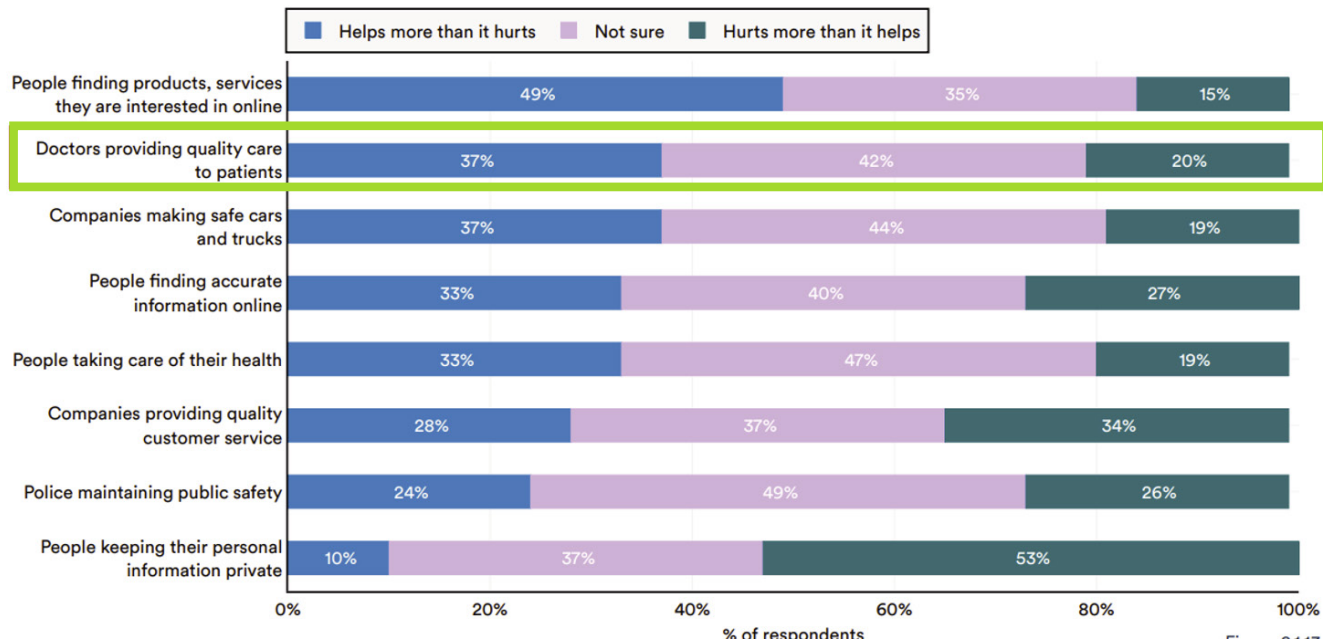
The same 2023 McKinsey report reveals:

• AI adoption is changing the workforce in many industry sectors

• Predictions for the next 3 years: more changes are likely

*• In the **Professional Services and Healthcare Systems and Services** sectors, a net increase in workforce is predicted*

• Many other sectors are expecting significant cuts in workforce

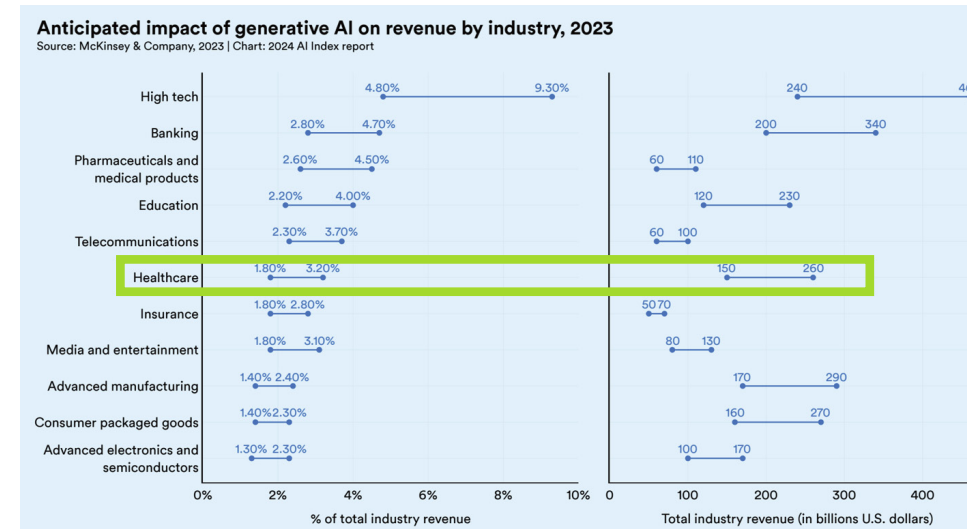# 3 What Does the Data Tell Us About AI? *continued*

What is the Opinion About AI Providing Medical Care? *(Pew)*

Americans' opinions of whether AI helps or hurts in specific settings (% of total), 2023
Source: Pew Research, 2023 | Chart: 2024 AI Index report

Legend: Helps more than it hurts | Not sure | Hurts more than it helps

Setting	Helps more than it hurts	Not sure	Hurts more than it helps
People finding products, services they are interested in online	49%	35%	15%
Doctors providing quality care to patients	37%	42%	20%
Companies making safe cars and trucks	37%	44%	19%
People finding accurate information online	33%	40%	27%
People taking care of their health	33%	47%	19%
Companies providing quality customer service	28%	37%	34%
Police maintaining public safety	24%	49%	26%
People keeping their personal information private	10%	37%	53%

% of respondents

This survey data shows that the opinion about AI in medical care is still evolving. Think about the complexity of your primary care provider possibly connecting all the dots about your medical history over one's lifetime. It's really not possible for a human, even augmented with patient records, to remember every patient, and understand every linkage in their medical history. As physicians start to harness AI tools which are tied to information about their patient's medical history, unique genetic traits, information from wearable devices, diagnostic scans, blood-work, and other metrics. Your provider will be able to make more effective recommendations, better treatment options, not currently possible. It may even be possible that your "provider" could notify you "pre-emptively" on a continual basis about how decisions you make in your daily routine could possibly affect you with real-time wearables connected to the AI systems.

How Will AI Impact Healthcare Revenue? *(McKinsey)*

Anticipated impact of generative AI on revenue by industry, 2023
Source: McKinsey & Company, 2023 | Chart: 2024 AI Index report

McKinsey report (2023) examined the degree to which generative AI might impact revenues:

• As a % of total industry revenue
   Healthcare: 1.8-3.2%

• In total $ amounts
   Healthcare: $150B to $260B

The survey data from McKinsey shows revenue percentages and and total revenue dollars is significant in many sectors of the economy. Specifically for healthcare, there is significant anticipation shown.
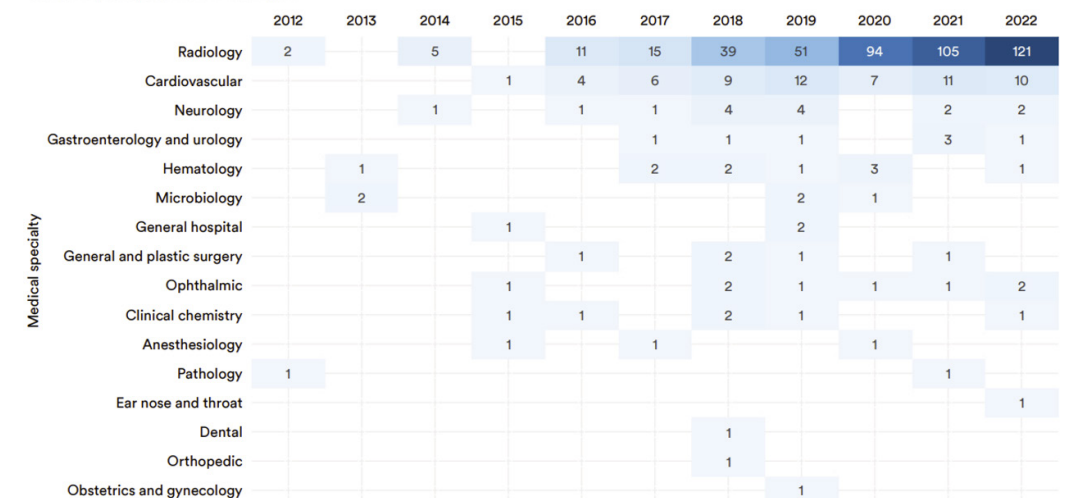
What is the Growth of AI in Medical Devices? *(FDA)*

"In 2022, the FDA approved 139 AI-related medical devices, a 12.1% increase from 2021.

Since 2012, the number of FDA-approved AI-related medical devices has increased 45-fold

AI is increasingly being used for real-world medical purposes."

Number of AI medical devices approved by the FDA by specialty, 2012–22
Source: FDA, 2023 | Chart: 2024 AI Index report

Medical specialty	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Radiology	2		5		11	15	39	51	94	105	121
Cardiovascular				1	4	6	9	12	7	11	10
Neurology			1		1	1	4	4		2	2
Gastroenterology and urology						1	1	1		3	1
Hematology		1				2	2	1	3		1
Microbiology		2						2	1		
General hospital					1			2			
General and plastic surgery						1		2	1	1	
Ophthalmic					1		2	1	1	1	2
Clinical chemistry					1	1	2	1			1
Anesthesiology						1		1		1	
Pathology	1									1	
Ear nose and throat											1
Dental								1			
Orthopedic								1			
Obstetrics and gynecology								1			

The FDA is a good way to measure the growth of AI in healthcare quantitatively, and this graph tracks those devices by Medical Specialty and year. Medical Device Manufacturers are betting on AI enabled devices and increasing research and development in this area. Presumably, to achieve FDA approval, whatever AI is included must work consistently, safely, and ethically. This is a good example of an existing regulatory requirement which will need to be adapted to evaluate AI tools.

4 Will AI Lower Costs, Improve Safety, Improve Outcomes?

Image: AI Generated

How we utilize Artificial Intelligence ethically, safely and optimally in healthcare to drive down costs, improve outcomes, and improve safety for patients and caregivers, begins with the movement to an "N of 1" Philosophy about health and population. The "N-of-1" philosophy shifts the focus from population-based averages to individualized care, aiming to optimize treatment decisions for each patient. "N of 1" is simple to understand: A good example of why this is a significant change is demonstrated in how we have developed and administered antibiotics for generations. "Broad-based" antibiotics were introduced to achieve the highest benefit for the largest number of people to "prevent" health impacts in the overall population. However, many who receive "broad-based" prevention and care may have "adverse" or "reactive" impacts based on their individual genetics, DNA, health circumstances, daily choices, and social position.

With the advent of AI, the reduction in cost for Genetic Testing, and the endless capacity and immediacy of computing power, healthcare will transform by adopting individualized, or personal, health and wellness. The power of AI in applying an "N of 1" philosophy to every patient is a significant change in healthcare delivery. It will enable individual personal factors about a patient to be reviewed against a larger population to identify similar unique conditions, and tailor treatments in ways that have not been possible without extensive time and expense. The potential improvement in treatment efficacy, potential cost reductions for not applying ineffective and potentially harmful treatments, will be one of the more revolutionary applications of AI in general medicine, disease treatment, as well as surgery.

But there are many impediments to achieving an "idealized state" when it comes to using the power of AI in this way. Namely, the current system of reimbursement for the "cost of healthcare". CMS Medicare & Medicaid, and in turn, private insurers, follow the model of payments based on treatment; otherwise known as "sick care". The disruptors that are being introduced by an AI driven "N of 1" philosophy have found that health outcomes can be optimized through disease prevention, eradication, and early detection. Although not entirely novel in concept, the reimbursement structure that offsets rapid adoption is counter to payment based on these principles. What is certain, is that asymptomatic disease identification has proven that the cost to treat before symptoms surface, is lower in cost, and increases longevity and wellness.
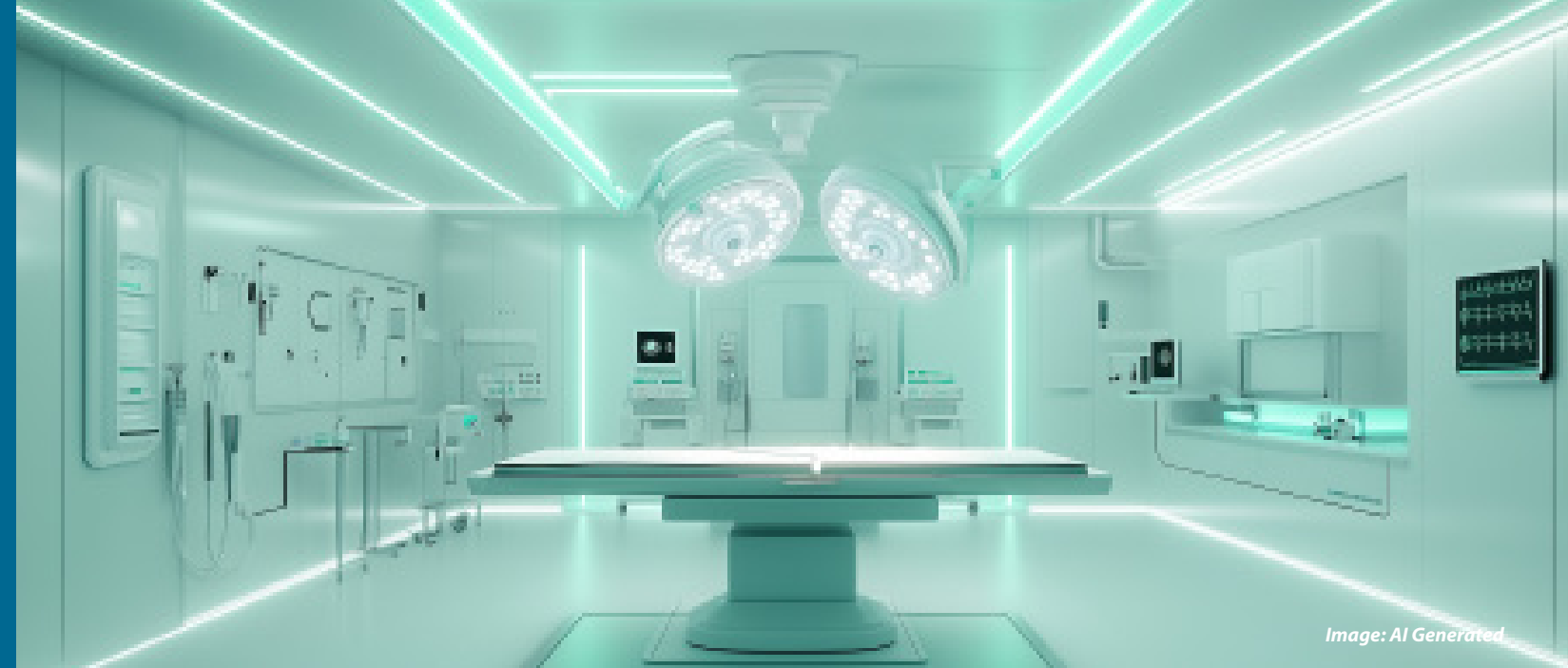
AI has found its way into mainstream healthcare in advancing the efficacy and proficiency of complex surgical techniques and imaging studies. "DaVinci" Surgical Robots, coupled with human planning and guidance, has shown that safety and reduction in complications through a minimally invasive approach is saving lives and achieving results that once were not possible from a surgeon's hands, or a radiologist's eyes, prior to these advancements. With machine learning through AI, these techniques are sure to improve in ways that are even more effective.

Therefore, AI has the potential to transform healthcare from a reactive and population-based system to a proactive and personalized one, where patients can benefit from the best available knowledge and data tailored to their specific needs and conditions. However, this transformation also requires overcoming the barriers of the current reimbursement model, the ethical and regulatory challenges, and the technical and social limitations of AI adoption. The future of healthcare depends on how well we can leverage AI to achieve the goals of improving outcomes, reducing costs, and enhancing safety for both patients and caregivers.

- *AI will lower some care provider costs through improved efficiencies in resource scheduling, automation of supply ordering, and off-loading certain admin tasks. Partial savings offset by high investment in AI systems, hardware & infrastructure.*

- *AI will improve Patient Outcomes: AI tools will assist in treatment options tailored to the individual patient vs. patient type.*

- *AI could improve safety by identifying specific risk factors for individual patients. AI could reduce the need for certain invasive diagnostic procedures . AI can be used to monitor possible interactions with drug prescriptions. AI can help develop safer new drugs.*

5 AI Impacts to the Design & Planning of Health Facilities

To understand Artificial Intelligence's (AI) impact on how we design and plan healthcare facilities, we must first examine the broader transformation AI is driving in healthcare delivery, operational management, and research. While the rapid pace of change and the ever-expanding knowledge base make precise future predictions challenging, some key trends are starting to emerge.

Operations

AI is transforming healthcare operations, making them more efficient, data-driven, and cost-effective. AI can automate repetitive tasks like appointment scheduling, claims processing, and report generation, freeing up staff time for more patient-centered activities and improving overall effciency. In more sophisticated ways, AI can analyze patient data to identify those at high risk of developing certain diseases. This allows for early intervention and preventive measures, improving overall population health. AI is also playing an increasingly important role in robotic-assisted surgery, allowing for greater precision, minimally invasive procedures, and improved surgical outcomes. Finally, AI is contributing to the augmentation of human labor through autonomous guided vehicles, autonomous mobile robots, and humanoid robots, enhancing facility effciency and patient care delivery.

Care Delivery

AI is transforming healthcare delivery, making it smarter, more accessible, and ultimately, more effective for everyone. AI-powered telehealth platforms allow for remote consultations, increasing access to care and reducing hospital visits. AI can also analyze a patient's medical history, genetics, and current condition to suggest personalized treatment plans. This paves the way for precision medicine, tailoring treatments to individual patients for improved effectiveness. Finally, AI algorithms are revolutionizing diagnostics by analyzing medical images (X-rays, mammograms) with high accuracy allowing early disease detection.

Research

Most promising, AI is accelerating research and development in healthcare increasing the speed of breakthrough innovations. AI can analyze vast data sets to identify potential drug targets, accelerate drug development timelines, and predict drug interactions, leading to faster creation of new and effective treatments. AI can be used to design more effcient clinical trials, analyze massive amounts of data collected during trials, and identify promising new treatments faster, accelerating medical breakthroughs. AI can help researchers analyze genetic and health data to understand individual disease risks and develop personalized treatment strategies, paving the way for a future of targeted healthcare.

AI is transforming healthcare across the spectrum. From diagnosing diseases and personalizing treatment plans to streamlining operations and accelerating research, AI's impact is undeniable. The trends in delivery of care, operations, and research will in turn have profound repercussions on the design and planning of healthcare facilities starting with near-term impacts in the next 5-10 years.

Image: AI Generated

Image: AI Generated

Facilities - Near-Term:
An Incremental Optimization

The healthcare landscape in the next 5-10 years is poised for polarization. On one hand, we can expect a continued rise in smaller, decentralized outpatient clinics catering to routine checkups, urgent care, and chronic disease management. These convenient, localized clinics will be equipped with AI-powered diagnostics, allowing for faster and more accurate evaluations. Additionally, features like remote consultation capabilities and AI automation for tasks like appointment scheduling will enhance convenience and efficiency.

On the other hand, existing acute medical centers will begin transforming into centralized "Centers of Excellence" specializing in specific diseases or treatments. These hubs will leverage AI's capabilities and potentially co-locate medical education, research, and advanced care facilities. This co-location fosters collaboration and innovation while offering patients access to the latest advancements within a single location.

Crucially, AI will play a vital role in seamlessly coordinating care across these different healthcare providers and facilities, ensuring a smooth patient experience regardless of location or treatment type. Furthermore, AI will optimize logistics within facilities, managing resource allocation and streamlining supply chains, leading to improved efficiency and resource utilization.

While these near-term changes represent an incremental shift, they pave the way for a more transformative future in the years to come.

Facilities - Long-Term:
An Exponential Transformation

The AI revolution is poised to usher in a new era of healthcare, one that fundamentally shifts the focus from reactive treatment to proactive wellness. This "Lifestyle Healthcare" model will move healthcare beyond the walls of traditional buildings and institutions, becoming seamlessly integrated into our everyday lives.

Medicine will no longer be a one-size-fits-all approach. AI will analyze vast amounts of patient data, not just to diagnose illness, but to predict potential vulnerabilities before they manifest. This allows for proactive interventions and personalized wellness plans that prevent disease instead of simply treating it. Wearables and implanted technologies will continuously monitor key wellness indicators (KWIs), allowing adjustments to be made for health to be optimized. Interactions will be on-demand, virtual consultations with healthcare professionals, augmented by virtual reality (VR) for a more immersive and patient-centered experience from the comfort of your own home.

While the focus shifts to distributed and personalized wellness, centralized healthcare "innovation" hubs will remain the driving force of the transformation. These centers will house advanced learning, research facilities, and cutting-edge technology for complex interventions, surgeries, and diagnostics. AI will power personalized treatment plans and data-driven care within these highly technical environments. The "innovation" hubs will boast highly personalized spaces, adaptable to the specific needs and preferences of each patient, optimizing comfort and recovery. Humanoid robots will become more integrated into care delivery, assisting with tasks like medication dispensing, material movement, and providing basic patient support. This integrated ecosystem will seamlessly blend cutting-edge technology with personalized care, offering a whole new level of healthcare experience.

The potential of an AI-powered Healthcare transformation is undeniable. It promises a future where healthcare is preventive, personalized, and accessible, empowering individuals to take control of their own well-being.
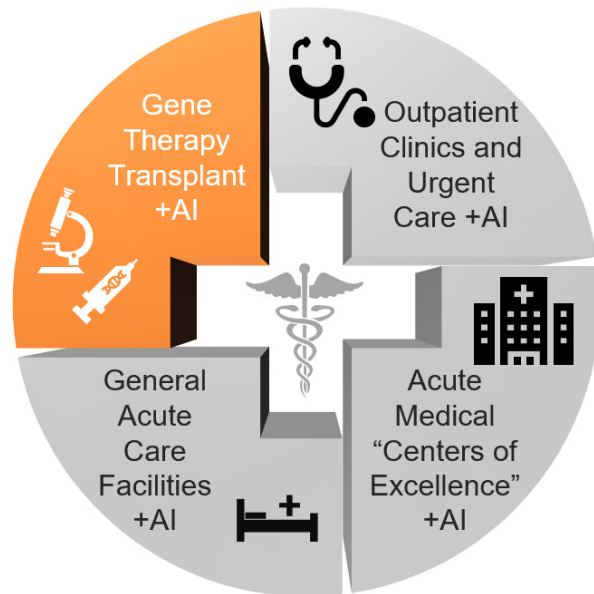
AI will advance Gene Therapy

The U.S. Food and Drug Administration (FDA) has approved **gene therapy** products for several conditions, including cancer, spinal muscular atrophy, hemophilia and sickle cell disease. But for most people, gene therapy is available only as part of a clinical trial today. AI will advance this technology by improving research and bringing personalized medicine to patients.

In the near-term, expect additional needs for **stem cell transplant nursing units** with supporting laboratories. Long-term this could create a need for a new **advanced outpatient clinic type** in lieu of in-patient units.

AI will help evolve specialty centers

Some **Acute Medical Centers** will begin transforming into centralized **"Centers of Excellence"** specializing in specific diseases or treatments. These hubs will leverage **AI's growing capabilities to enhance treatment** and potentially co-locate medical education, research, and advanced care facilities.

AI will enable personalized medicine in the near-time that will continue to evolve. In the long-term, AI+Robotics will require new department planning and designs to incorporate new smart features as clinical operations evolve.
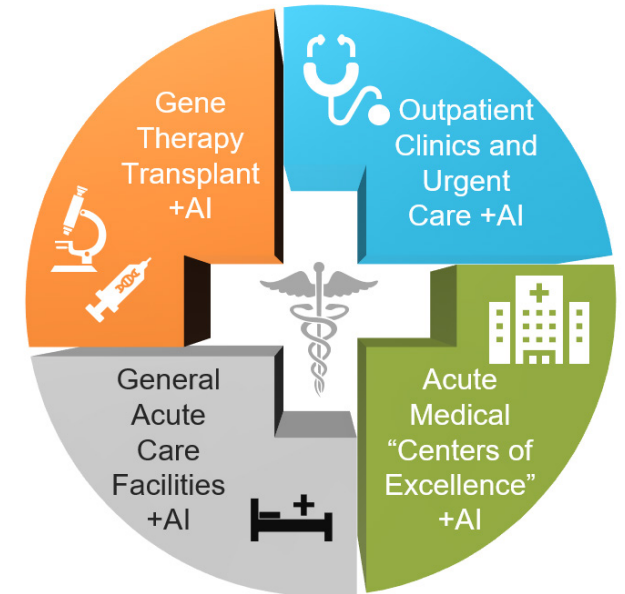
AI will create Smart Buildings

There will be a continued rise in smaller, decentralized **Outpatient Clinics** catering to routine checkups, urgent care, and chronic disease management.

In the near-term, these convenient, localized clinics will be equipped with **AI-powered diagnostics**, allowing for faster and more accurate evaluations. **AI automation for tasks** like appointment scheduling, staff scheduling, and supply ordering will enhance efficiency. Design changes will be minimal initially. In the long-term, AI+Robotics could make these facilities more fully automated and evolve into a more sophisticated facility type.
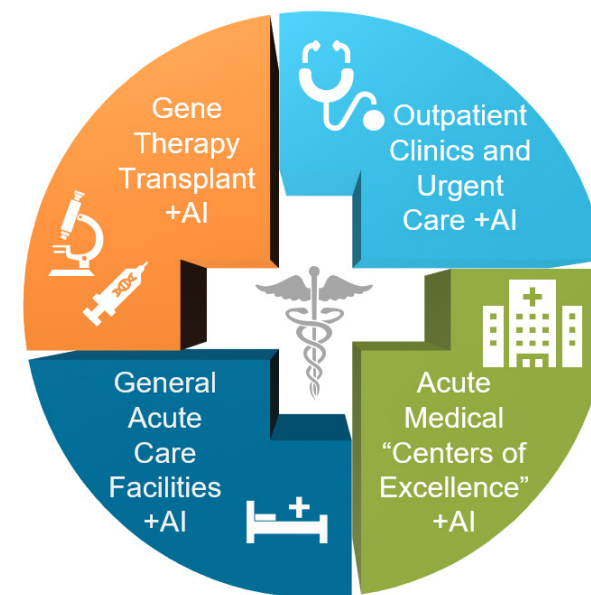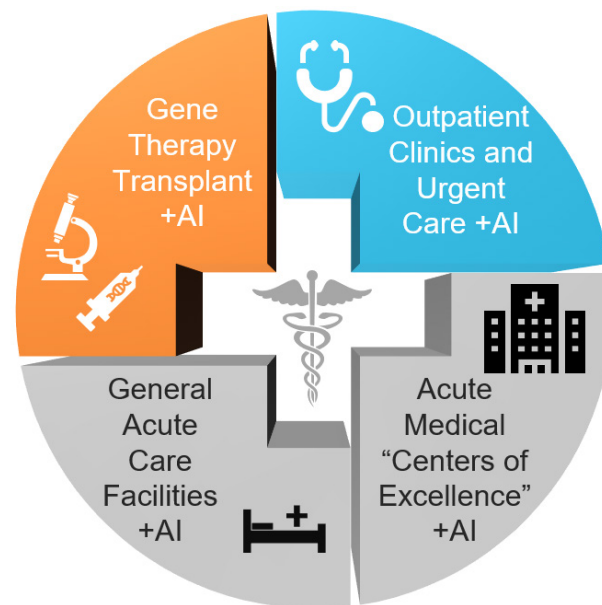
AI will make incremental changes

Acute Medical Centers will remain the backbone of the healthcare system with even more acute patients presenting. In the near-term, more **AI-powered diagnostics and imaging equipment** will replace older systems for faster and more accurate evaluations. **AI automation for tasks** like appointment scheduling, staff scheduling, and supply management will enhance operating efficiency. In the long-term, additional use of AI+Robotics will change department planning needs and will eventually affect nursing unit and clinical operations as Hospitals become smarter.

6 AI Impacts to Hospital Space Planning

Image: AI Generated

Emergency departments are the main access points for patients into the inpatient environment. Initially AI's ability to enhance the triage process and predict patient influx has major impacts on throughput improvement. AI can reduce administrative burden on providers, and allow for better resource allocation. Remote monitoring and tele-medicine can reduce the number of patients needing to visit the ED, reduce space needs. Use of surgical robots in trauma rooms can increase the space needs. Overall we predict a net even re-balance of space.

In the surgical suite, AI can assist in schedule and resource management. Robots are already widely used in surgeries. Robotic systems and AI-driven tools are becoming more compact and integrated that a single robotic system might handle multiple tasks. We could also see an increase in remote surgical procedures. Flexibility of the OR suite ensures that the space can be optimized for various types of surgeries and technological advancements. More cases in the OR will result in more sterile processing.

Imaging services in the future AI can reduce the processing time for imaging, increasing throughput and the need for multiple high tech imaging rooms. Integrated imaging equipment will allow for multiple imaging techniques in one room.

Predicted Impact of AI on Hospital Department Space

INPATIENT - DIAGNOSTIC AND TREATMENT		Next 5 Years	5-10 Years	10-20 Years	Space Program Impacts
	Emergency Services	**AI** Assistance with triage and diagnosing some patients	**AI & Robotics +** Diagnosis and treatment plans created, increased use of automation, to support services	**AI & Robotics +++** Development of surgical robots for trauma in the ER will occur to support certain emergent care	**Rebalance of Space, Net Even** Over time, we believe that efficiencies will reduce some space, but some space will grow
	Surgical Suite	**AI & Robotics** Surgical robots are already widely in use, AI will further enhance their capabilities	**AI & Robotics ++** AI will be used to enhance OR and resource scheduling, robotics will expand further	**AI & Robotics +++** Some surgeries and procedures could become mostly automated by AI	**Increase in Space** Robotic surgeries require larger ORs, increase in flow will result in more sterile processing
	Imaging Services	**AI** Imaging software is reading results for distinctive patterns today	**AI+** Imaging software will be greatly enhanced with AI to reduce procedure times and assist diagnosis	**AI++** Emergence of imaging equipment and software to do multiple imaging techniques in 1 room	**Reduces Space** New imaging equipment will be faster and more capable with ability to combine modalities

6 AI Impacts to Hospital Space Planning *continued*

AI can automate repetitive tasks such as medication and supply delivery, patient monitoring, and administrative work. This can free up nurses to focus more on direct patient care and complex clinical tasks.

Enhanced Patient Monitoring: can possibly remove the requirement for direct visibility into patient rooms , removing the need for decentralized nurse stations.

Support for Daily Activities: Robots can reduce the physical workload on nurses.

Tele-presence and Communication: Tele-presence robots can facilitate remote consultations and communication. The demand for skilled nurses to manage and oversee these technologies will remain crucial. Rooms have more technology and equipment. Storage space for robots.

Clinical Decision Support: AI can assist in and Centralized remote monitoring and communication at Command centers.
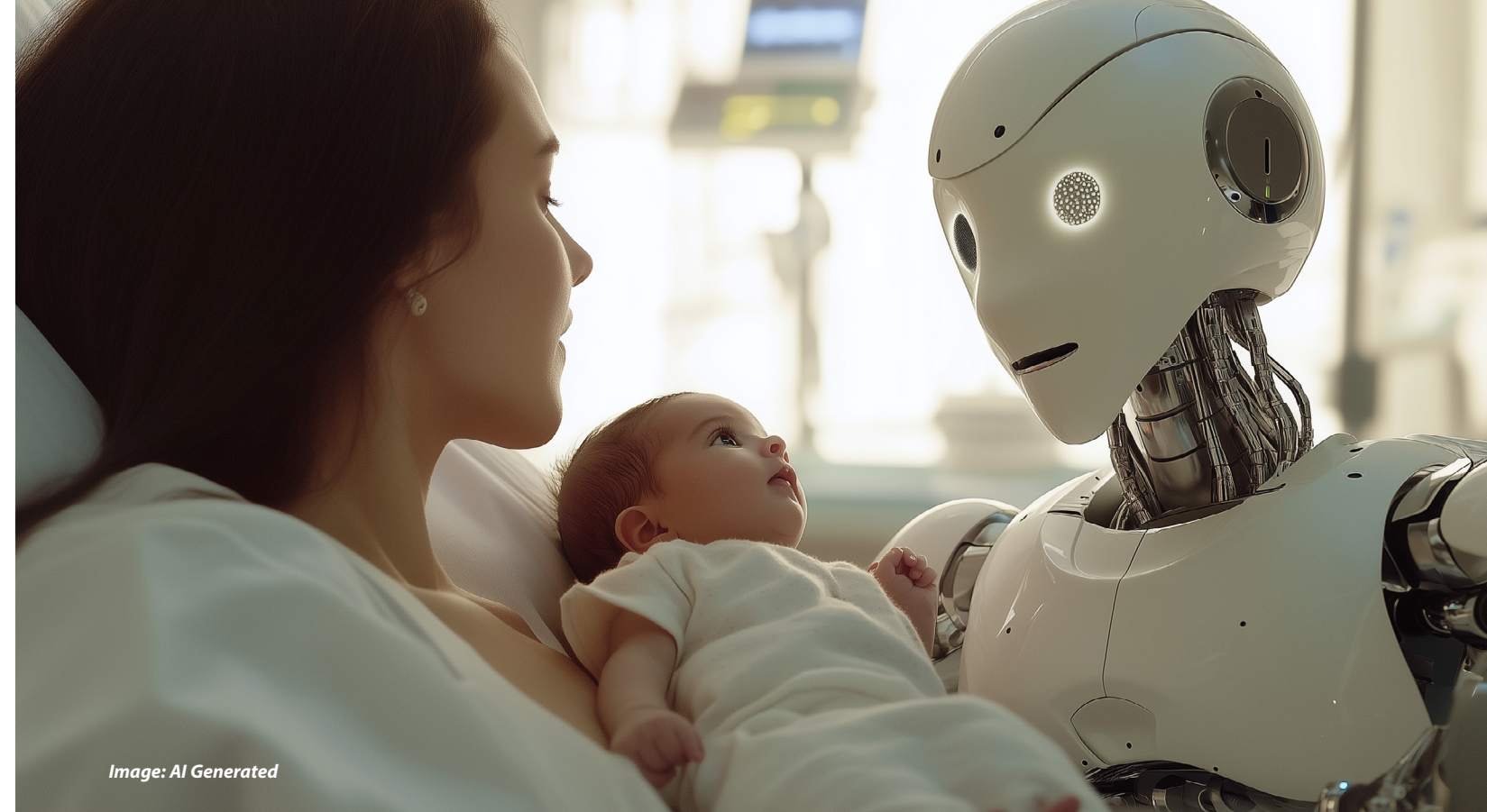
Image: AI Generated

Predicted Impact of AI on Hospital Department Space

	Next 5 Years	5-10 Years	10-20 Years	Space Program Impacts
Acute Care	**AI & Robotics** Assistance diagnosing patients and preliminary use of robotics for supply support	**AI & Robotics +** New processes reduce HAI risk to patients through automation, some patient movement	**AI & Robotics ++** Nursing assisted with automation at the bed-side, some patient handling and movement	**Increase in Space** Rooms will have more automation and robotics or portable equipment shared between rooms
Intensive Care	**AI & Robotics** Assistance diagnosing patients and preliminary use of robotics for supply support	**AI & Robotics ++** New processes reduce HAI risk to patients through automation, robotic patient handling	**AI & Robotics +++** Nursing assisted with automation at the bed-side, robotic patient handling and movement	**Increase in Space** Rooms will have more automation and robotics in the rooms to handle more critical patients
NICU / PICU	**AI+** Some Assistance diagnosing patients based on sensory environmental inputs	**AI++** Enhanced diagnosis based on sensory inputs, recommended treatments	**AI+++** Full Integration of AI into temperature, acoustics, lighting, recommended treatments	**Same Space** Although some robotics will provide support, AI enhancements will need no more space

INPATIENT – PATIENT CARE UNITS

It is tough to imagine a robot taking care of your newborn, but that could be a possibility with the rise of AI and humanoid robots as shown in this image.

After creating quite a few of these images, where the humanoid robots did not provide a level of comfort, this image seemed convincing enough for us to believe this is a distant possibility.

6 AI Impacts to Hospital Space Planning *continued*

Image: AI Generated

AI can assist in managing medication inventory, predict medication demand, identify drug interactions and adverse reactions. Through continuous monitoring of the patient adherence, can increase pharmacists' involvement with their patients and intervene before medication-related complications occur. Pharmacies evolve from dispensing medications to providing services. Expect a lot more automation from pharmacies, including the likely addition of AI-powered humanoid robots, which can be programmed to answer patients' routine questions.

In inventory management, AI can enhance supply chain visibility, automate documentation and tracking goods. digitized systems and robots close to just in time point of care, warehousing automation, augmented reality, drones & advanced sorting systems. Separation of patient and supply transport can increase the area.

Food services AI and automation offer solutions to streamline food prep, increase productivity, and reduce errors. Self-ordering kiosks and AI-powered robotic servers can improve the guest experience, increase average check size, and help optimize labor costs.

Predicted Impact of AI on Hospital Department Space

INPATIENT – SUPPORT SERVICES

	Next 5 Years	5-10 Years	10-20 Years	Space Program Impacts
Lab / Pharmacy	**AI & Robotics** — Assistance diagnosing patients and preliminary use of robotics for supply support	**AI & Robotics +** — Continuous monitoring of the patient, improves safety from adverse reactions	**AI & Robotics ++** — More automation of pharmacies and use of humanoid robots for patient interface	**Increase in Space** — Space will have more automation and robotics or portable equipment
Materials Management	**AI & Robotics** — Enhance inventory management, transportation, robots for supply support	**AI & Robotics ++** — Automated, digitized systems and robots close to point of care	**AI & Robotics +++** — Warehousing automation, augmented reality, drones & advanced sortation systems	**Increase in Space** — More automation and robotics to handle material storage and distribution
Food Service	**AI+** — Streamline food prep, reduce errors, self ordering kiosks and AI powered robotic servers	**AI & Robotics ++** — Robots handle tasks in the kitchen, improving product quality and reducing waste	**AI & Robotics +++** — More reliance on AI powered robots to do prep, serving and cleaning tasks	**Same Space** — Although some robotics will provide support, AI enhancements will need no more space

7 Roadblocks that May Prevent AI from Reaching its Potential

The implementation of AI in healthcare design and practice presents a future of increased efficiency and data driven processes and results. Improved data collection in the industry will require new processes and standards for decisions concerning diagnosing and treating patients. According to a published report by Accenture titled "Reinvention in the Age of Generative AI", from January 11, 2024, 52% of organizations are already reshaping their workforce by redesigning jobs and roles to be centered around AI. In addition, the report states that: "An overwhelming majority (97%) of executives believe generative AI will transform their enterprises and industries and will play a major role in their strategies over the next three to five years."

The potential added economic value over the next 10 years will lead to the further breakdown of the traditional roles in the healthcare industry. Ultimately, this industry is a business whether it is for profit, or not for profit. Repetitive tasks and lower-level decision making procedures are the first tier of the employment infrastructure that can be easily replaced with AI. There will be push-back from the industry to maintain current roles, processes, and structures. This is typical with implementing any new technology, but AI has the potential to transform or even reinvent the delivery of healthcare.

But, the issues that follow are significant "roadblocks" to this revolution, or at least "speed bumps".

Currently, we are still in the beginning of marketable AI development where security can often be a secondary consideration since nobody is certain how AI systems actually work. But, data security must be a core requirement, not just in the development phase of an AI system, but throughout its life-cycle. AI powered software programs are being used by many Architectural and Engineering firms to help supplement their design process. Programs like ChatGPT, upCodes with Copilot, and Midjourney, are AI tools that are proving to be extremely useful to streamline proposal writing, identifying design constraints, and provide unique, custom imagery for marketing or project ideation. One of the main drawbacks when using these programs is the collection, storage, and use of proprietary data and designs. Large companies such as Apple, Amazon, and Spotify have banned the use of ChatGTP in their offices due to the lack of security protocols and the potential leak of privacy data. At many design firms, the use of these programs is often restricted to certain individuals, certain activities, and certain projects, due to security and data concerns.

Risk Assessment Matrix – Data Privacy and Security of AI

	LOW	MEDIUM	HIGH	EXTREME

RISK RATING KEY

	SEVERITY			
	Acceptable Minimal damage likely	Tolerable Moderate damage likely	Undesirable Heavy damage likely	Intolerable Significant damage likely
Improbable Risk is Unlikely to Occur	LOW **1**	MEDIUM **4**	MEDIUM **7**	HIGH **10**
Possible Risk is Likely to Occur	LOW **2**	MEDIUM **5**	HIGH **8**	EXTREME **11**
Probable Risk Will Occur	MEDIUM **3**	HIGH **6**	HIGH **9**	EXTREME **12**

(LIKELIHOOD)

Data security breaches have a high likelihood of happening in the short-term and the long-term. With AI being so poorly understood overall, even by its programmers and the organizations that train the models, it may be very difficult to even detect when an AI model has been hacked or compromised in some way. We could even see AI models designed to appear as trusted models that are indistinguishable from the real models we do trust. Over time, the standardization of security protocols will make the severity less, but it will always be a high priority issue until that occurs. Consumers will need to prioritize providers with a good track record in data privacy and security as well as results.

The Severity of the risk is "Undesirable" because we haven't developed the processes and protocols that define the industry. The likelihood is a "Probable High".

Image: AI Generated

Security concerns with the proliferation of AI and will remain a major roadblock for the short-term, and potentially the long-term.

Over time, standard processes will be developed for every stage of the life-cycle of AI software. IN the UK they are developing Guidelines for Secure AI system Development by the National Cyber Security Center UK. This will establish nationwide standards for securing data at every stage of AI usage and development:

- *Secure Design – language models, limiting factors*
- *Secure Development – supply chain security, documentation management*
- *Secure Deployment – infrastructure protection, incident management, responsibility release*
- *Secure Operation and Maintenance – logging, monitoring, updating, sharing information. Similar standards will start to emerge and inform each other about the best practices for data security around the globe*

Another AI risk concerns the decision-making process. AI algorithms are highly efficient at analyzing vast data-sets and making decisions or predictions based on that analysis. Often the process is left unsupervised, and the decision-making process of the AI system is not fully transparent or understandable to humans. The lack of transparency can create outcomes that are difficult to predict and mitigate, and will need to be verified.

Risk Assessment Matrix – Patient Trust of AI

RISK RATING KEY	SEVERITY			
	Acceptable Minimal damage likely (LOW)	**Tolerable** Moderate damage likely (MEDIUM)	**Undesirable** Heavy damage likely (HIGH)	**Intolerable** Significant damage likely (EXTREME)
Improbable — Risk is Unlikely to Occur	1 (LOW)	4 (MEDIUM)	7 (MEDIUM)	10 (HIGH)
Possible — Risk is Likely to Occur	2 (LOW)	**5 (MEDIUM)**	8 (HIGH)	11 (EXTREME)
Probable — Risk Will Occur	3 (MEDIUM)	6 (HIGH)	9 (HIGH)	12 (EXTREME)

LIKELIHOOD (rows)

According to a Pew Research Center survey done in December 2022, 60% of Americans are uncomfortable with their healthcare provider relying on AI with their own healthcare (Pew Research Center). Language models that inform the decisions and outcomes generated are often based on the internet, books, and other users' data that has not been developed or tested in order to control results. Such data sets can contain inherent biases, which can thereby lead language models to perpetuate gender and racial stereotypes, which can invariably lead to discrimination. Researchers have discovered bias in up to 38.6% of facts generated by AI (Accenture).

In a study done by Washington State University in July of 2024 found that companies potentially hurt their sales by including the words 'artificial intelligence' when describing their products and services that use the technology. Researchers conducted a study with more than 1,000 adults in the U.S. and the findings showed products described as using artificial intelligence were less popular.

The Severity of the risk is "Tolerable", and the likelihood is "Possible Medium". All indications are that this will likely improve over time as people continue to increasingly use AI in their daily lives and as it continuously improves in quality.

Risk Assessment Matrix – Regulatory Changes /Legal Liability

RISK RATING KEY	SEVERITY			
	Acceptable Minimal damage likely (LOW)	**Tolerable** Moderate damage likely (MEDIUM)	**Undesirable** Heavy damage likely (HIGH)	**Intolerable** Significant damage likely (EXTREME)
Improbable — Risk is Unlikely to Occur	1 (LOW)	4 (MEDIUM)	7 (MEDIUM)	10 (HIGH)
Possible — Risk is Likely to Occur	2 (LOW)	5 (MEDIUM)	**8 (HIGH)**	11 (EXTREME)
Probable — Risk Will Occur	3 (MEDIUM)	6 (HIGH)	9 (HIGH)	12 (EXTREME)

LIKELIHOOD (rows)

One possible issue that could arise from the use of AI in healthcare treatment is the government's ability to restrict or regulate it. Depending on the country and its political system, the government may have different motives and interests in controlling the access and quality of AI-based healthcare services. For example, some governments may want to limit the use of AI for ethical, legal, or security reasons, such as protecting the privacy of patients' data, ensuring the accountability of AI decisions, or preventing the misuse of AI for malicious purposes. Other governments may want to promote the use of AI for economic, social, or strategic reasons, such as enhancing the efficiency and effectiveness of healthcare delivery, improving the health outcomes and well-being of their citizens, or gaining a competitive edge over other countries. Therefore, the government's role and influence in the development and deployment of AI in healthcare treatment may vary significantly across different contexts and scenarios. Some possible factors that could affect the government's ability to restrict or regulate the use of AI in healthcare treatment are as follows:

- *The level of public trust and acceptance of AI in healthcare. If the public is skeptical or fearful of AI, they may demand more oversight and regulation from the government, or even resist or reject the use of AI altogether. On the other hand, if the public is confident or enthusiastic about AI, they may welcome more innovation and experimentation from the private sector, or even demand more access and availability of AI services.*
- *The degree of collaboration and competition among different stakeholders. If there is a high level of cooperation and coordination among the government, the private sector, the academic community, and the civil society, there may be more opportunities and incentives for developing and implementing shared standards, guidelines, and best practices for the use of AI in healthcare. On the other hand, if there is a low level of collaboration and a high level of competition among these actors, there may be more challenges and conflicts for establishing and enforcing common rules and norms for the use of AI in healthcare.*
- *Working with and educating the public and policy makers will be the biggest challenge for this industry in the next 5-10 years. The average age of congress is 59 years old, and the average age of Americans is 39. AI will need to bridge this gap between policy makers, the public, and technology advancement in order for AI to become a trusted source of solutions and product design. Europe has enacted the EU AI act that is directing the governance of AI based on 5 principles: Transparency, Privacy Adherence, Human Control, Fair Application, and Accountability. This is a start, and it will likely influence U.S. policy as it eventually evolves into law. For now, legal liability issues will be resolved in civil court for issues concerning damages, copyright infringement, negligence, and similar issues. As these cases are settled, and precedents are created, AI tools and models could be affected in positive and negative ways.*
- *The trust and accountability issues that already exist in Healthcare will add another complicated layer to the implementation of AI. Administrators, nurses, risk managers, and facility clients are potential roadblocks to the early implementation of AI.*
- *Given the environment today, regulatory changes and legal liability remain a clear and present potential roadblock to AI tools. Imagine if a new law imposed severe financial penalties, or even prison time under certain conditions that could not be fully controlled in a model?*

For all of these reasons, the Severity is "Undesirable" and the Likelihood is a "Possible High".

Risk Assessment Matrix – Effects on the Workforce and Labor

RISK RATING KEY	LOW	MEDIUM	HIGH	EXTREME
	SEVERITY			
	Acceptable Minimal damage likely	**Tolerable** Moderate damage likely	**Undesirable** Heavy damage likely	**Intolerable** Significant damage likely
Improbable Risk is Unlikely to Occur	LOW **1**	MEDIUM **4**	MEDIUM **7**	HIGH **10**
Possible Risk is Likely to Occur	LOW **2**	MEDIUM **5**	HIGH **8**	EXTREME **11**
Probable Risk Will Occur	MEDIUM **3**	HIGH **6**	HIGH **9**	EXTREME **12**

LIKELIHOOD

AI will have an effect on the healthcare workforce. It will not replace large portions of the workforce, but it certainly will have some impact over time. Robotics driven by AI will also have a considerable impact. The roles of healthcare workers will be forced to evolve to incorporate these technologies. This augmentation will be welcomed in some cases, but not all, particularly when it comes to repetitive tasks or mundane activities. In other cases, it could eliminate long held positions by some human healthcare workers. As we have seen in many high profile nationwide strikes in 2024, union positions included terms that included complete bans on the use of automation, robotics, and AI. We could see similar situations in healthcare delivery in the next 10-20 years.

The Severity is "Tolerable", and the likelihood is "Probable High".

Risk Assessment Matrix – Data Privacy and Security of AI

RISK RATING KEY	LOW	MEDIUM	HIGH	EXTREME
	SEVERITY			
	Acceptable Minimal damage likely	**Tolerable** Moderate damage likely	**Undesirable** Heavy damage likely	**Intolerable** Significant damage likely
Improbable Risk is Unlikely to Occur	LOW **1**	MEDIUM **4**	MEDIUM **7**	HIGH **10**
Possible Risk is Likely to Occur	LOW **2**	MEDIUM **5**	HIGH **8**	EXTREME **11**
Probable Risk Will Occur	MEDIUM **3**	HIGH **6**	HIGH **9**	EXTREME **12**

LIKELIHOOD

AI hardware, particularly GPUs and specialized AI chips that power AI consumes significant power and produce a lot of generates heat. Managing power consumption and efficiently dissipating heat is critical to maintaining the hardware's performance and longevity. High energy consumption can also lead to increased also means high operational costs and environmental impact. Data centers housing multiple high-performance GPUs require advanced cooling systems to manage heat dissipation and maintain optimal operating temperatures which means there is also significant up-front investment as well.

A major challenge is ensuring AI hardware can scale to meet growing demands while integrating seamlessly with existing systems. Hardware must support expanding workloads and adapt to evolving AI algorithms without significant performance degradation. Compatibility with diverse software ecosystems and other hardware components is also crucial.

Despite all of these challenges, much of the hardware is becoming more efficient and additional energy capacity is being added. This even includes restoring a previously retired nuclear power plants at the Palisades in Township, Michigan. It also includes Microsoft's $16 billion dollar deal to turn back on "Unit 1" (835 megawatts) at Three Mile Island in Pennsylvania, This 20 year deal is to provide zero carbon energy for all of Microsoft's current and planned data centers that will be needed to help support AI compute power in this region.

Since there are solutions, the Severity is "Acceptable" and the Likelihood is "Probable Medium".

8 Conclusions & Predictions

1 Robotics & Automation

AI training of robots is advancing robotics significantly. This will mean we will need spaces that accommodate robotic assistants for supply delivery, cleaning, clinical care, patient transportation, and logistics. Initially these robots will augment existing staff, and over time, start to replace unskilled labor and some skilled labor. These machines will need places to be charged, stored, maintained and repaired.

Healthcare Architects should start planning space and infrastructure to anticipate growth in this area over the next 10 to 20 years.

2 Data-Driven Design

AI applications that will be providing new data to our healthcare clients, particularly for outpatient care. Unbiased, and in real-time, AI will be able to analyze customer trends, survey results, comparisons with other data, and then provide new insights about what healthcare customers really want and expect, versus what is typical for population demographics. This new AI driven data analysis will be able to inform healthcare executives about how healthcare consumers want to receive their healthcare experience when they have choices.

Healthcare Architects should expect to be ready to respond by providing new and flexible planning solutions in response to this new data that stream available to the healthcare C-Suite.

Image: AI Generated

3 Smart Buildings

Facilities will incorporate AI-driven smart technologies for energy management, predictive maintenance, and patient tracking systems.

Healthcare Architects should expect to be ready to coordinate even more technology into new building designs and provide increasing space for IT infrastructure rooms and raceways.

4 Adaptive Spaces

Healthcare facilities must be flexible and adaptable to accommodate new technologies, including AI driven robotics, and to respond to AI data streams that about how to enhance the customer or patient experience. The built environment will need to move toward more modular construction systems that can more quickly be adapted to respond to facility needs without requiring extended periods of design and construction.

Healthcare Architects should expect to be more involved in creating adaptive spaces, coordinating future construction phasing ideas in current designs, and specifying and designing for modular systems.

5 AI-powered Diagnostics

AI algorithms will analyze X-rays, MRIs, SPECT, PET, and CT scans, with even more remarkable precision. From these scans, it will identify issues, and even suggest personalized treatment options. This could change planning and programming requirements, by creating the potential for new workflows, new patient flows, and possibly even new combined imaging results.

Healthcare Architects should expect to be more involved in understanding the use of AI in imaging, diagnostics, and treatment that will be transforming healthcare delivery over the next 10 to 20 years. Typical layouts may be challenged, and could affect the planning for these departments.

"As a technologist, I see how AI and the fourth industrial revolution will impact every aspect of people's lives."
–Fei-Fei Li

8   Conclusions & Predictions *continued*

Image: AI Generated

6   Decision Support Systems

AI tools will assist healthcare professionals by suggesting treatment options based on patient data and trauma protocols for paramedics. Possible changes to planning and programming of emergent care spaces could be needed. AI tools could be incorporated into emergency vehicles to enhance and augment diagnosis in the field and during patient transport.

Healthcare Architects should expect to also understand how this incorporation of AI tools may impact emergent care design and planning.

7   Efficiency & Workflow Optimization

AI will streamline administrative tasks, freeing up time for healthcare professionals. We may see redesigned workspaces for face-to-face patient interactions in some areas, and a reduction of staff in other locations.

Healthcare Architects should expect to respond to planning changes that may result from these changes.

8   New Facility Types

AI will lead to significant advances in Gene Therapy treatments that becomes more personalized and with more predictable results. This could lead to new outpatient facility types over time for stem cell therapy and transplantation.

Healthcare Architects should expect to be ready for what could be in increase in outpatient infusion centers focused on gene therapy for higher risk and acuity patients.

"

'We need to design and build AI that helps healthcare professionals be better at what they do. The aim should be enabling humans to become better learners and decision-makers.'

– Mihaela van der Schaar, PhD, director of the Cambridge Centre for AI in Medicine at the University of Cambridge in the U.K.

9   Population Data Mining for Individuals

AI tools will access multiple sources of data to identify unique patient risk factors for diseases (acute and chronic) and personalize it to individuals for prevention and treatment. Health facilities will need to be designed to focused on a greatly expanded use of imaging, laboratory resources, and the possible creation of new types of treatment spaces.

Healthcare Architects should expect to be ready for a progressive shift to personalized medicine that will create new patient, staff, and processing workflows.

10   Population Data Mining for Everyone

AI tools will use these same sources of data to identify the next pandemic risk, new treatment options, and develop new drugs. AI will accelerate the development of treatments and possibly even developing cures for Heart Disease, Cancer, Respiratory Disease, Stroke, Diabetes, Alzheimers Disease, Parkinsons Disease, and other chronic diseases. This will lead to programmatic changes because of the introduction of a variety of new treatment options.

Healthcare Architects should expect to be ready to respond to what could be a revolution in understanding disease diagnosis and treatment options.

9 Sources

Case Study: 2024 Cognizant/Oxford Economics Study, Ollie O'Donoghue and Duncan Roberts, www.cognizant.com/us/en/aem-i/generative-ai-economic-model-oxford-economics

Report: 2024 Stanford University Human Centered Artificial Intelligence Index Report 7th Edition, Co-directors Ray Perrault and Jack Clark, Nestor Maslej, Loredana Fattorini, Raymond Perrault, Vanessa Parli, Anka Reuel, Erik Brynjolfsson, John Etchemendy, Katrina Ligett, Terah Lyons, James Manyika, Juan Carlos Niebles, Yoav Shoham, Russell Wald, and Jack Clark, "The AI Index 2024 Annual Report," AI Index Steering Committee, Institute for Human-Centered AI, Stanford University, Stanford, CA, April 2024. https://aiindex.stanford.edu/wp-content/uploads/ 2024/04/HAI_2024_AI-Index-Report.pdf

Case Study: Can Generalist Foundation Models Outcompete Special-Purpose Tuning?, (ChatGPT 4+Medprompt), Arsha Nori, Yin Tat Lee, Sheng Zhang, Microsoft, November 2023

Report: Frontiers in Bioengineering and Biotechnology, Advancing genome editing with artificial intelligence: opportunities, challenges, and future directions, Part of the CRISPR tailored gene editing – the real promise to treat human disease, Report, Shriniket Dixit, Anant Kumar, Kathiravan Srinivasan, Durai Vincent, Nadesh Krishnan, January 2024, https://www. frontiersin. org/journals/bioengineering-and-biotechnology/articles/10.3389/fbioe.2023.1335901/full

Survey: McKinsey Analytics, "Global AI Survey: AI Proves its Worth, but few scale impact", McKinsey & Company, The survey content and analysis were developed by Arif Cam, a consultant in McKinsey's Silicon Valley office; Michael Chui, a partner of the McKinsey Global Institute and a partner in the San Francisco office; and Bryce Hall, an associate partner in the Washington, DC, office

Report: Pew Research Center, December, 2018, "Artificial Intelligence and the Future of Humans"

Report: Pew Research Center, June 2023, "Experts Predict the Best and Worst Changes in Digital Life by 2035"

Report: Pew Research Center, October, 2023, "How Americans View Data Privacy"

Report: Pew Research Center, February 2023, "60% of Americans Would Be Uncomfortable With Provider Relying on AI in Their Own Health Care"

Report: Matheny ME, Whicher D, Thadaney Israni S. Artificial Intelligence in Health Care: A Report From the National Academy of Medicine. JAMA. 2020;323(6):509–510. doi:10.1001/jama.2019.21579

Report: Ethics and governance of artificial intelligence for health: WHO guidance. Geneva: World Health Organization; 2021. Licence: CC BY-NC-SA 3.0 IGO

Report: United Nations, UN News, Global Perspective Human News, Boom in Artificial Intelligence Patents, Points to Quantum Leap in Tech, Jan 2019

Article: Balancing The Cost Of AI In Healthcare: Future Savings Vs. Current Spending, Forbes Innovation, Forbes Technology Council, April 2024

Article: Global Generative AI in Healthcare Industry Report 2023: Emerging Applications in Drug Discovery & Development, Imaging Analysis, Digital Twins, Synthetic Data, EHR Management, and Virtual Assistants, PR Newswire, January 2018

Article: 6 Nurse AI Robots That Are Changing Healthcare in 2024, Sarah Falcone, Nurse.org

Book: Life 3.0: Being Human in the Age of Artificial Intelligence, Max Tegmark, Penguin Random House publishing

Book: The Coming Wave, Mustaf Suleyman with Michael Bhasker, Penguin Random House publishing

Book: Machine Learning: Architecture in the age of Artificial Intelligence, Phil Bernstein, RIBA publishing

Book: Quantum Computing Explained, Pantheon Space Academy

Report: The State of AI in Architecture 2024, Architizer and Chaos survey report

Book: AI 2041 Ten Visions of Our Future, Kai-Fu Lee and Chen Quifan, Random House publishing

Book: The AI Revolution in Medicine: GPT-4 and Beyond, Peter Lee (Author), Carey Goldberg, Isaac Kohane, Pearson Publishing

Book: Artificial Intelligence in Healthcare: AI, Machine Learning, and Deep and Intelligent Medicine Simplified for Everyone, Dr. Parag Mahajan, MeMantra LLC.
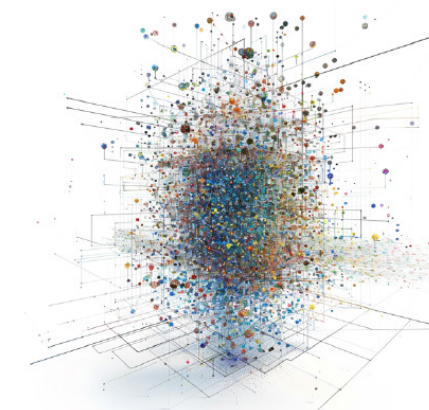
10   AI Definitions
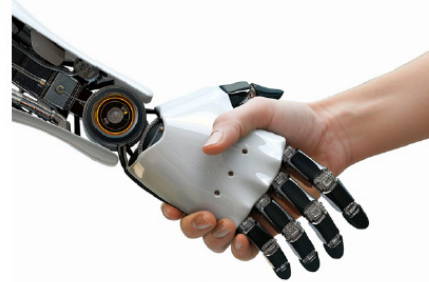
MACHINE LEARNING

Machine Learning (ML) is a field of artificial intelligence (AI) that focuses on developing computer algorithms that can improve automatically through experience. Unlike traditional programming where you explicitly define every step the computer takes machine learning algorithms are trained on data.

- This data can be text, images, numbers
- The algorithms learn to identify patterns and relationships.
- Over time, they can improve their performance on a specific task without being explicitly programmed for every situation.
- Started in 1950 with checkers; really has flourished since 1990

Popular ML Tools Include: *Anaconda, TensorFlow, Yooz, Weka, Amazon ML,* and *Google Cloud AI*

DEEP LEARNING

Deep Learning (DL) is a field of artificial intelligence (AI) that is a more advanced form of machine learning inspired by the structure and function of the human brain. It gained prominence in 2006.

- Relies on artificial neural networks that consist of multiple layers of interconnected nodes (artificial neurons)
- Deep learning models involve multiple layers of neural networks stacked on top of each other, often referred to as a deep architecture. This is where the term "deep" comes from.
- Each layer learns to extract higher-level features from the data it receives from the previous layer.
- Deep learning models excel at handling complex tasks like image recognition, natural language processing, and speech recognition.

Popular DL Tools Include: *Comet, Prime AI, Torch, NVIDIA GPU Cloud, Keras, MIPAR, Amplifire,* and *Cauliflower*
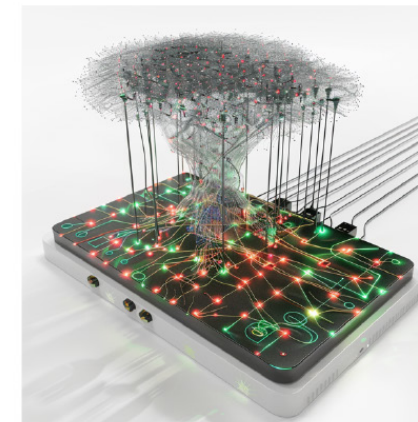
LARGE LANGUAGE MODELS

A **Large Language Model (LLM)** is a type of artificial intelligence (AI) that's been trained on massive amounts of text data specifically related to language.

- Understand and respond to your questions in a comprehensive and informative way
- Generate poems, code, scripts, musical pieces, email, letters, etc.
- Translating languages
- Summarizing factual topics
- Started in the 1950s with ELIZA, but really advanced in 2017

Popular LLM Tools Include: *ChatGPT, Google PaLM, Google Gemini, Meta LLaMA, Anthropic Claude, Mistral AI,* and *DBRX*

GENERATIVE ARTIFICIAL INTELLIGENCE

Generative AI uses models focused on creating new content by utilizing machine learning algorithms trained on massive datasets of existing content like text, images, code, or audio. The models learn the underlying patterns and relationships within that content. This allows them to generate entirely new content that is similar to, but not a copy of, the data they were trained on.

- Text: new poems, books, songs, program code, letters, etc.
- Images: new photorealistic or artistic images and video
- Audio: music, speech, soundscapes, effects
- Advances in 2014 led to 2022 launch of ChatGPT and Midjourney

Popular Generative AI Tools Include: *ChatGPT, Dall-E, Stable Diffusion (Dreamstudio/NightCafe/LookX.ai), Google ImageFX, Midjourney, MS Designer, Adobe Firefly,* and *OpenAI Sora (soon)*

"*I imagine a world in which AI is going to make us work more productively, live longer, and have cleaner energy.*"

-Fei-Fei Li, Professor of Computer Science at Stanford University