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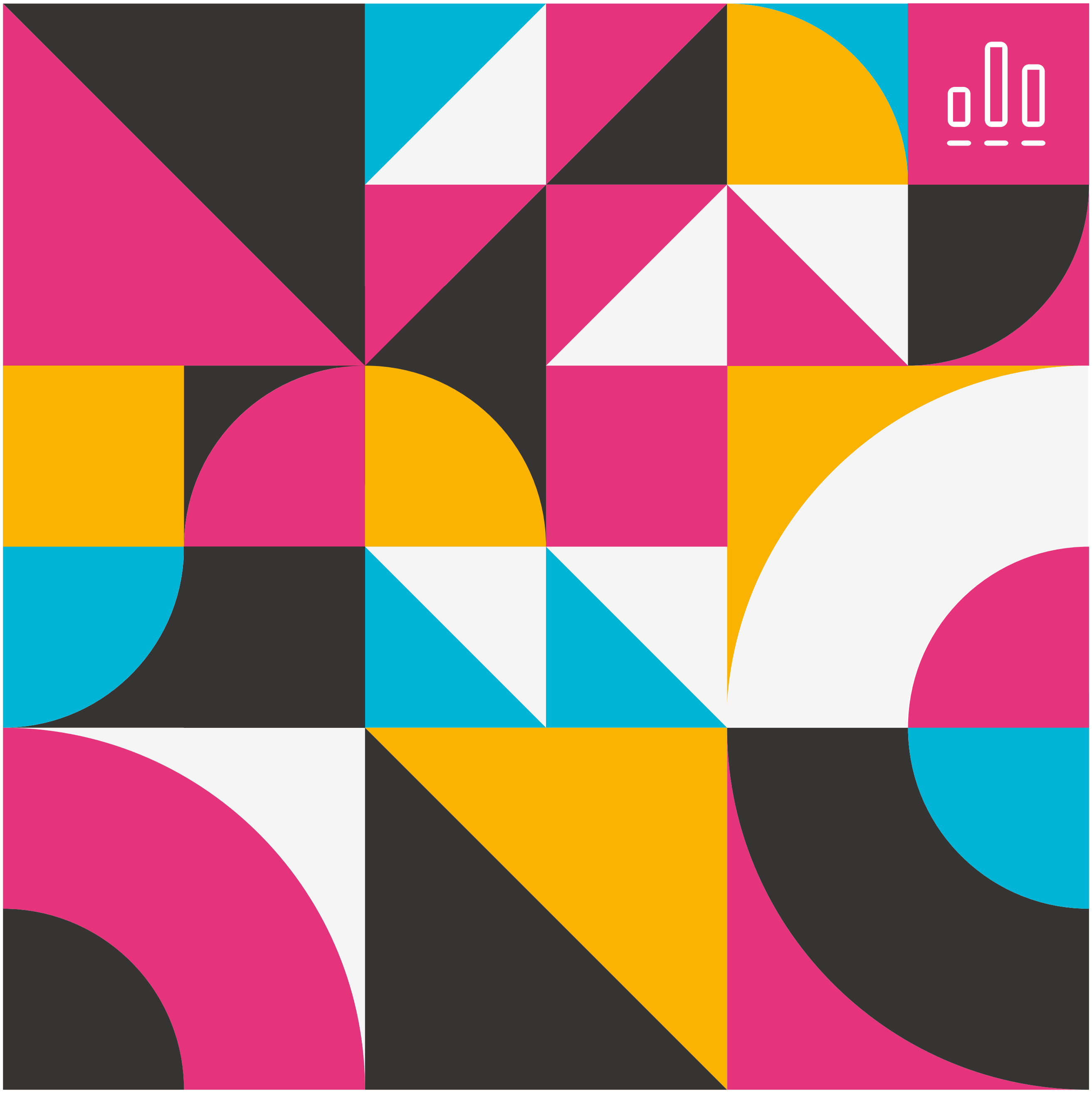

Economic Futures

THE FUTURE OF VALUE

How emerging technologies shift value in the economy

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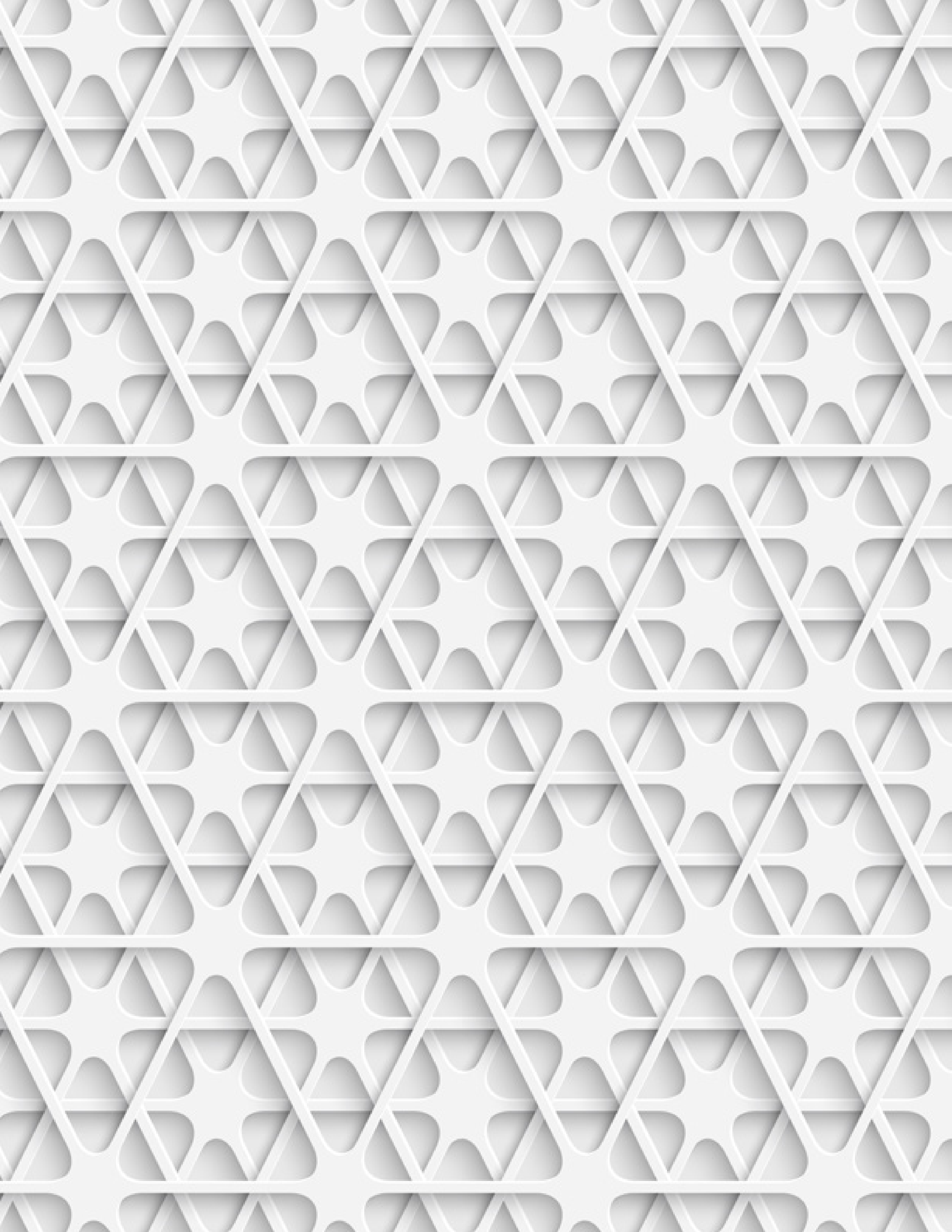

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FOREWORD

What will have value in the future? How is value created, and how might it change?

Building on our previous work, The Next Digital Economy, The Future of Work, and Exploring Biodigital Convergence, this paper explores how a suite of emerging and maturing technologies are enabling changes in the economy. It looks at how these technologies could shift value by creating new ways of carrying out business activities.

Although people have been developing technologies to address scarcities for millenia, the speed and scope of change could be unlike anything we have seen before. New technologies are reducing and even eliminating key scarcities of labour, materials, and knowledge that have driven market value for businesses until now.

Guided by our mandate, we hope to spark thought and conversation surrounding the future of value and its potential impacts on companies, individuals, educational institutions, and governments. Our goal is to contribute to the development of policies and programs that are robust in the face of the changes ahead.

On behalf of Policy Horizons Canada, I would like to thank those who generously shared their time, knowledge, and thoughts with us.

We hope you will find this report insightful.

Kristel Van der Elst
Director General, Policy Horizons Canada

EXECUTIVE SUMMARY

This report sets out a new way of looking at how technologies can transfer economic value. It proposes that business operations can be described using one or more of 14 basic human activities. Each one represents a unique combination of characteristics including one or more of four scarcities: temporal, spatial, absolute, or artificial. Any business can be described using different combinations of these basic activities. Businesses create value by addressing the scarcities associated with the combination of activities they use.

A suite of emerging and maturing technologies has the potential to affect these scarcities, and therefore, shift where economic value is generated. A deeper, system-wide understanding of economic disruption emerges when one realizes that these basic human activities exist across many sectors, jobs, and professions. Consequently, an instance of technological disruption by an early adopter could spread rapidly through the economy.

Analyzing technological disruption at the basic human activity level can help companies, academic and vocational institutions, individuals, and policy makers understand systemic disruptions to the economy. It can provide insight into where new challenges and opportunities might arise so that we can prepare, respond, and prosper in the Next Digital Economy.

THE 14 BASIC HUMAN ACTIVITIES

1. Physical services to living beings
2. Human use of tools, devices, and objects
3. Transportation and distribution of matter and/or energy
4. Information acquisition
5. Knowledge generation
6. Knowledge transfer
7. Experiences changing an emotional state
8. Energy generation
9. Resource extraction of non-living material
10. Harvest of naturally occurring resources
11. Agriculture
12. Transformation of matter
13. Disposal of unwanted materials
14. Application of rules and procedures

A HUMAN ACTIVITY-BASED FRAMEWORK FOR ANALYZING TECHNOLOGY-DRIVEN DISRUPTION TO A BUSINESS

1
Which of the 14 basic human activities are used by the business?

2
What is the relative proportion of each basic human activity in the business?

3
Which of the activities are a cost and which are a source of revenue?

4
What technologies could affect each activity?

5
Are those technologies sufficiently developed to change how an activity is carried out?

6
Would adoption (or development) of those technologies reduce costs or increase revenues?

INITIAL POLICY-RELEVANT QUESTIONS

Which types of workers are most likely to be affected? How could they be retrained or upskilled?

Could adoption of new technologies allow governments to provide better public services at lower cost?

As it becomes easier for people to work separately from their colleagues and/or their equipment, will commercial or industrial real estate drop in value? How could it be used differently?

Will home offices or neighbourhood-based work centres in suburban or rural areas become more valuable? Will the value of the Internet increase? Will the value of commuter transportation decrease? How should governments respond to changing infrastructure needs?

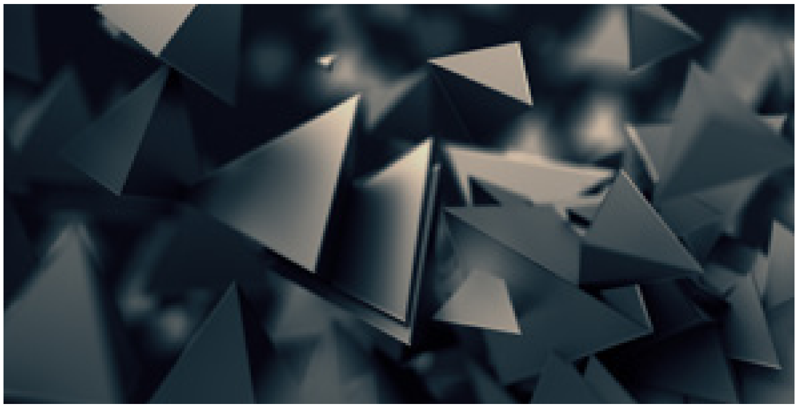
What aspects of the shifts in value will Canadians or groups of Canadians want to accelerate? Which ones may they want to slow down? How might regulatory and policy frameworks influence the speed and depth of digital and biodigital disruptions?

Would transformed businesses create vulnerabilities for important areas of the economy? How could policy best deal with these new risks?

What are the costs or benefits of accelerating or moderating changes? How might the shifts in value affect government revenue streams?

What does this imply for economic modelling and industrial development strategies? How could this affect the tax regime?

1 INTRODUCTION



The Future of Value

New technologies are upending how value is created and distributed through the economy. By value we mean the amount of money received for selling a good or service in a market economy. This could take the form of a price, wage, interest, or rent. Many other things that have value to humans are exchanged outside the marketplace, but these are outside the scope of this report.

Many of the sectors, jobs, and professions we know are changing. Some will transform, while others will fade away. Meanwhile, new ones will emerge over time or appear suddenly.

Most analyses focus on how economic transformation will affect sectors, jobs, or professions. However, there is another way to think about what is happening: examining the human activities used by businesses. This approach can provide additional insights into the transformations that may arise.

The 14 basic human activities presented in this report form a framework for thinking about how value shifts when different technologies cause disruption.

“Shifts in value” are nothing new. Value has been shifting from labour to capital since the invention of the steam engine. What is new today are the pace, depth, and scope of change.

Ten main technologies are driving these profound value shifts: The Internet of Things (smart connected devices), artificial intelligence (AI) and automation software, robotics, telepresence, virtual and augmented reality, decentralized production technologies (e.g. 3D printing), biodigital technologies, advanced materials, blockchain, and high-speed connectivity.

Consider how technology could affect the two basic human activities associated with trucking: human use of tools, devices, and objects (Activity 2) and transportation and distribution of matter and/or energy (Activity 3).

An analysis focused on sectors might note that self-driving trucks could disrupt the transportation sector by eliminating the need for human drivers. An analysis based on activities would go further. It would recognize that these same technologies could be transferred to other sectors such as farming and mining that also involve human use of similar tools, devices, and objects. In other words, an activity-based analysis could identify potential changes to other sectors before they happen.

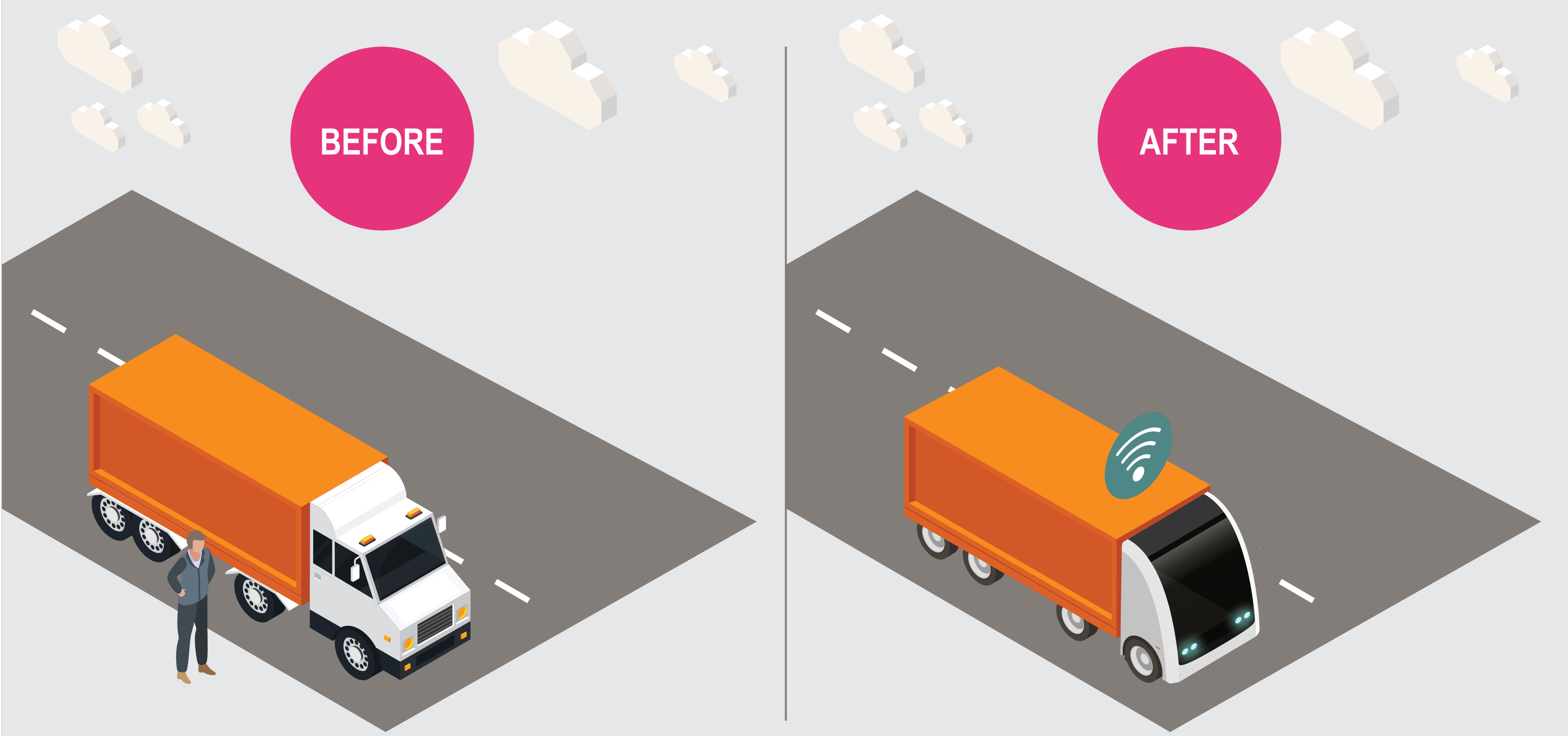
An activity-focused analysis would also look at how technology could disrupt the need for transportation and distribution of matter and/or energy (Activity 3). For example, 3D printing could affect demand for trucks. Instead of making physical products and transporting them to consumers via trucks, producers could transmit designs digitally. Consumers could then access the locally produced 3D-printed products.

Adopting self-driving technology could shift value from truck drivers to companies that produce software and hardware for autonomous vehicles. It might also increase the value of trucking companies by increasing profits if it is cheaper to buy software and hardware than to pay a driver. Alternatively, it might shift value to customers through lower prices if the transportation sector passes savings from lower operating costs onto consumers. Similarly, increased 3D printing could shift value from the transportation sector to others. These could include designers of digital product templates, providers of digital infrastructure, and 3D printer manufacturers.

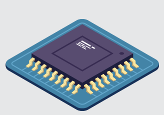
Whether someone sees a shift in value as good or bad will depend on their relationship to the affected activity (see Figure 1). Truck drivers may fear that automation will take their jobs. But since driverless trucks may also reduce shipping costs (and possibly lead to cheaper prices for products), the technology may win over consumers.

FIGURE 1

HUMAN USE OF TOOLS, DEVICES, AND OBJECTS—TRUCKING



HOW VALUE SHIFTS



EXPERTISE

The value of driving expertise shifts from humans to automated vehicle technology (e.g. software, sensors, actuators).

The value of automated vehicle engineering and software development increases.

RESTAURANTS

The value of food services along trucking routes decreases (e.g. restaurants, coffee shops).

ACCOMMODATION AND ENTERTAINMENT

The value of some hospitality services not needed by autonomous vehicles decreases (e.g. motels, entertainment venues).

MAINTENANCE

The value of maintenance services may decline if autonomous vehicles operate at optimal conditions.

FUEL

The value of fuel will remain if autonomous vehicles use fossil fuel.

The value of fuel will decrease if autonomous vehicles are more fuel efficient or electric.

Value is determined by scarcity relative to demand. In the truck driving example, the scarce expertise of drivers generates value for them. In other words, a limited number of drivers means more scarcity, which would make them more valuable. But if automated driving costs the same or less than a human driver, the expertise required to drive the truck is no longer scarce—it becomes encoded into the automated driving software and can be replicated as needed.

We identify four different types of scarcities that drive the creation of value in an economy.

Spatial scarcity: a place-based scarcity or constraint. For example, a human needs to be in a certain place for an interaction to happen (e.g. to have a haircut, you need to be in the same place as the hairdresser). Specific inputs, such as petroleum or natural gas, may only be available in a limited number of places in the world.

Temporal scarcity: a time-based scarcity or constraint. For example, a person needs to be available at a specific time for the interaction to proceed (e.g. a doctor's appointment). It could also be a specific input, service, or product that is available only at a specific time (e.g. a live concert).

Absolute scarcity: a quantity-based scarcity or constraint, in which there is a finite amount of something. For example, a mineral resource; a unique thing such as the Mona Lisa; or a specific person with a unique skill set, such as Yo-Yo Ma. Absolute scarcity includes expertise, which can be broken down into two parts: knowledge (knowing how to do a task) and ability (capacity to do the task).

Artificial scarcity: a framework to create one of the other scarcities. For example, a permit system that gives someone exclusive rights to something, a system that approves or certifies certain skills, or intellectual property regulation.

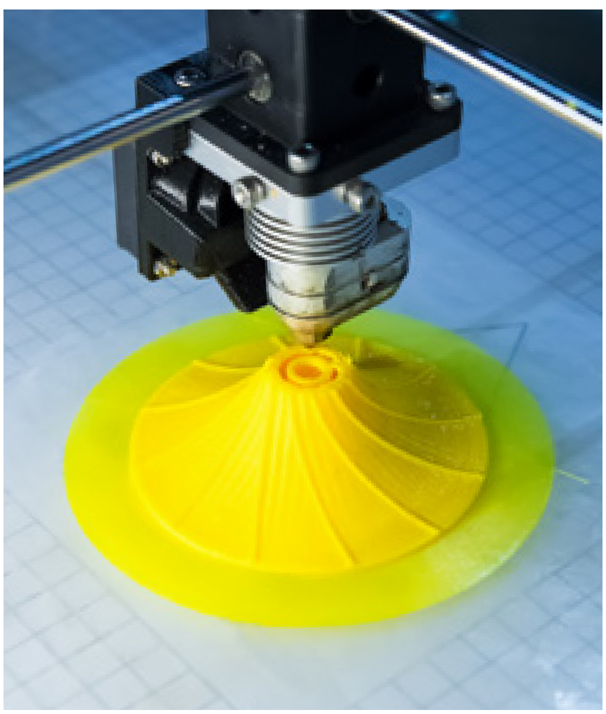
The four scarcities are often present together in a market transaction. For example, to obtain the services of a surgeon, a person needs to be in a specific place (spatial scarcity) at a specific time (temporal scarcity); there is a finite number of people with the necessary expertise (absolute scarcity), and only those with the relevant accreditation are allowed to provide the service (artificial scarcity).

Throughout history—reaching back to simple tools such as the lever and wheel—the desire to overcome scarcity has motivated humans to invent and apply new technologies. Some scarcities have been broken for so long that we no longer remember life without them. For example, before the telephone, real-time knowledge transfer for most people involved spatial scarcity. The one with the knowledge and the one receiving it had to be in the same place to talk to each other.

The 14 basic human activities are described below in the way they were carried out before industrialization. Many of them have already been affected by technologies that are now pervasive and common. For these activities, the impact of new technologies is ongoing. The emerging and maturing technologies presented in this paper are simply adding new chapters to this story.

A single basic human activity can form a simple business. Combinations of activities can form more complex businesses. These businesses create value by addressing scarcities associated with the basic human activities that comprise them.

History has seen three spikes in technologies overcoming scarcities—steam power (the Industrial Revolution), electrification and assembly lines (the second Industrial Revolution), and computers (the third). All three spikes resulted in significant changes in the relative value of factors of production, shifting the wealth of individuals, corporations, and nations. Governments then had to respond to the economic and social fallout.



We are now entering the Next Digital Economy. Its impacts were first felt in manufacturing as the Fourth Industrial Revolution, but its effects are increasingly spreading across other sectors of the economy. As new technologies mature and combine, individuals, companies, and governments must adapt. Many companies must rethink their activities. Governments must rethink policy and regulatory frameworks, and public services.

The 14 human activities set out in the coming pages aim to help individuals, governments, and companies think about how to adapt. They are not intended to be comprehensive but rather to offer starting points for more in-depth analysis.

2 THE 14 BASIC HUMAN ACTIVITIES

LEGEND

1 Physical services to living beings

2 Human use of tools, devices, and objects

3 Transportation and distribution of matter and/or energy

4 Information acquisition

5 Knowledge generation

6 Knowledge transfer

7 Experiences changing an emotional state

8 Energy generation

9 Resource extraction of non-living material

10 Harvest of naturally occurring resources

11 Agriculture

12 Transformation of matter

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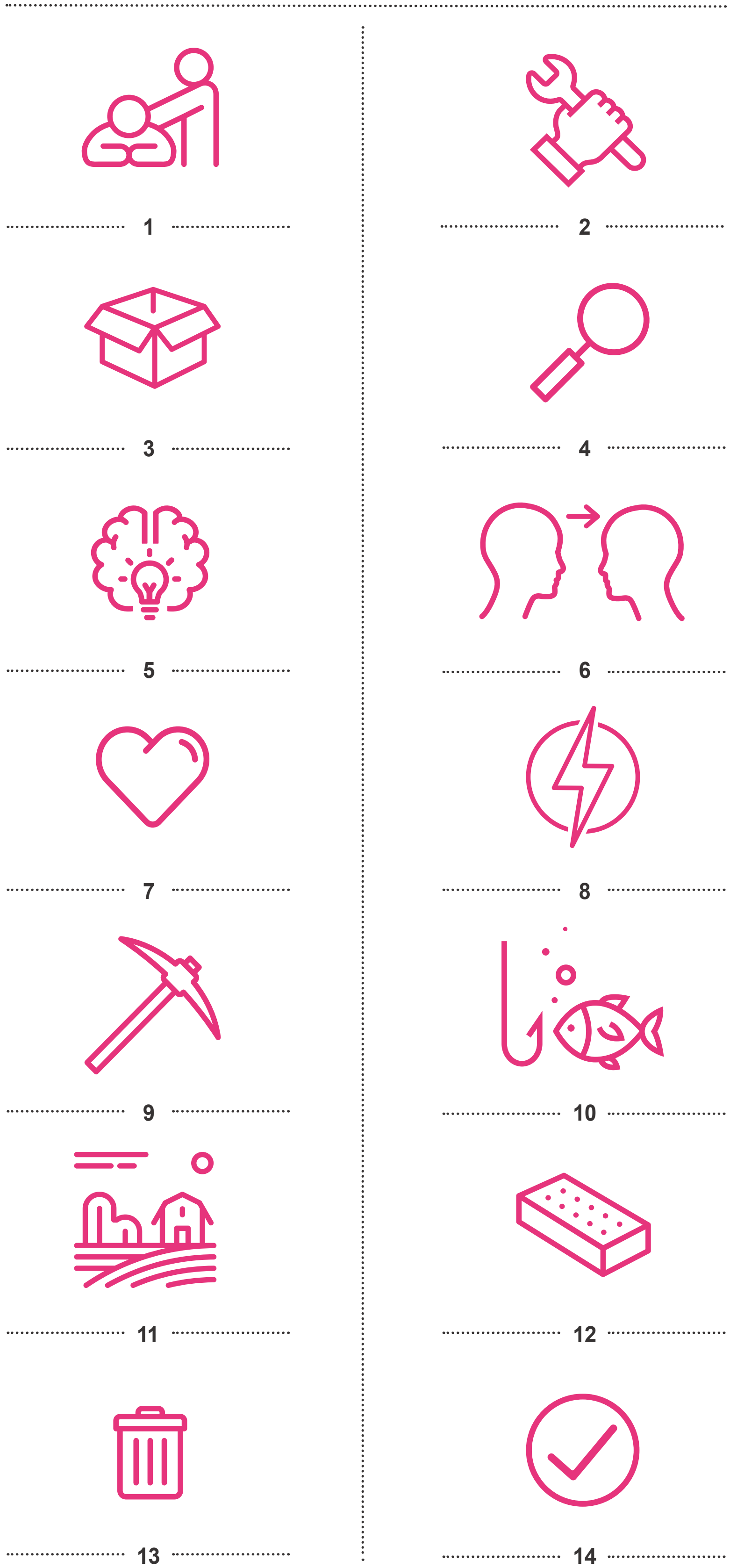


ACTIVITY 1

PHYSICAL SERVICES TO LIVING BEINGS

Definition
A living being receives a service that involves physical contact.

Examples
Cutting hair; filling cavities in teeth; massage; surgery.

Typical scarcities

- **Spatial scarcity:** the two people must be in the same place.
- **Temporal scarcity:** they must be there at the same time.
- **Absolute scarcity:** expertise—the person providing the service must have the expertise required; physical space—the interaction must take place in a suitable location; transportation infrastructure—both parties must be able to travel to the location for the service.
- **Artificial scarcity:** expertise—this could exist if there is an accreditation or licensing requirement to offer the service.

Technologies that could affect scarcities

- Virtual and augmented reality could enable a person with less specialized skills to provide the service with help from someone in another place (e.g. a remote expert).
- Robotics could initially allow humans with expertise to provide the service with a remotely controlled robot. As robots become semi-autonomous, the work could be split between robots and humans. For example, robots might perform simpler parts, leaving humans to do the more complex parts. Or, the robot could do complex parts but with human supervision and guidance. Ultimately, robots could provide the service without any help from a human.

Potential shifts in value

- The human continues to lose value, while the robot continues to gain value. The code that runs the robot also gains value. Related areas such as robot manufacturing and providers of remote control technology also gain value.
- The value of expertise generally declines. However, it could become concentrated in a small number of humans with high levels of knowledge. This could happen because remote operation allows the most qualified experts to offer their knowledge to the highest bidder anywhere in the world.
- Value may also shift in the real estate and transportation markets. For example, humans with expertise no longer need to live near their clients. They can also provide the service from a home office, eliminating travel.

ACTIVITY 2

HUMAN USE OF TOOLS, DEVICES, AND OBJECTS

Definition
A person physically interacts with a human-manufactured or constructed object.

Examples
Driving a truck; repairing an aircraft.

Typical scarcities

- **Spatial scarcity:** the human must be in the same place as the object.
- **Temporal scarcity:** the human must be there at the time of the interaction.
- **Absolute scarcities:** expertise—the human providing the service must have the expertise required; physical space—the interaction must take place in a suitable location; transportation infrastructure—either the human or object must be able to move to where the other is located.
- **Artificial scarcity:** expertise—this could exist if there is an accreditation or licensing requirement to offer the service.

Technologies that could affect scarcities

- Robotics could increasingly allow many objects to operate autonomously or with less input from an expert human.
- Telepresence could enable a human expert to interact with the object from a distance. The expert could control a robot that could interact with the object.
- As more objects become "smart," they can be accessed and repaired remotely.
- Virtual and augmented reality can allow a person interacting with the object to receive advice or direction from a remotely located expert.

Potential shifts in value

- The human continues to lose value, while the robot continues to gain value. The code that runs the robot also gains value. Related areas such as robot manufacturing and providers of remote control technology also gain value.
- The value of telepresence technologies, smart devices, and the digital infrastructure to support them increases.
- The ability component of expertise generally declines in value while the knowledge component could increase if it becomes concentrated in a small number of humans with high levels of knowledge. This could happen because remote operation breaks spatial scarcity. In this scenario, humans could offer their expertise to a number of less knowledgeable workers performing the physical component of the interactions.
- Value may also shift in the real estate and transportation markets. For example, humans remotely operating equipment or instructing others using telepresence no longer need to live near their work. They can also provide the service from a home office, eliminating travel.

ACTIVITY 3

TRANSPORTATION AND DISTRIBUTION OF MATTER AND/OR ENERGY

Definition

Physical things are moved from one location to another.

Examples

Movement of raw materials or goods using trucks, trains, ships, or pipelines; movement of people in vehicles or aircraft; movement of electrons in electrical grids; movement of electrons and photons; the propagation of electromagnetic waves using information and communication technology infrastructure.

Typical scarcities

- **Spatial scarcity:** the matter or energy is located or generated in one place and needed elsewhere.
- **Temporal scarcity:** if the item can go bad (e.g. food, vaccine) or is needed at a specific time to enable another interaction (e.g. as part of a just-in-time supply chain).
- **Absolute scarcity:** infrastructure—the matter or energy needs to be moved using physical infrastructure such as roads, warehouses, or fibre optic cables.
- **Artificial scarcity:** may also exist due to licensing (e.g. an Internet service provider's licence to access wavelengths on the electromagnetic spectrum).

Technologies that could affect scarcities

- Converting physical goods to digital goods shifts value from road, rail and port infrastructure, and fossil fuels to telecommunications and electrical infrastructure, and digital interface technologies.
- Telepresence reduces the need for humans to travel but shifts value to computer code and telecommunications infrastructure.
- Decentralized production technologies (e.g. 3D printing) allow products to be produced close to the end consumer shifting value to manufacturers of that equipment and to digital designers.
- Biodigital technologies such as cellular agriculture (e.g. lab-grown meat and microbial dairy production) and computerized container/vertical farming allows food to be grown closer to consumption reducing the need and value of physical transportation.

Potential shifts in value

- Physical transportation infrastructure and equipment lose value. More value goes to digital infrastructure and the devices used to create and consume digital goods. Production of physical goods using digitally transmitted instructions also gains value.
- Value shifts from the use of petroleum for energy to the use of electricity. This reduces the physical transfer of fossil fuels through trucking, shipping, and pipelines.

ACTIVITY 4

INFORMATION ACQUISITION

Definition
Information is collected and recorded, without analysis.

Examples
Read a meter; take a food order; record measurements.

Typical scarcities

- **Spatial scarcity:** the person collecting the information needs to be in the same place as the information.
- **Temporal scarcity:** may exist if the information is needed to allow another interaction that is time sensitive.
- **Absolute scarcities:** expertise—this may exist if specific expertise is required to collect and/or record the information (e.g. an inspector needs to know what is required and where to look for it; a bookkeeper needs to know how to enter financial information into accounting records); transportation infrastructure—the human must be able to move to where the information is generated/available, or vice versa.
- **Artificial scarcity:** expertise—this may exist if accreditation or licensing is required.

Technologies that could affect scarcities

- The Internet of Things allows smart connected devices to collect data remotely and without human interaction, including location data through GPS.
- Augmented reality devices with cameras would expand the possibilities for video-based data capture as humans move through their environments.
- Remotely operated or autonomous robots and drones mounted with cameras and sensors can be sent to gather information from their surroundings.

Potential shifts in value

- Value shifts from humans to devices (e.g. a human is not needed to read a smart meter).
- Value shifts from transportation infrastructure to digital infrastructure—the human no longer needs to visit a location, but digital infrastructure is required to transfer information.
- The knowledge component of expertise shifts to software (e.g. tax return software has value because it “knows” where to put information in your tax form).

ACTIVITY 5

KNOWLEDGE GENERATION

Definition
A person uses information to create knowledge.

Examples
Scientific research; data analysis; musical composition; engineering.

Typical scarcities

- **Absolute scarcities:** expertise—the human must know how to understand and use information to generate knowledge; physical space—the human must occupy a suitable physical space; specialized equipment, if it is required (e.g. laboratory, musical instruments).

Technologies that could affect scarcities

- AI and software automation break the scarcity of both basic knowledge and applied knowledge. AI can ingest large volumes of data and turn it into usable information such as news articles and live sports interpretation. AI can discover patterns and meta-information faster than humans or that humans cannot find at all. It may even be able to break the scarcity of creativity, by inventing novel and useful solutions (e.g. a move in the game Go that a human player has never considered and helps win the game).
- Digital simulations can break the scarcity of physical space and equipment required for knowledge generation (e.g. software-based simulation of experiments such as protein folding; creating music on computers without instruments or a sound studio; creating Computer Generated Imagery movies without actors or movie sets).
- Telepresence can enable collaboration and concentrate knowledge.

Potential shifts in value

- Value shifts from expert humans to AI code and related infrastructure (e.g. computers, connectivity, interfaces). Value also shifts initially to programmers, although AI will increasingly be used to produce software.
- Value shifts from highly trained scientists to less skilled operators of AI.
- Value shifts from physical equipment to digital simulations and their interfaces.

ACTIVITY 6

KNOWLEDGE TRANSFER

Definition
Knowledge is transferred to a person.

Examples
Teaching; providing medical, legal, or financial advice; aspects of customer service or administrative assistance.

Typical scarcities

- **Spatial scarcity:** the humans must be in the same place.
- **Temporal scarcity:** the humans must be there at the same time.
- **Absolute scarcities:** physical space—the interaction must be in a suitable location; transportation infrastructure—both parties must be able to travel to where the knowledge is transferred; expertise—the advisor or teacher must know what matters and how to convey that to the recipient for the desired effect.
- **Artificial scarcity:** since knowledge is intangible, the only way to limit it is by creating artificial scarcity (e.g. through laws on secrecy, intellectual property, and copyright, or regulations and licensing).

Technologies that could affect scarcities

- Telepresence through video conferencing platforms such as Zoom, Meet, and Teams are making it easier to transfer knowledge remotely. The same is true for collaborative “whiteboarding” tools such as Mural.
- Virtual and augmented reality will offer further possibilities to encode knowledge into devices, or to transfer it to users in real time and context.
- High-speed connectivity has already broken many scarcities (e.g. spatial, temporal, and absolute) through on-demand digital audio and video recording with (e.g. YouTube, online learning courses).
- AI-driven chatbots can break the scarcity of expertise by customizing answers and advice; AI-enabled interactive gamification of learning can transfer the right knowledge at the right time for it to be absorbed.

Potential shifts in value

- Value shifts from the creators of knowledge to the distributors of knowledge.
- Value shifts from physical places (e.g. schools, labs, training facilities, clinics) and transportation infrastructure to digital infrastructure, interface devices, and energy systems.

ACTIVITY 7

EXPERIENCES CHANGING AN EMOTIONAL STATE

Definition
A person's emotional state is changed as a result of an interaction with a person, place, or thing.

Examples
Attending a concert or sports event; visiting a place of natural beauty; social interactions.

Typical scarcities

- **Spatial scarcity:** exists if the exchange generating the experience occurs in a specific place.
- **Temporal scarcity:** exists if the exchange generating the experience occurs only at a specific time.
- **Absolute scarcities:** exist if the experience is generated by interaction with a specific person, place, or thing; expertise—the performer must know what matters and how to convey that to the recipient for the desired effect; some experiences (e.g. dance, music, stunts, circus performances) also require specific physical skills; absolute scarcity of transportation infrastructure if the human must travel to the location in which the experience is generated.
- **Artificial scarcity:** exists if access to the person, place, or thing is limited (e.g. limited number of concert tickets; place or thing only accessible during opening hours).

Technologies that could affect scarcities

- High-speed connectivity has broken many of the scarcities through on-demand access to digital audio and video recordings.
- Virtual and augmented reality can allow an immersive experience of a place without visiting it. Holodecks can add environmental factors such as smells and radiant heat. This may even be better than the real thing as it avoids the inconvenience of travel and crowds. Augmented reality may provide a mix of physical and virtual experiences—for example, eating a meal at home while being virtually in a Paris restaurant. Tactile components of an experience are difficult to reproduce, but technologies such as haptic suits are in development.
- Telepresence: non-VR but shared digital spaces, such as massively multiplayer online role-playing games, and live concerts or events within video games. Travis Scott, for example, performed live in the video game Fortnite.

Potential shifts in value

- Value shifts from specific physical places (e.g. museums, national parks, concert halls, sports arenas, resorts) and transportation infrastructure to digital infrastructure and interface devices.
- Value shifts from physical creators to digital creators or digital captures of physical creations.

ACTIVITY 8

ENERGY GENERATION

Definition
Kinetic, thermal, or electrical energy is created.

Examples
Capturing potential energy of wind or falling water; combustion of fuels; capture of sunlight by photovoltaic panels.

Typical scarcities

- **Spatial scarcity:** the energy source is in a specific location.
- **Temporal scarcity:** this may exist if the energy source is intermittent (e.g. sunlight, wind) or seasonal (e.g. water flow).
- **Absolute scarcities:** supply—this exists if there is a natural limit on the rate at which a source can generate energy; physical infrastructure—this is required to convert the energy source into usable forms of energy.
- **Artificial scarcity:** may exist if energy generation requires a license or is a state monopoly.

Technologies that could affect scarcities

- Advanced materials enabling progress in battery technologies could reduce the temporal scarcity of energy from renewables.
- Biodigital technologies may enable the production of materials at ambient temperatures using sunlight and biological processes eliminating the need for energy from other sources.

Potential shifts in value

- Electricity storage technologies at scale, such as the dramatic reductions in the cost of lithium cells, may shift value from hydrocarbon-based sources towards renewable energy (or other energy technologies as they mature).
- Value shifts from centralized towards decentralized energy provision, and from transport towards storage and off-grid energy production.
- Value for low-energy biodigital production technology could increase.

ACTIVITY 9

RESOURCE EXTRACTION OF NON-LIVING MATERIAL

Definition
Non-living material is physically acquired from the environment.

Examples
Mining of mineral and metal ores; extraction of petroleum, natural gas, or water.

Typical scarcities

- **Spatial scarcity:** the resource is in a specific location.
- **Absolute scarcity:** there may be a finite amount of the resource in the world.
- **Artificial scarcity:** may exist because of cartels, conflict preventing access to the location, or licensing.

Technologies that could affect scarcities

- Absolute and spatial scarcity can be reduced by using biodigital technologies to develop substitute materials closer to the point of their consumption, use, or transformation.
- High-speed connectivity enables delivery of digital substitutes for many physical goods reducing demand for some resources.
- AI and 3D printing can optimize design to reduce the amount of material needed and improve recycling.

Potential shifts in value

- Value shifts from raw materials and extraction equipment (e.g. for mining and drilling) to biodigital technologies and related infrastructure (e.g. bioreactors).
- Value shifts from resources needed for traditional physical goods (e.g. iron ore) to those needed to produce new technologies (e.g. rare earths for electronic devices, or cobalt and lithium for batteries).

ACTIVITY 10

HARVEST OF NATURALLY OCCURRING RESOURCES

Definition
Naturally occurring living material is physically acquired from the environment.

Examples
Forestry; fishing; hunting; foraging.

Typical scarcities

- **Spatial scarcity:** the resource is in a specific location.
- **Temporal scarcity:** the resource may be seasonal.
- **Absolute scarcity:** there may be a finite amount of the resource.
- **Artificial scarcity:** may exist because of cartels, conflict preventing access to the location, licensing, or quotas.

Technologies that could affect scarcities

- Biodigital technologies could reduce absolute and spatial scarcity by developing alternatives through technologies such as cellular agriculture (e.g. lab-grown meat rather than hunting or fishing); pharmaceutical drug development (e.g. the anti-malaria drug artemisinin) to break the scarcity of foraged natural remedies (e.g. quinine); precision aquaculture to reduce the absolute scarcity of fish resources worldwide.
- High-speed connectivity enables delivery of digital alternatives to printed material reducing absolute scarcity in forestry by reducing demand for paper.
- AI and software automation can optimize design to reduce the amount of wood needed to make products.

Potential shifts in value

- Value shifts from raw materials, related harvesting equipment (e.g. logging equipment, fishing boats), and transportation infrastructure to 3D printing, AI, biodigital technologies, and related infrastructure.
- Value shifts away from licences and land leases.

ACTIVITY 11

AGRICULTURE

Definition
Specific plants, animals, or microbes are intentionally grown.

Examples
Farming grains, fruits, vegetables, fibres; animal husbandry; plantations; aquaculture.

Typical scarcities

- **Spatial scarcity:** the plant or animal exists only in a specific location.
- **Absolute scarcity:** suitable land—a limited number of areas have the right characteristics (e.g. soil, water, insolation, and temperature) to grow specific plants and animals.
- **Artificial scarcity:** may exist because of quotas or licensing.

Technologies that could affect scarcities

- Biodigital technologies such as cellular agriculture can reduce spatial and absolute scarcities. For example, genetically modified algae can directly produce casein and lactose to obtain cheese without dairy cows. Vertical farming could remove spatial, temporal, and absolute scarcities by optimizing land use. This would remove the need for arable land for some crops, and create ideal conditions for growing plants year-round.
- AI and software automation could reduce absolute scarcity by increasing efficiency of farming, smoothing prices, and optimizing supply and demand.

Potential shifts in value

- Value shifts from land and traditional food production (e.g. cattle farming for dairy and meat), storage and processing equipment and facilities to bioproduction infrastructure and expertise, and vertical farming.
- Land previously used for crops that are grown through vertical farming could be used for other crops that cost too much to grow this way.
- If vertical farming is close to markets, the value of transport-related infrastructure and expertise could decrease.

ACTIVITY 12

TRANSFORMATION OF MATTER

Definition
Matter is combined or manipulated to change its state, structure, or form.

Examples
Steel or cement production; petroleum refining; smelting of ores; construction; furniture and clothing production; baking bread; electronics manufacturing.

Typical scarcities

- **Spatial scarcity:** the transformation process happens in a specific place.
- **Temporal scarcity:** this may exist if the inputs or outputs can go bad.
- **Absolute scarcities:** physical space—the transformation process must happen in an appropriate space; physical capital—specialized tools, machinery, or equipment may be needed for the transformation; expertise—the transformation process requires know-how.
- **Artificial scarcity:** may exist because of quotas.

Technologies that could affect scarcities

- Decentralized production technologies can reduce some spatial scarcities if physical goods are turned into digital designs that use less material and are produced on demand in the geographical location where they are needed.
- Biodigital technologies could create different ways of producing the same outputs as many transformations (e.g. direct biosynthesis of petrochemicals) or create substitutes that reduce the need for some types of transformations.
- Robotics can remove the absolute scarcity of expertise needed for production.

Potential shifts in value

- Value shifts from traditional physical capital to 3D printing and biodigital production capital, and related digital infrastructure.
- Labour may decline in value while robotics could increase as the expertise becomes encoded into the software controlling the robot.

ACTIVITY 13

DISPOSAL OF UNWANTED MATERIALS

Definition
Unwanted materials, substances, or energy are returned to the environment.

Examples
Combustion gases (including vehicle exhaust); effluent; industrial waste; agricultural and agri-food waste; mining and smelting waste; commercial and municipal garbage.

Typical scarcities

- **Spatial scarcity:** solid materials are disposed of in a specific place; liquid and gaseous materials are dispersed in specific media (water and air respectively).
- **Absolute scarcity:** absorptive capacity—the ecosphere may have an upper limit on its capacity to absorb or metabolize waste products.

Technologies that could affect scarcities

- Biodigital technologies could discover or develop organisms that can break down dangerous substances into benign or reusable molecules (e.g. bioproduction processes using CO_2 as a feedstock). They could also enable the production of substances traditionally created by resource extraction, harvest, or agriculture, in ways that avoid harmful by-products.
- Advanced materials such as bio-based alternatives to traditional materials could be developed that will be more readily absorbed by the environment.
- Decentralized production technologies (e.g. 3D printing) could reduce the waste associated with transportation by making products closer to markets.

Potential shifts in value

- Value shifts away from some types of waste and pollutant treatment and disposal facilities, and associated land and transportation infrastructure. Some land may have negative value if it would cost more to remediate than to develop alternative uses for it.
- Value shifts towards biodigital technologies and associated equipment, and research and development facilities.
- Value also shifts towards waste management facilities that are associated with biodigital production facilities, and associated land and infrastructure.

ACTIVITY 14

APPLICATION OF RULES AND PROCEDURES

Definition
The application of a framework that allows value to be retained or transferred.

Examples
Contracts; deeds; licenses; accreditation; banking; real estate; insurance; auditing.

Typical scarcities

- **Spatial scarcity:** occurs if one or both parties need to be present for the interaction; it will also exist if the framework only applies in a jurisdiction defined by geography.
- **Temporal scarcity:** exists if transactions can occur only during business hours.
- **Absolute scarcity:** trust—human transactions will not happen without a mechanism to ensure reciprocal exchange of value. Traditionally, much of the value associated with this activity comes from third parties that can assure the terms of a framework are respected.
- **Artificial scarcity:** trusted third parties need to be professionally accredited (e.g. by law societies, accountancy institutes).

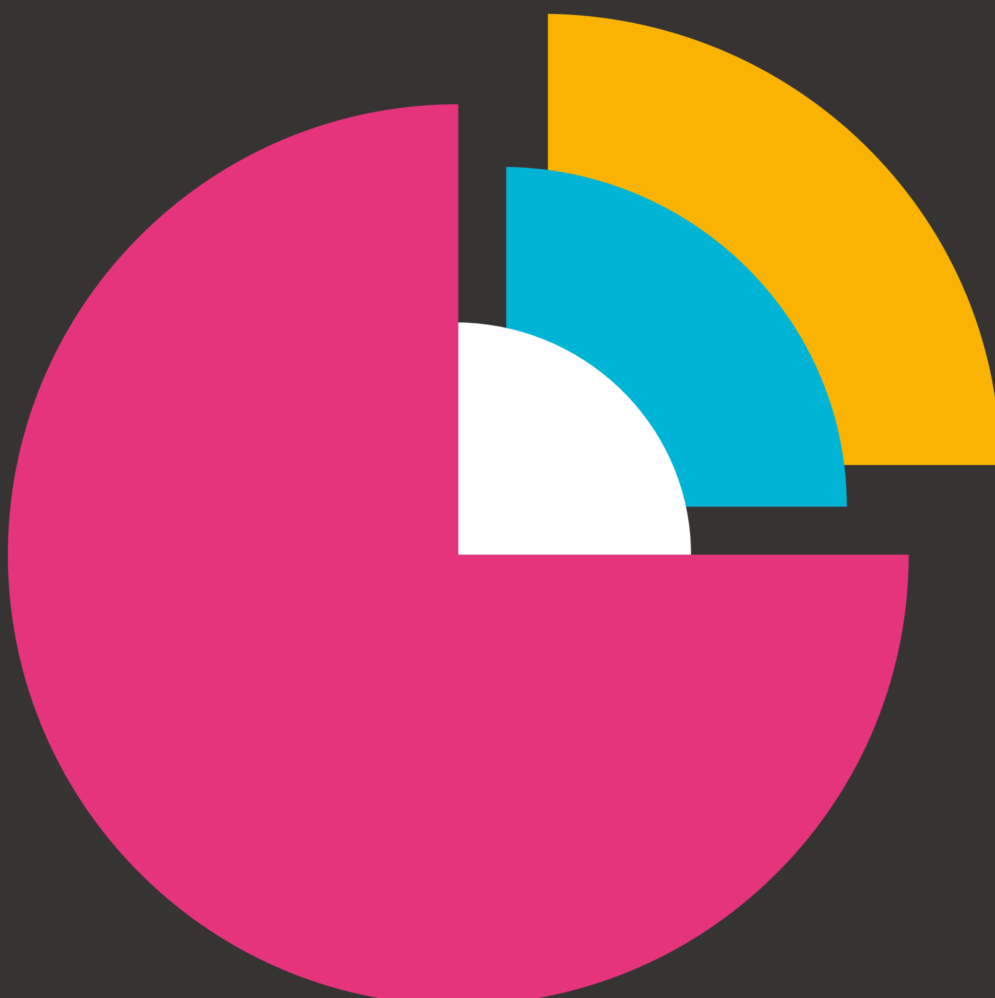
Technologies that could affect scarcities

- AI and software automation may advance quickly in this activity as it essentially involves applying rules to data, which in principle can be done by algorithms. Algorithms can reduce the need for human expertise (e.g. calculating loan repayment schedules or projecting retirement income from investments). Algorithms can also eliminate the scarcity of trust—when an algorithm is trusted to replace humans, there is no need to worry about the competency and honesty of those humans.
- Blockchains could accelerate digitization of framework activities by providing assurance that digital information about an interaction is accurate. Blockchains also permit the creation of “smart contracts” in which the contract comes into effect automatically after the terms are fulfilled.

Potential shifts in value

- Value shifts away from expert humans and associated physical infrastructure (e.g. office space in financial centres), and towards algorithms and associated infrastructure (e.g. digital platforms, connectivity, and interface devices).
- Value shifts away from institutions that train and accredit expert humans, and towards institutions that verify the accuracy of what is put on a blockchain.

3 IMPLICATIONS FOR BUSINESSES AND POLICY MAKERS



Analyzing technological disruption of the economy through the lens of the 14 basic human activities has three aims. It can help companies, academic and vocational institutions, individuals, and policy makers understand what is happening to the economy and to businesses. It can provide insight into how new businesses could be created. And it can identify how different actors could respond to shifts of value in the economy. Figure 2 depicts a human activity-based framework for examining technology-driven disruption to a business.

Companies could use this framework to better understand where to invest by identifying the human activities that make up their business. This would allow them to understand where emerging technologies will affect profit most, either positively or negatively. They might also consider how these technologies can disrupt existing products and services with the aim to sell new ones to other companies or to governments.

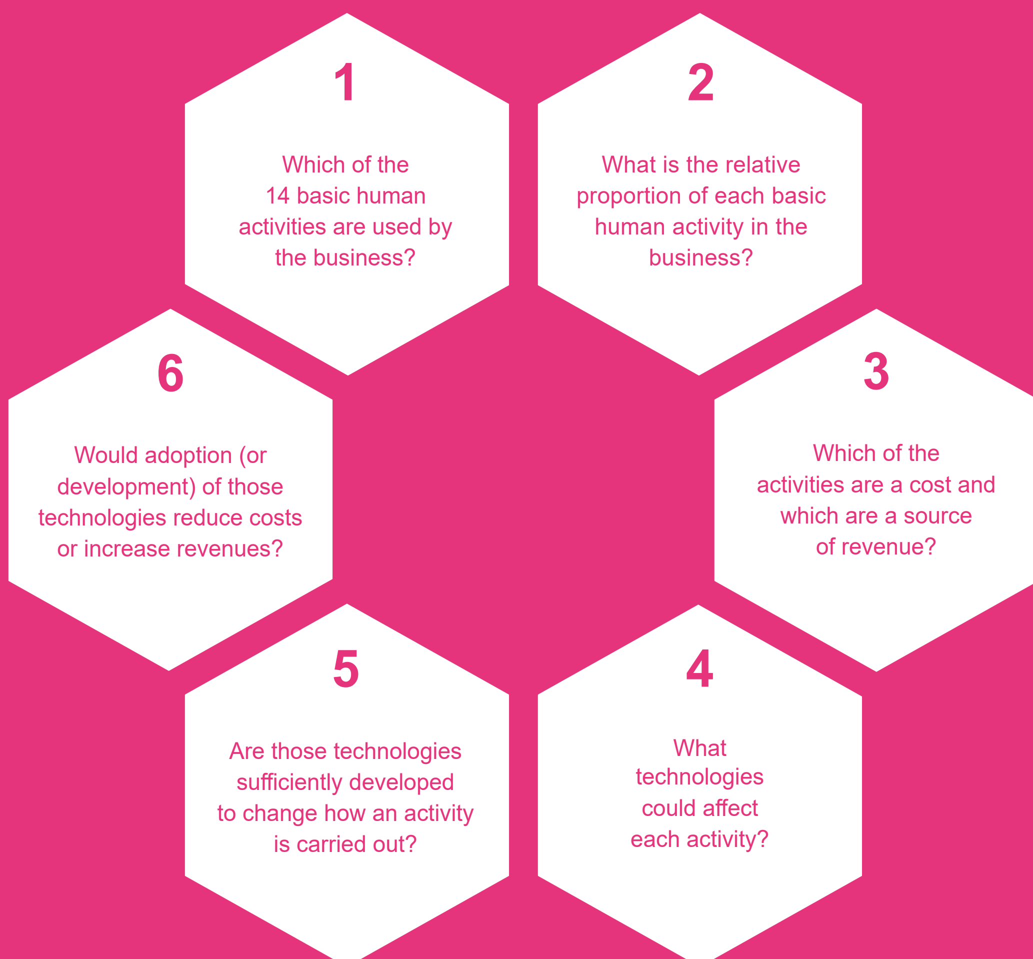
Academic and vocational institutions could analyze their programs to see which ones will likely see growing demand. They could also explore how traditional occupations may adopt or adapt to new technologies. Using this knowledge, they could offer programs to prepare their graduates for these changes.

Individuals could better understand the value of their work to employers or clients, and how technologies may affect them. This could help individuals prepare for change through reskilling or upskilling.

An activity-based approach to analyzing technological disruption could help governments understand, anticipate, and plan in a range of areas.

FIGURE 2

A human activity-based framework for analyzing technology-driven disruption to a business

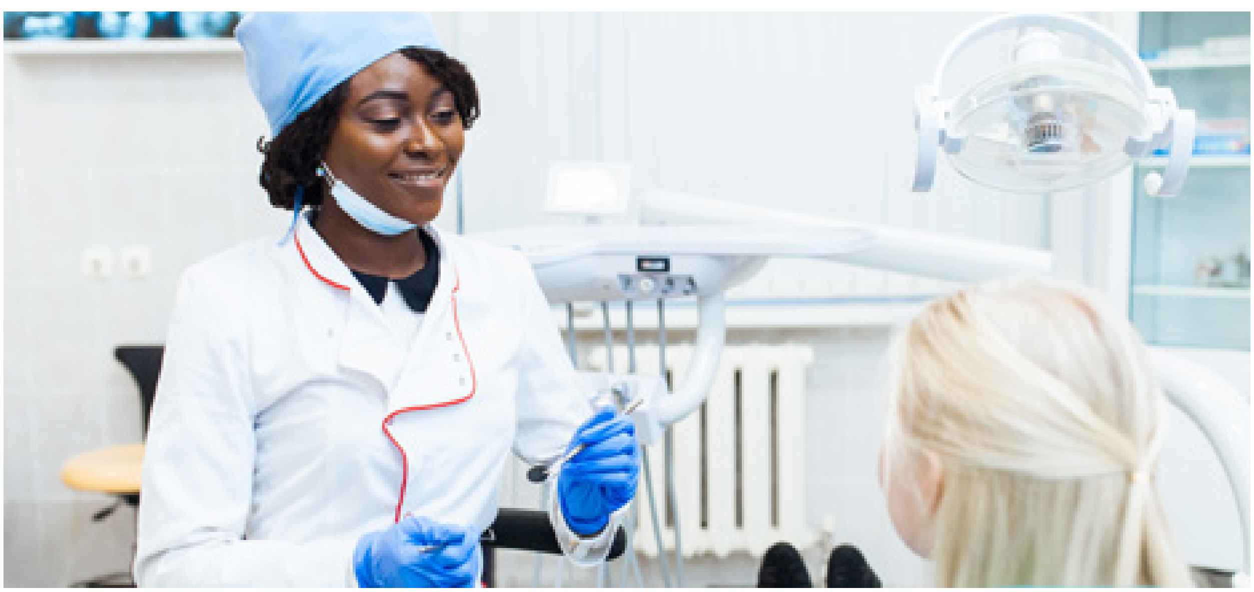


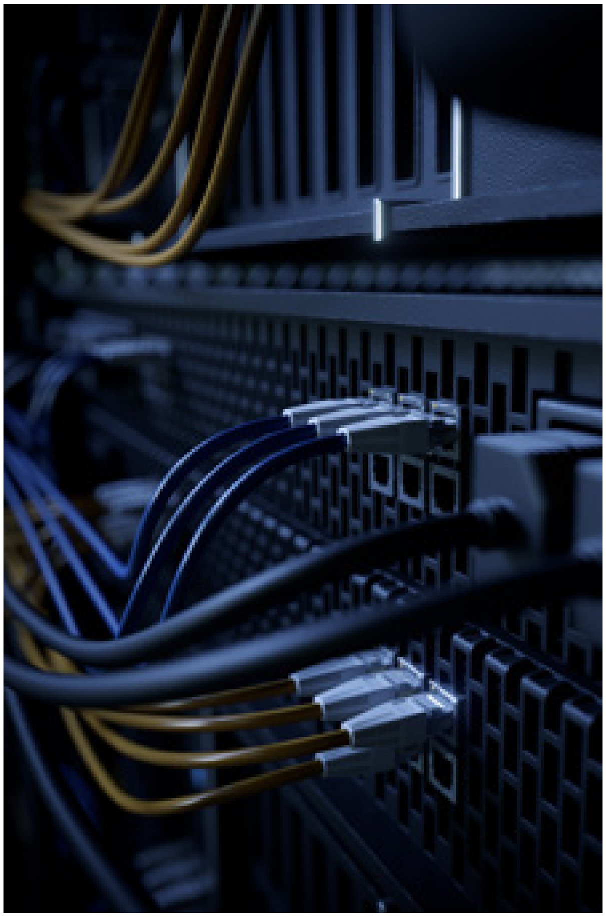
Let us apply the framework to a dental practice as an example.The business primarily involves physical services to living beings (Activity 1). These services are provided by dentists, assistants, or hygienists. Secondary human interactions include information acquisition (Activity 4) in examinations and gathering information about clients. There is knowledge generation (Activity 5) in interpreting the results of the examination and the information gathered about the client's diet or brushing frequency for example. There is knowledge transfer (Activity 6) in providing oral health advice, booking appointments, and in billing and payments. There may be an experience component that changes an emotional state (Activity 7) if the dental office has friendly staff and is aesthetically pleasing, and the application of rules and procedures (Activity 14) takes place in the billing and payment process, and in allowing only accredited staff to perform certain functions.

In combination, these activities make up the business of a dental practice. Reducing or eliminating the scarcities associated with an interaction will affect the revenue and expenses of the practice.

If the activity is an expense, the dental practice will carry out its business at a lower cost. If the scarcity associated with the activity limits the practice from expanding its revenue, increasing that capacity will increase its revenues. The owners could retain the increased revenue as increased profits. Alternatively, they could maintain the same profit margin and pass the reduced costs onto clients. This could take the form of lower prices or more services at the same price.

Booking appointments, for example, has value to the business. Scheduling patients requires a human with expertise to gather information (e.g. name, service required, dates patient is available—Activity 4), generate knowledge (e.g. identifying times when the patient and dentist are both available for the required service—Activity 5) and transfer knowledge (informing the patient of the time and date of the appointment—Activity 6). Because there is a limited supply of this expertise relative to demand (a form of absolute scarcity), the dentist pays someone a salary to do the work. The dentist also provides the physical space and physical capital required for the person to do their job—e.g. a desk, chair, phone, space for their personal effects, lunch room, etc. These non-salary costs are incurred because of temporal and spatial scarcities. The person needs to be on the telephone during working hours and at the same time as the patient. The person also needs to be in the dentist's office because that is where the telephone and scheduling calendar are located.





Breaking the different scarcities reduces or transfers where value resides (see Figure 3). Replacing the person booking the appointments with someone working from home breaks the spatial scarcity. The telephone and the Internet eliminate the need for physical space in the dentist's office as well as the physical capital (e.g. desk). The value that was associated with them shifts to the space in the person's home, their physical capital, as well as their telephone and Internet service.

A spatial scarcity still exists because the person booking the appointments has to be located somewhere, but the cost of that new location may be lower. For example, the cost of a home-based workspace for a person booking appointments is likely much lower than the same type of workspace in a professional office building. Although the dentist might pay the same wage for that person's service, the dentist may be able to move to a smaller office space. That makes office space less scarce. As a result, the commercial landlord may have to reduce the rent. There would also be reduced value for transportation (e.g. car, bus) since the person is working from home, and they would no longer visit places like coffee shops or restaurants in or near the office building.

The temporal scarcity still exists because the person booking appointments needs to speak with the patient at the same time. However, it could be broken if the dentist replaces the booking function with an AI-powered chatbot such as Google Duplex that patients can interact with at any time.

The AI would also break the expertise scarcity that gave the booking person their value. Value shifts from the person to the software and the infrastructure it runs on. Value also shifts from the home office to the building where the computer is located. The actual space required may be minimal and available at even lower cost than the home-based work space.

Initial policy-relevant questions include:

Which types of workers are most likely to be affected? How could they be retrained or upskilled?

Could adoption of new technologies allow governments to provide better public services at lower cost?

As it becomes easier for people to work separately from their colleagues and/or their equipment, will commercial or industrial real estate drop in value? How could it be used differently?

Will home offices or neighbourhood-based work centres in suburban or rural areas become more valuable? Will the value of the Internet increase? Will the value of commuter transportation decrease? How should governments respond to changing infrastructure needs?

What aspects of the shifts in value will Canadians or groups of Canadians want to accelerate? Which ones may they want to slow down? How might regulatory and policy frameworks influence the speed and depth of digital and biodigital disruptions?

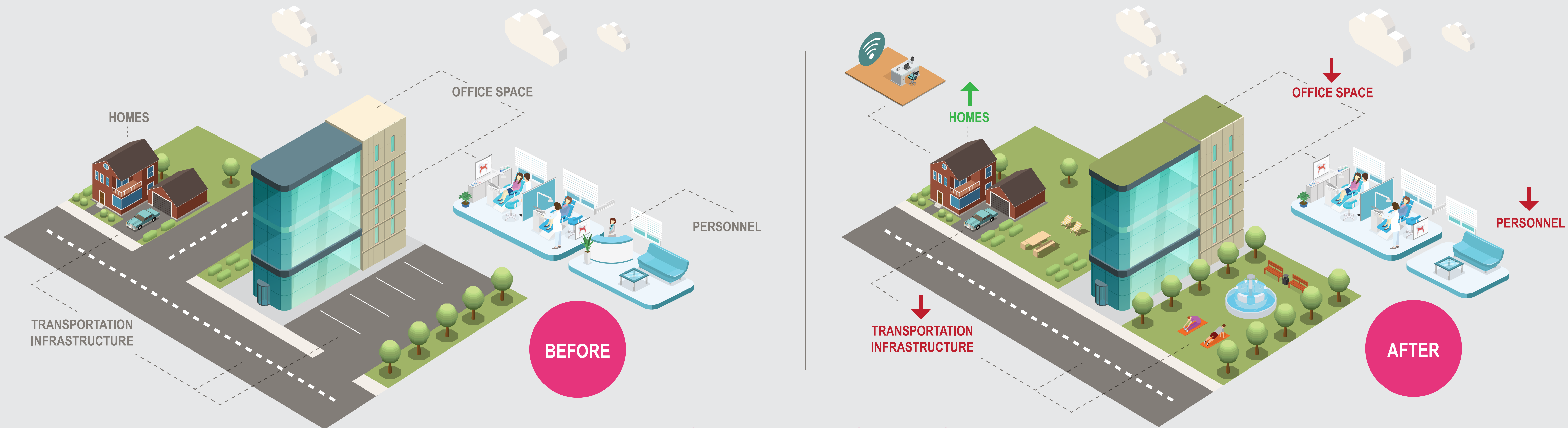
Would transformed businesses create vulnerabilities for important areas of the economy? How could policy best deal with these new risks?

What are the costs or benefits of accelerating or moderating changes? How might the shifts in value affect government revenue streams?

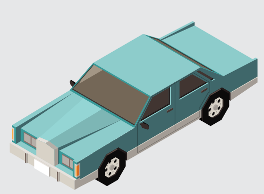
What does this imply for economic modelling and industrial development strategies? How could this affect the tax regime?

FIGURE 3

SHIFTING VALUE IN A DENTAL OFFICE



HOW VALUE SHIFTS

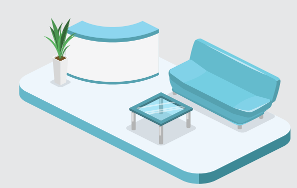


TRANSPORTATION INFRASTRUCTURE

- Shift from commercial to home office space decreases need for travel
- Decreased value of private and shared vehicles, taxis, public transit
- Decreased value of transportation infrastructure (e.g. roads, parking lots & garages)
- Decreased value of related products (e.g. fuels, lubricants, replacement parts)
- Decreased value of related services (e.g. sales, maintenance, repair, cleaning)

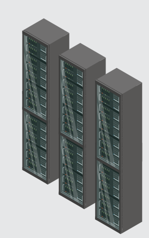
PERSONNEL

- Initially, an administrative assistant is still required
- If technology replaces all or part of that task:
  - The need for the position is reduced or eliminated
  - Value transfers to the software and digital infrastructure



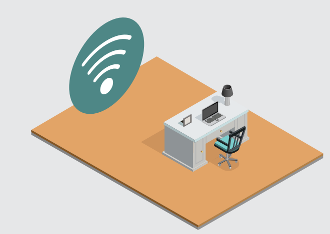
OFFICE SPACE

- Shift to home-based work frees up commercial office space
- Decrease in scarcity and value of commercial office space



EXPERTISE

- Initially, an administrative assistant is still required
- If technology replaces all or part of that task:
  - Value of human expertise transfers to the software
- Decrease in value of expertise:
  - Software-based expertise is no longer scarce
  - Expertise can be replicated at low marginal cost



HOME OFFICE SPACE

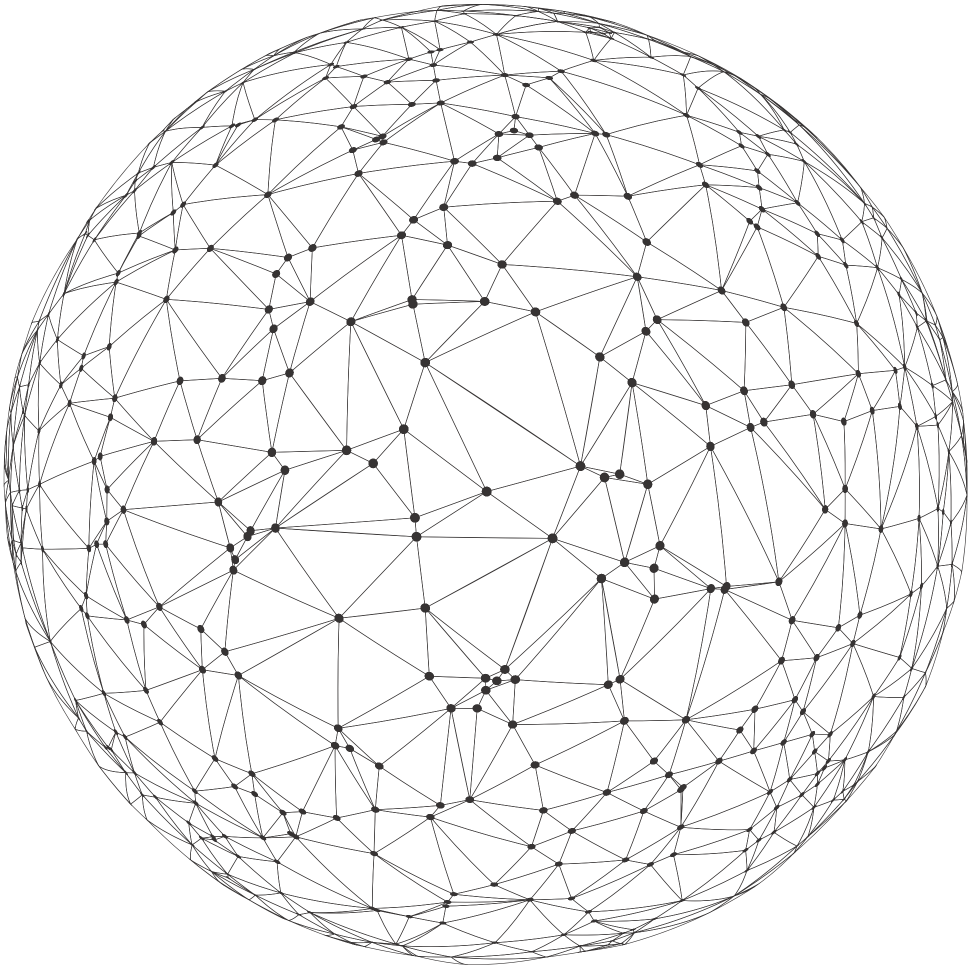
- Increase in value of residential space as administrative assistant works from home
- Increase in value of home Internet and telecommunications services
- Increase in value of larger homes to accommodate home-based work
- Value shift from urban to larger suburban and peri-urban spaces

OTHER SERVICES

- Decrease in value of services that rely on commercial tenants (e.g. restaurants, coffee shops, food courts)
- Decrease in value of retail shops and services that rely on foot traffic in office building
- Decrease in value of cultural and entertainment venues that rely on after-work traffic

LEGEND ↑ INCREASE IN VALUE ↓ DECREASE IN VALUE

4 NEXT STEPS



This first report lays out a new framework to inform our thinking about how technology will continue to shift value in the economy. Along the way, it identifies the potential implications for different actors. It is the starting point for additional foresight that will apply this framework to sectors of the economy.

The planned work will shed more light on the timeline and depth of digital disruption for different activities. It will look at the degree to which a sector includes the different activities, as well as which sectors may be affected. This will inform thinking about disruption of the domestic and global economy, and outline policy challenges and opportunities. Policy makers, businesses, individuals, and educational institutions could then explore a range of responses to the potential changes.

ACKNOWLEDGEMENTS

Policy Horizons is spearheading an area of foresight on the future of value. This scoping paper is the initial framework for a forthcoming in-depth foresight study. The study will examine plausible ways in which the future of value may change and the resulting policy questions that may arise.

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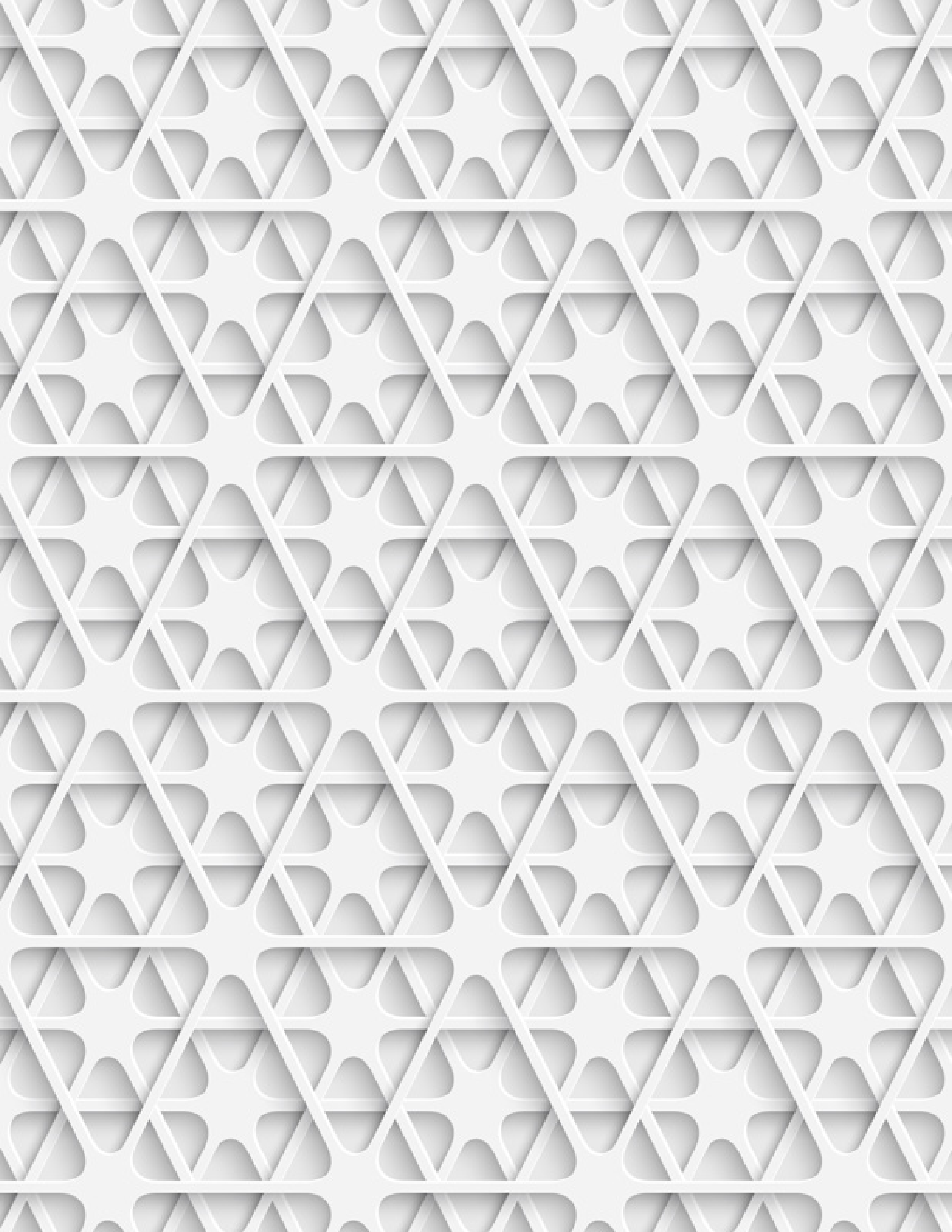
We look forward to collaborating with partners and stakeholders as we study the future of value.



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