WORLD ECONOMIC FORUM

COMMITTED TO IMPROVING THE STATE OF THE WORLD

White Paper

The Digital Arab World

Understanding and embracing regional changes in the Fourth Industrial Revolution

January 2018

World Economic Forum®

REF 131217

Contents

6 Future of Platforms and Systems
How to navigate the Fourth Industrial Revolution like an Arab souk

8 Future of Technology, Values and Policy
Reaping benefits while minimizing risks

9 Future of Human Enhancement
What is the future of human enhancement in the Arab world?

10 Future of Innovation and Entrepreneurship
How Arab entrepreneurship can solve regional challenges

12 Future of Advanced Materials
How non-metallics are creating transformative opportunities in the oil and gas industry

15 Future of Space Technologies
How space technology will affect the Arab world

16 Future of Artificial Intelligence and Robotics
Robotics and AI: Enabling an Arab Spring

17 Future of Neurotechnologies and Brain Science
Impact of neurotechnologies and brain science on the future of the Arab world

18 Future of Civic Technology and Human Rights
Securing the future of civic tech in the Arab world

18 Future of Cybersecurity
Ensuring cybersecurity in a digital Arab world

20 Future of Behavioral Economics
How behavioural insights are changing the stakeholder landscape in the Arab world

22 Future of Biotechnology
Preventative medicine in the Middle East must be a collaborative effort

24 Future of Computing
How is the future of computing likely to impact the Arab world?

26 Future of Transport
The digital underpinning of the transportation revolution

27 Acknowledgements

28 Endnotes

Foreword

Mirek Dusek
Head of Regional Strategies - Middle East and North Africa, Member of the Executive Committee, World Economic Forum

Sheikha Bodour Al Qasimi
Chairperson, Sharjah Investment and Development Authority - Shurooq, United Arab Emirates; Chair, World Economic Forum Middle East and North Africa Regional Business Council

Emerging technologies, such as robotics, artificial intelligence, nanotechnology and the Internet Things, will leave no geographic region, business sector, or society untouched. These technologies are transforming how we, as citizens and leaders, create, exchange and distribute value in society.

As World Economic Forum Founder and Executive Chairman Klaus Schwab explains in his book The Fourth Industrial Revolution, we are already witnessing disruption in almost every industry and country. The increasing convergence and affordability of digital, biological and physical technologies will, therefore, affect how the Arab world produces, consumes, trades and moves, and it may challenge how we relate to one another and even what it means to be human.

It is becoming increasingly vital for regional leaders to steer a steady course through potential reforms to maximize opportunities and promote citizen participation in innovation and technology development. To shed light on this digital transformation, we invited several leading regional and international thought leaders to think about collaborative solutions to further the digital agenda in the Arab World and unlock regional opportunities presented by the Fourth Industrial Revolution.

This white paper is an initial step to identify a regional agenda for countries and leaders in the Arab world for how governments, businesses and societies can work together to design and govern new technologies. The Regional Business Council has named this broad framework for action the Digital Arab World initiative. The council will continue to explore how the region can work together to benefit from the changes of the Fourth Industrial Revolution.

We look forward to continuing the conversation with you.

Future of Platforms and Systems

How to navigate the Fourth Industrial Revolution like an Arab souk

By Habib Haddad, President and Managing Director, E14 Fund, USA

To navigate the Fourth Industrial Revolution, the Middle East should learn from its *souks* (local Arab markets). One of my favourite things to do in an Arab city is to take a stroll through its old souk and embrace the sounds of haggling merchants, the rich aroma of spices and the colourful stores displaying their wares. Some of these stores go back several generations.

The souk is a living organism made of interconnected actors – the suppliers, the merchants and the shoppers – serving not just as a marketplace, but also as a place facilitating social meet-ups. It emerges bottom up, evolving over time by responding and adapting to the situation on the ground. There is no central designer of the system, but the actors themselves who set the tone. The souk, therefore, is a perfect example of a decentralized, complex, adaptive and resilient system.

Systems are all around us – school, neighbourhoods, cities, companies, national economies. Yet designing good systems is hard and sometimes we end up with a result completely opposite from the goals we started with. We have much to learn from resilient systems like the souks that maintain integrity of purpose, despite external challenges.

I am lucky to have been part of the change that has led to the creation of a thriving entrepreneurship environment in the Arab world. In less than five years, a few fragmented initiatives have transitioned to a flourishing ecosystem made up of start-ups with international scale, institutional investors, support organizations and university programmes, which all interact together and mutually reinforce each other. Prior to 2012, those various elements and organizations existed, but were poorly interconnected, working in silo with weak feedback loops. The system emerged bottom up without a central organization, figure, or country managing it.

In retrospect, here are the system interventions that worked and their sequence: First, a cultural shift happened, raising the profile and importance of entrepreneurship which made everything else easier. As the cult of the "hooded entrepreneur" travelled from the Bay Area in California to the Arab world, it encouraged regional role models in the same way. Eventually, media publications began focusing on entrepreneurship, and yearly prizes began to be awarded celebrating entrepreneurs. This encouraged more people to take the entrepreneurial leap, creating in their wake a demand for support organizations such as mentorship programmes. As those were established, they strengthened the skills of entrepreneurs, giving their mentors a good reason to invest in them; the amount of venture capital investments in the Arab region increased five-fold between 2013 and 2016.[1]

Eventually, angel funds were established, encouraging yet more people to create start-ups. With seed funding, some ventures started showing early signs of success, thus needing to raise more money. This gave reason for funds to raise more capital. The influx of a larger pool of capital attracted even more talent, and those living in the diaspora started to return. Universities took notice and established curriculums.

It was only after this happened that governments decided to play a role. Successful regional top-down support came at the end of the chain; most of which came before did not really work. For example, the Central Bank in Lebanon launched Circular 331 only in 2015, a few years after the bottom-up emergence of the local ecosystem. Much like traditional souks, clusters of start-ups, venture funds and accelerators formed and continue to form in the region.

In contrast, top-down attempts at setting up systems more often than not fail. Take the example of an Arab city that wanted to spur local innovation. A team was handed the mission to create the next 100 successful start-ups. So, they established a large incubator with all the latest tech gadgets. Their success was to be measured by how many start-ups they could host. With pressure to hit their target, they started accepting small traditional businesses instead. They also offered major incentives for budding entrepreneurs to start a company and base it in the city by offering free space and infrastructure. However, new founders need much more than space or even capital; they need great mentors, service providers such as lawyers and bankers that really understand the start-up lifecycle, and a good community around them to serve as a support group. Without any of this, the new founders tended to quit at the first major obstacle, which is common in the start-up world. So they closed shop and the traditional businesses took over, turning the space into a subsidy scheme instead. The city's goal of spurring innovation went back to square one.

The souks and the previous entrepreneurship system design intervention teach us some important lessons that the region can learn from as it looks towards playing a leading role in the Fourth Industrial Revolution:

- **Top down does not work.** This does not mean that hierarchy is not important, but rather that it has to evolve from the bottom up, with the upper layers serving the lower layers.

- **Stay true to the purpose.** While many initiatives start by having an altruistic purpose, some end up with an inverse result; it is important to avoid this trap and be ready to kill the initiatives that do not work.

– **Identify levers.** While there are no easy ways to control a system, there are ways to shape its direction towards an intended goal and make it more resilient to external events.

– **Pay attention to the edges.** Innovation happens at the fringes. This is where the probability for creative and disruptive ideas to form is much higher away from the conservative and risk averseness of the mainstream centre; for that purpose, it is important to strengthen one's peripheral vision to spot what works there and bring it to the centre for larger impact.

– **Have patience and foresight.** There are long delays in feedback loops and so changes take time, but this also means that foresight is essential before making any intervention; to act only when a problem become obvious is to miss an important opportunity to solve the problem.

Future of Technology, Values and Policy

Reaping benefits while minimizing risks

By Wendell Wallach, Scholar, Interdisciplinary Center for Bioethics, Yale University, USA

At a star-studded investment conference in Riyadh, Saudi Arabia, on 24 October 2017, Crown Prince Mohammed bin Salman announced an ambitious programme to reinvent the Saudi economy. Central to the initiative he outlined are an embrace of the Fourth Industrial Revolution, the building of a modern futuristic city near the capital, and the development of a robust high-tech entertainment and ecotourism industry. Two days later, British billionaire entrepreneur Richard Branson announced plans to create a space centre adjacent to the new city.

Cognizant of the fact that economies built upon oil cannot last forever, leaders throughout the Arab world are exploring means to diversify. Bahrain, for example, has plans to serve as an IT hub for the pan-Arab region. The United Arab Emirates launched an artificial intelligence (AI) strategy and appointed a State Minister for Artificial Intelligence. Research on synthetic biology is progressing throughout the region. A focus upon reaping the rewards of emerging technologies, however, poses unique challenges for Arab leaders. These challenges range from value clashes, to minimizing risks and undesirable societal impacts of technological innovations.

While there exist plenty of opportunities for Arab countries to take the lead in the development of emerging technologies, the most significant progress will lie in adopting innovations deployed first by other nations. The US and China, for example, are expected to lead research in AI for at least the next decade or two, but some of the greatest strides will ensue from analysing regionally specific data utilizing openly available algorithms. To do so, it will be necessary to train young scientists with the necessary tool sets, and then retain their services in a highly competitive international competition for talent. An increasing share of that talent is women scientists and engineers, whose demands for advancing women's rights will force hard choices and at times exacerbate societal tensions.

In 1930, the economist John Maynard Keynes coined the term "technological unemployment" to represent downward pressure on jobs and wages caused by automation. The prospect that advances in AI and robotics will automate a wide array of tasks and decimate many jobs must be taken seriously. The prospect of technological unemployment is already alerting world leaders to the simple fact that in adopting new technologies there are trade-offs; some trade-offs entail risks and undesirable societal consequences. Lethal autonomous weapons (LAWS), for example, can lower the loss of soldiers during combat, but LAWS might also unintentionally start new conflicts, escalate existing hostilities, commit acts that violate international humanitarian law, and expunge any sense of virtue for those serving in the military. I am among those who contend that we need an international arms control treaty to restrict the development of LAWS.

The European Union and the Institute of Electrical and Electronics Engineers (IEEE) are among the bodies that are taking seriously the risks and undesirable societal consequences of deploying new technologies. Even the adoption of self-driving vehicles will be accompanied by requirements for new norms, proposals for reinventing urban landscapes and eventually demands that driving by humans be restricted. Concerns that robotic caregivers demean the homebound and elderly will need to be addressed, as will broader concerns that technological progress can be intrinsically dehumanizing.

Arab nations can certainly follow the lead of others in setting their own standards, but individual nations and the region must at least evaluate whether those standards might, for example, be overly stringent and will unnecessary hinder national and regional goals, or might invoke values that will precipitate conflicts that could be defused through a different approach. All leaders must recognize that benefiting from technological innovations implicitly invokes values that can be challenging for tradition-bound institutions.

There is a fundamental mismatch between existing governmental approaches to the legal/ethical oversight of technology and the increasing speed of scientific discovery and technological innovation. New, more agile, approaches to governance will be required for countries to take advance of, to adapt to and to minimize harms from emerging technological possibilities. These technological possibilities will alter every aspect of life. More forward-thinking countries will not merely adopt technologies because they are available, but will engage in reflection and discrimination, responsible innovation, and anticipatory planning and governance as they work toward shaping a future worth bequeathing to the next generation.

Future of Human Enhancement

What is the future of human enhancement in the Arab world?

By Nayef Al Rodhan, Honorary Fellow, St Antony's College, University of Oxford, United Kingdom

Human enhancement is increasingly considered among the most transformational forces of the 21st century. Its impact extends into a wide range of human activities, from the workplace to the battlefield, as well as into the domain of ethics and existential questions, leading to serious concerns about our own future as a species.

Human enhancement refers to the range of technologies and interventions to boost human capabilities – physical and cognitive – beyond the normal characteristic of our species. Human enhancement is, therefore, an intervention to the human body, which improves performance beyond normal physiology and what is necessary to sustain health or restore lost functions. Enhancement is therefore different from treatment and restorative medicine, which are concerned with healing and bringing damaged or lost functions back to normal parameters. This distinction is not without controversies, but in most cases it is easy to separate treatment from enhancement.

For example, a treatment to stall or prevent muscle atrophy is clearly different from an intervention that increases muscle power in healthy individuals and gives them endurance and strength beyond what is typically normal for that age group. Similarly, hearing aids to help maintain or restore declines in sensory perceptions is different from hearing implants that boost auditory acuity far above what is normally perceptible to humans.

Other examples of cognitive enhancements include drugs such as amphetamines (used widely by the US during the Vietnam War), Modafinil, which enhances decision-making skills and alertness, but also non-pharmacological enhancements, such as transcranial electrical stimulation. Physical enhancement includes diverse methods such as genetic therapies to modify human digestion, nutrition and metabolism, implantable devices, brain-computer interfaces or external devices that enhance human endurance in extreme conditions of physical stress (such as extreme heat or cold). Some of these technologies might still appear sinister to many, but they may well become the new normal in a decade or two.

When US-based company Three Square Market proposed implanting its employees with a chip the size of a grain of rice between theirs thumbs and index fingers, most volunteered. While this is not yet a form of enhancement (the chip has functions such as opening doors, logging into the computer, or paying food at the cafeteria), the privacy concerns and health implications are already offering a preview into the ethical questions surrounding enhancement. This example is also telling of the wider appeal of enhancement technologies.

A general prediction for the future of enhancement is that human nature will make the adoption of these technologies inevitable, even when these technologies will threaten to change us beyond recognition and change what it means to be human. I refer to this previously as "inevitable transhumanism". Humans are motivated by what I called the Neuro P5: power, profit, pleasure, permanency and pride. If a new technology promises to enhance one or more of these motivators, we will be drawn to use and adopt those technologies even if they carry long-term ethical and existential risks.

Human enhancement and Islamic beliefs

It is difficult to speak of the Arab world as a homogenous entity as many states in the region are sharply divided by politics, and are at different stages of socioeconomic development. In fact, the region comprises a remarkable array of states, from weak and failing to highly stable and successful ones. It is therefore easier to imagine that enhancements will first reach the urban centres in some of the Gulf countries, and maybe decades later other parts of the region.

In addition to the different economic contexts, the Arab world is at the same time bound together by a common faith, Islam, and the range of social norms that derive from it, as well as a specific understanding of humanity that promotes dignity and equality (even if often absent and neglected).
Islam professes equality among people and places great emphasis on justice. Islamic law also provides a unique right in the provision of the "right to sufficiency", which implies that everyone should live on the adequate needs of life, with a decent and appropriate standard of living – a right that is achieved through work. This right is also connected with the idea of responsibility, and the obligation of not abandoning those in need, especially when one's own means permit to help others.

Enhancement technologies will therefore, by definition, clash with core beliefs of Islam, as they will be privileging some people over others. In a larger sense, enhancements will disrupt the notion of justice, robbing a class of individuals of the opportunities to participate in society on the same footing as others.

How will human nature – and the Neuro P5 – be able to accommodate the equitable, meritorious and just teachings of Islam? This remains an open and complicated question. A likely outcome is that human enhancement will encounter significant resistance in Arab societies on the regulatory and theological level – although state militaries and large corporate entities might have a different approach. Emboldened by the necessity to adapt and close the technological gap, as well as by the non-negotiable priorities of national defence, security and competitive economies, they might not afford to repudiate human enhancement in the military or the mega-corporate level, if other states are deploying enhanced soldiers and enhanced executives.

Future of Innovation and Entrepreneurship

How Arab entrepreneurship can solve regional challenges

By Khaled Kteily, Lead, Middle East and North Africa, World Economic Forum

Being an entrepreneur in the Arab world is a category in and of itself, with a regionally unique set of challenges and opportunities. Our culture does not reward failure the way it might be celebrated in Silicon Valley. Young Arabs are encouraged to become engineers, doctors, or lawyers – skills that are transferrable across borders and countries. Our investment strategies do not encourage risk, when stability is a celebrated virtue in countries that have been wracked with geopolitical conflict. And when many countries have been reliant on oil for revenues, the safety nets that support their citizens also disincentivize risk-taking.

We value strong family ties and large families, but challenging economic climates have led to the highest rate of youth unemployment in the world. We have a language, traditions and a culture that tie us together, and yet a colonial legacy means that French, English and Arabic flow across the region. A French-educated Tunisian may not be able to fluidly communicate with an English-educated Jordanian or an Arabic-educated Qatari.

And yet, somehow, the region is buzzing with activity in a way that few outside the Middle East and North Africa would expect. When the World Economic Forum put out a call for the top entrepreneurs in the Arab world, the team received over 250 applications from almost every Arab country and in industries from blockchain to voice recognition to space technology – ultimately selecting the 100 that were deemed to be shaping the Fourth Industrial Revolution. Something is working.

Tackling regional challenges with regional solutions

Dig deeper and you realize that many successful start-ups are providing local solutions to local problems. Mujeeb, from Damascus-based Aghyad Al Kabbani, is a chatbot that understands Arabic. BitOasis, by Dubai-based Ola Doudin, provides access to cryptocurrencies for residents in the Arab world. Nafham, led by Cairo-based Mostafa Farhat, provides online educational courses in Arabic.
Indeed, the future lies here: regional solutions to regional challenges.

When Fadi Ghandour, one of the best-known investors in the region created Aramex, he allowed cash payment on delivery, rather than requiring pre-payment by credit card. Similarly, when Palestinian Faris Zaher created hotel booking website Yamsafer, he allowed customers to book without putting a credit card down. A simple phone call in advance of expected arrival at the hotel significantly reduced no-show rates. Today, Harvard Business School offers a case on the operations of his company.

The region's first unicorn – Careem – is no different, allowing cash payment, in line with local norms. A challenge like identifying an address – simple in much of the world but complicated in ours – was solved by UAE-based Fetchr, which allows you to use your phone's GPS to pinpoint your delivery address.

Regional challenges create regional opportunities

Our future depends on capitalizing on these unique elements of the Arab world. The oil wealth that disincentivized risk-taking has also created large sovereign wealth funds – the UAE, Saudi Arabia, Qatar and Kuwait being among the largest in the world. The Abu Dhabi Investment Authority alone ranks second only to Norway's well-known government pension fund. As these funds become increasingly comfortable emerging in new technologies, this could be a critical source of funding and incentives for new start-ups. Mubadala, for example, recently announced its investment in SoftBank's technology-focused Vision Fund.

Governments' centralized decision-making can also serve to steer their countries more quickly towards the future, as in Saudi Arabia, where the ambitious Vision 2030 plan aims to wrench the country away from its reliance on oil by diversifying its economy. The United Arab Emirates, which has not yet celebrated its 50th anniversary, has recently appointed the world's first Minister of Artificial Intelligence and created the Council for the Fourth Industrial Revolution to study its effects on the world.

The strong ties between governments and business will also be a critical part of this transformation. In Bahrain for example, the Economic Development Board signed a critical partnership with Amazon to host its warehouse services and is partnering with the World Economic Forum on a project exploring regulations for digital trade and cross-border data flows. In Sharjah, Sheikha Bodour Al Qasimi's ambitious Arab supply chain initiative is working to secure pledges from major corporations operating in the region to procure 10% of their supplies from start-ups.

Improving cooperation between governments and the private sector

The future of entrepreneurship lies in more closely bringing together governments with incumbent businesses and start-ups to collectively address our regional challenges. The

first step is to improve cooperation and collaboration on a country-by-country level. During the World Economic Forum on the Middle East and North in Jordan in May 2017, start-ups from each country met top government representatives, such as the Jordanian start-ups that met with the King of Jordan, and the Egyptian start-ups that met with the Minister of International Investment and Cooperation. These are critical steps towards improving communication and collaboration between parties that stand to benefit from one another.

Some entrepreneurs have also taken this into their own hands, providing grassroots information that the government might not otherwise be aware of. In Tunisia, for example, the creators of the Start-ups Act" identified the key government regulations that are preventing the growth of start-ups. The Start-ups Manifesto" in Egypt aims to do the same. As governments recognize the critical role entrepreneurs play in addressing revenue diversification, youth unemployment and more, they will be more willing to create the space for entrepreneurs to flourish.

Ultimately, closer collaboration between these parties will slowly create the ecosystem necessary for entrepreneurship to thrive, and, ultimately, a regional answer to what Arab entrepreneurship will be.

Future of Advanced Materials

How non-metallics are creating transformative opportunities in the oil and gas industry

By Bashir Dabbousi, Manager, Technology Strategy and Planning Department, Saudi Aramco, Saudi Arabia

Innovation and digitization in manufacturing are transforming both the oil and gas industry and the Arab world. At the centre of this transformation is digitization, which enables physical infrastructure to become increasingly data-enabled and more resilient as asset owners use algorithms to manage risks, anticipate failures and implement centralized management of energy consumption.

Increasingly, accelerated advanced materials innovation and manufacturing are enabled by continued reduction in the cost of energy. Technology examples that can drive economic growth include batteries and energy storage, nanotechnology, lightweight materials and non-metallics, photonics and advanced lighting, microsystems, and additive manufacturing. Together with digitization and predictive analytics, these technologies create efficiencies and reduce the energy intensity of manufacturing.

Role of non-metallics in enabling advanced materials growth opportunities

While the need for light-weighting, increased fuel efficiency and other benefits from non-metallics have led to increased adoption of polymers and composites in automotive and aerospace applications. The penetration rate of non-metallics in the oil and gas industry has been moderated due to technical limitations of commercial products, their inability to be fully compatible with aggressive operational environments, and the lack of inspection methodologies to assess performance during long-term service.

Unlocking the potential for non-metallic materials in the oil and gas industry, particularly polymer-based composite pipes, will accelerate their utilization in many upstream and downstream applications, and will eventually ensure their acceptance and adoption as a reliable alternative to carbon steels. The relative advantages include: improved performance and corrosion resistance; ease of installation, maintenance and transport due to lower weight; and reduced total cost of ownership in selected applications, resulting from higher performance and durability.

As shown in Figure 1, construction applications are the primary driver for global plastic pipe demand, which has recently experienced rapid growth. Demand growth is expected to decelerate slightly until 2020 due to the economic slowdown in China, with an increasing share in other uses, including agriculture, and oil and gas, as a result of materials substitution. The opportunity for suppliers of non-metallics in the oil and gas industry is attractive. In 2015, the oil and gas sector was the fifth largest consumer of steel, with pipes representing approximately 75% of the steel consumed by the sector.

In line with these requirements, scientists and engineers in oil and gas companies in the region and globally are pursuing research and collaborative technology development efforts to develop next-generation, non-metallic materials and inspection tools, which expand the operating envelope of existing products. A key example that is finding commercial use today in the oil and gas industry are reinforced thermoplastic pipes (RTP), as shown in Figure 2, which are replacing steel in several applications (e.g. process water, recycle water and hydrocarbon flowlines).

Figure 1. Global plastic pipe demand by sector ($b). (Market Analysis/Freedonia)

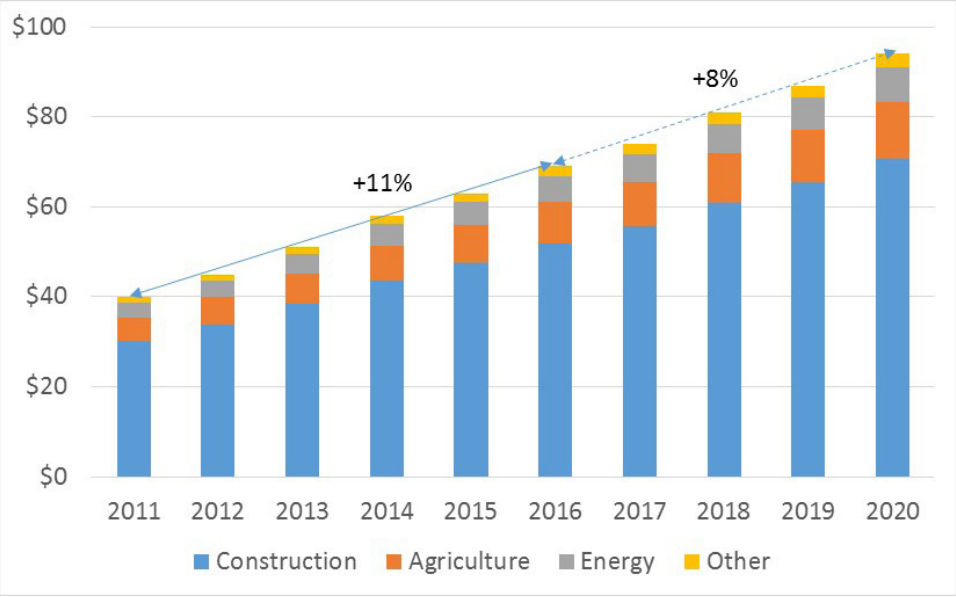

Figure 2. Installation of spoolable reinforced thermoplastic pipe. (Courtesy of Saudi Aramco)

Non-metallics are also finding greater use in oil and gas exploration, drilling, production, storage, distribution and related applications. The primary uses include pipes, tanks, vessels, connectors and other components, with the key objective of reducing cost associated with maintenance and failure.

To accelerate further adoption of non-metallics in the oil and gas sector, additional R&D is required to improve mechanical and thermal properties of non-metallic pipes, and develop reliable inspection technologies and fitness for service testing protocols.

Recently, Saudi Aramco scientists developed an innovative inspection technology, based on the response of nanostructured optical materials to material deformations. These materials are applied on the substrate to be inspected and a simple optical inspection device (tablet or iPad) is used to detect deformations, based on the modification of a diffraction pattern generated by the structured materials in response to light. This novel technology also has potential applications in the inspection of non-metallic aircraft materials or wind-turbine blades.

Figure 3. Typical applications for steel in oil and gas.

Accelerating non-metallic solutions through open innovation models

To leverage world-class expertise in non-metallics development, manufacturing and deployment, governments, companies and universities in the Arab world and globally continue to explore collaborative models to establish capabilities in integrated education, research and technology centres. Such centres – typically involving academia, research institutes, manufacturers and end- users – are designed to bridge the gap between materials discovery and design, and value-creating solutions, which can be commercially deployed while creating an environment for training and developing talent in this burgeoning field of research and innovation.

Specific objectives in the area of non-metallics include: novel, cost-effective composite systems to sustain high pressure/temperature applications; customized robotic and unmanned aerial inspection and structural monitoring technologies; reliable fitness for service and lifetime prediction tools relying on large data sets; and advanced repair and rehabilitation techniques for metallic and non-metallic pipes (Figure 3). While there are a variety of experimental inspection technologies available, most are ineffective due to limited sensitivity or elevated costs. The main reason is that most of these technologies have been adapted from metallic inspection, while the physical properties of composite materials (in particular conductivity) are very different.

The focus in this field going forward will be on multidisciplinary innovation in composite materials science, synthesis and characterization, experimental and computational mechanics, modelling, structural design, prototyping and products qualification, as well as strong know-how in non-destructive and fitness for service testing. The region has a golden opportunity to be at the forefront of this transformation and to position itself as the key supplier of raw materials and finished products for use both locally and globally.

Future of Space Technologies

How space technology will affect the Arab world

By Salem Al Marri, Assistant Director-General, Mohammed Bin Rashid Space Center, United Arab Emirates

Have you ever wondered why many of the stars have Arabic names? The region's scholars and scientists were pioneers in astronomy, mathematics and navigation. Part of this interest stemmed from understanding timekeeping and directions to perform daily Muslim prayers towards Mecca. The need for accurate maps and ways to navigate and calculate distances was even greater for the pilgrimage to Mecca that every Muslim should make at least once in their lifetime.

Scientists such as Muhammad ibn Musa Al-Khwarizmi, the inventor of Algebra, performed calculations on the positions of the celestial bodies and produced maps of Earth with latitudes and longitudes. Al-Idrisi, a geographer, produced an atlas of the world that was used for hundreds of years; his maps of the East were especially valuable.

The turning point

Looking at the region today, the Arab world is predominantly a user of space technology rather than a developer of it; we utilize it on a daily basis, perhaps without even knowing or noticing. Much of the remote sensing data that is used in the region is sourced from foreign satellites and is usually used for a specific study in one sector rather than a constant flow of data for all sectors. However, the region is waking up to the socioeconomic realities, and space technology is seen as a beacon to start transforming our economies and empower our youth who will be entering the job market.

Countries have started to establish active space programmes, with Algeria, Egypt, Saudi Arabia and the United Arab Emirates leading the way. These countries have focused on know-how and knowledge transfer through satellite development and scientific programmes to start development locally. Algeria has built its own satellite, Saudi Arabia has a vibrant space education sector and the UAE has a long-term vision to explore space. These countries are now benefiting from the use of these space assets and are supporting the academic research community, environmental agencies, municipalities, mapping entities and logistics companies with space-derived data.

The Arab world is positioning itself to have a significantly positive impact on the future of space technologies and their applications, including in the following domains:

- Security and stability
- Environmental protection
- Water, food and energy security

Security and stability

Space technology can help address the challenging security situation the Arab world. Constellations of thousands of small satellites will have the power to image anywhere in the world, stream live video feeds and pinpoint locations of potential danger to authorities, quickly, efficiently and undetected. A combination of artificial intelligence, data mining, satellite images and communications systems would support in detecting and arresting terrorists before they take action. Pirates and drug smugglers would be detected immediately through geo-fences being monitored by satellites; any unauthorized ship, vehicle or person entering a pre-assigned location would be detected and tracked until apprehended.

Oil wells and pipelines – the economic lifeline of the region – would be monitored from space; devices on the pipeline would monitor any type of data set and send messages if anything out of the ordinary arises, and live tracking of the incident from space would support the oil companies.

Environment protection

Space technology will be able to support governments and decision-makers in making better decisions to protect the environment. Oil spills could be detected sooner and ships leaking oil could be easily tracked using satellite radar data. Pipelines seeping oil into the oceans and on land would be better detected and mapped and support clean-up operations quicker. Monitoring of coastline erosion, the emergence of red tide algae and heat maps of cities would provide actionable data to support the reduction of greenhouse gas emissions in the region.

Water, food and energy security

Technologies that will be developed to support life in space will also help those of us on Earth, especially in the Arab world where a large part of it has a very harsh climate and no access to clean water. In the coming decades we may see astronauts living on Mars, and we will have to develop technologies that can support life on a much larger scale. The UAE has recently launched the first step in its Mars 2117 strategy with the development of the Mars Science City – a city that will simulate what life may look like on Mars, and work to develop technologies that will make that happen, with a focus on water, energy and food research.

The Arab world has been relatively quiet in the first 60 years of the Space Age. The next 60 years will see a significant change, as a big part of the region's future lies in the future of space exploration.

Future of Artificial Intelligence and Robotics

Robotics and AI: Enabling an Arab Spring

By Imad Elhajj, Professor, American University of Beirut, Lebanon; Member of the World Economic Forum Global Future Council on Artificial Intelligence and Robotics

The term "Arab Spring" was possibly coined one season too early, during what had proven to be the Arab Winter. However, since December 2010 things have changed and the buds of the true Arab Spring are starting to show, buds which hopefully soon will transform into mature blooms. The true revolution we will witness in the Arab world is that of the Fourth Industrial Revolution. Are we there yet? No, but clear signs are showing across the region. You do not have to look further than the World Economic Forum list of 100 Arab start-ups shaping the Fourth Industrial Revolution.

What is the significance of this progress for the Arab world?
Until recently, the Arab region had been mainly a consumer of technologies. Although numerous Arab entrepreneurs had helped shape those technologies, they had to do so from outside the region. Currently, the convergence of several technologies – connectivity, access to information, softwarization, cloud and development in computing – has levelled the technology development field.

This progress is bringing opportunities closer to the Arab world and the global South in general. We can now witness products by the region for the region. There are numerous examples of this from the Arab region, such as Et3arraf, the Middle East-focused dating site, and Souq.com, acquired by Amazon for hundreds of millions of dollars. This development goes beyond the software realm into hardware products in competitive areas such as sports (Instabeat) and music (Roadie Tuner).

With the anticipated impact and change that robotics and artificial intelligence (AI) will bring, why not have the next ABB or KUKA come from the Arab region. Existing examples from the region include ADASI, which specializes in autonomous robotics; NAR, which is developing AI for autonomous pipeline inspection; Arabot, which is developing AI Arabic bots to improve customer experiences; and Votek Inc., which is leading automatic Arabic speech recognition. Several of these examples have been featured by wamda, a platform that aims to support the entrepreneurship environment in the MENA region.

This potential cannot be realized without nurturing the next generation of robotists and AI scientists. One prominent example is what the Arab Robotics Association is accomplishing through its activities and competitions. One such competition is the Open Arab Robotics competition, where the winner of this regional competition in 2014, Fast and Curious, went on to win the world championship against hundreds of teams from around the world.

Why should we care?
According to the Institute for Economics and Peace, instead of spending $14.3 trillion on conflict as we did in 2016, we should invest every $1 in peacebuilding because that can lead to a $16 decline in cost of armed conflict. Such financial estimates are difficult to accurately confirm, but one thing is for sure is that the revolution that robotics and AI can bring about in the Arab region will be a welcomed change for a region suffering too long from insecurity, financial instabilities and unemployment.

What should we spend the money on?
First, it should be spent on education, and I am not saying this because I come from academia. Most of the region troubles could potentially be traced back to the lack of education. Second is infrastructure, primarily communication networks, to enable connectivity to the world. Third is building an ecosystem to provide access to mentors, manufacturers and business developers. Fourth is funding, but this seems to be in abundance at this point according to research by Magnitt, indicating that investments in start-ups in the MENA region is close to $1 billion annually.

Why should we be excited?
Arguably, the biggest change enabling this Arab Spring has been intrinsic and that of a mindset. Fear of failure, which traditionally brings with it shame, has been diminishing. The new generation of engineers, scientists, business women and men, and entrepreneurs is not afraid to try and fail. They are no longer looking at only two options for their careers: to immigrate or secure a government job. Now there is a third more rewarding option. This will have a profound long-term impact on the region's development and stability. This is a spring that we can look forward to.

Future of Neurotechnologies and Brain Science

Impact of neurotechnologies and brain science on the future of the Arab world

By Frank Tarazi, Professor, Harvard Medical School, USA

Extraordinary advances in neurotechnologies and brain science have been at the crux of the Fourth Industrial Revolution. These technologies are providing novel and valuable insights into the most important organ of the human body, the brain, both at the system and the molecular levels. They are also excelling our understanding of two major debilitating brain diseases, depression and dementia, which exert heavy socioeconomic burdens on patients, families and society at large, as well as supporting the development of new and improved therapies for these diseases and other neuropsychiatric disorders.

In addition, neurotechnologies are becoming important tools to spot serious diseases in the asymptomatic phase. Advances in brain imaging techniques and identification of neuronal biomarkers have helped to identify individuals at a higher risk of developing neurodegenerative diseases such as Alzheimer's or Parkinson's disease, paving the way to developing new therapies that could prevent, or at least significantly delay the manifestations of clinical symptoms. Neuromodulator devices, which act as brain pacemakers, are available to continuously monitor the electrical activity in the brain for early signs of seizures, and can send electrical pulses to prevent epileptic seizures at their onset. Brain-computer interfaces allow paralysed patients to operate robots or move limbs with direct connections between the brain and machine. Several mobile apps are available to detect early signs of depression, anxiety and post-traumatic stress disorder (PTSD) as well as autism and attention-deficit hyperactivity disorder (ADHD) in children. Other apps are available to help patients cope with the mental and physical symptoms of their diseases and facilitate communications with their physicians or therapists.

Brain science in the Arab world

The MENA countries have not kept pace with the recent advances in brain sciences compared to other countries. For example, the US has launched the Brain Research through Advancing Innovative Neurotechnologies® (BRAIN) Initiative. Europe has launched the Human Brain Project. China has launched the China Brain Project. And Japan has launched the Brain/MINDS (Brain Mapping by Innovative Neurotechnologies for Disease Studies) initiative. All of these long-term projects and initiatives aim to foster collaborations between researchers in medicine, neuroscience, information technology and computer science to enhance our understanding of the human brain.

These projects will accumulate and store massive data on the dynamic interactions and complex circuitries of the brain at different levels. Such data can be retrieved instantly and shared by scientists and physicians to accelerate basic and clinical research, drug discovery as well as support the development of new neurotechnologies and ground-breaking tools to improve treatment and even prevent brain diseases.

The Arab world with its cultural diversity, rich resources and exceptional human talents should follow in the footsteps of the industrial countries and launch the Arab World Brain Project (AWBP), which will encompass all MENA countries, and perhaps operate in a centralized fashion under the auspices of the Arab League. Such a project, with its multi-facet domains and specialties, should promote collaborations between brain investigators across MENA countries, and should further help to decipher the mysteries of brain diseases that are rapidly growing in this part of the world, including Alzheimer's disease. More importantly, AWBP should propel the Arab world to the frontlines of brain sciences, and help the MENA countries reap the benefits of this rapidly evolving biomedical discipline.

Risks and opportunities

There is growing interest in discussing the ethical implications and legal ramifications of neurotechnologies and brain science. The pace of developing neurotechnologies and AI-linked machines has profoundly surpassed the pace of approving new laws and legislations regulating these technologies. Accordingly, the courts and the legislative institutes in the Arab world should adapt to the advanced neurotechnologies, in many instances socially disruptive ones, and create laws that can preserve human rights, and protect intellectual property and integrity.

The collection of enormous data from human brain projects as well as from patients could jeopardize clinical research and invade patients' privacy if the data were hacked, exploited or misused. Investments in enhanced cybersecurity to strengthen the security and resilience of cyberspace should minimize, if not negate, the potential negative aspects of AI-driven neurotechnologies. Needless to say, the benefits of neurotechnologies in health and in sickness will be greatly maximized if they are available to all individuals irrespective of their socioeconomic status. Development of public-private partnerships in different MENA countries to subsidize the costs of these neurotechnologies should increase access of individuals to many AI-driven devices and machines and their improved benefits.

In conclusion, advances in AI-driven technologies and brain science will positively impact the future of the Arab world. In addition to improving treatment of patients with psychiatric and neurological diseases, neurotechnology will actively shape how basic and clinical research is conducted and how medicine is practiced. Adopting new laws to fully protect humans' cognitive liberty and mental privacy should minimize the legal risks of these technologies, and increasing the accessibility of neurotechnologies to larger sectors of societies should enhance the quality of life for citizens of the Arab world.

Future of Civic Technology and Human Rights

Securing the future of civic tech in the Arab world

By Esra'a Al Shafei, Founder and Executive Director, Majal.org, Bahrain

The future of human rights advocacy lies in the fourth industrial wave of civic tech. It is encouraging to see developments in how people are creating and applying new technologies in the pursuit of social justice around the world, but it is vital that we understand how best to promote and embrace these evolutions within the true social, political and economic conditions of the Arab world.

The Arab world has one of the fastest growing rates of internet users, with some Gulf countries counting 90% of their populations online. Many of these users are youth seeking novel outlets to explore the wider world, fulfilling a curiosity not always satiated by the existing educational institutions. But despite the rapid rise of connectivity in the Arab world and the creativity of its youth, we see a very low rate of civic tech development in comparison to regions like Latin America and South-East Asia. Censorship, monopoly and control of digital activities have scared citizens away from engagement and innovation. Furthermore, existing tools do not cater specifically to us and do not encourage us to engage in the crucial, constructive dialogues necessary to begin to use technology to our advantage and to effect meaningful social change. They are not optimized for Arabic use, are not suited to our contexts, nor optimized for use on mobile, which is how most regional users are accessing the internet.

By supporting the innovations of our newly connected youth, we can encourage them to develop effective solutions to various social problems – anything from economic and gender inequality to the refugee crisis – by employing new technologies to take advantage of an explosive growth of regional internet users. If afforded the opportunity, they will take civic tech to the next level, enabling advocacy to ascend to new heights by reimagining how we document, report and act upon human rights violations. Support through financial resources, mentorship and legal flexibility will result in home-grown solutions that are tailored to our needs, and we will no longer need to rely on outsourced products that do not take into account our social and cultural environments.

To do this effectively, we must get rid of the roadblocks and bureaucracy that prevent innovation in the region and stop programmes of widespread censorship. Promising young developers and programmers face too many difficulties in establishing start-ups: the costs are prohibitively high and legal red tape makes the prospect unattractive for innovators to pursue their ideas. Most technologies that are born in the region are not civically oriented due to lack of available resources and support. We must help to foster a healthy ecosystem for the fourth industrial wave of civic tech by investing in the creation of spaces for the productive engagement and inclusivity of youth in our regional economic and moral growth.

This growth cannot and will not happen if censorship is consistent, surveillance is the norm, and if innovation is met with obstacles rather than encouragement and support. If current conditions persist the way they have in the digital age, we risk governments hijacking the Fourth Industrial Revolution in order to stifle dissent, further control their populations and carry out their own self-serving agendas.

We must not shy away from difficult conversations surrounding our societies. As we discuss evolutions in robotics, artificial intelligence and other new technologies eagerly adopted into state megaprojects that project power and grandiosity, we are still struggling with the basics of freedom of speech and digital privacy. The vast majority of the Arab world does not currently have any laws or regulations in place to protect net neutrality. There is a deep, troubling lack of transparency regarding how the internet is governed locally, and how closely aligned telecom companies are with government entities. None of this creates a healthy environment for digital growth and innovation.

We must provide a safe, nurturing space for Arab innovation in the region or risk losing our brightest minds – and with them the advancement of much-needed civic tech – to greener pastures elsewhere in the world. Arab countries need to be hospitable to their home-grown ideas and the best hopes for the future of its young people.

Recommendations

- Invite innovation by removing bureaucratic and monopolistic barriers
- End widespread censorship and surveillance that stifle creativity
- Recognize that creativity is vital in driving economic growth by way of unique and alternative models
- Invite diversity by making it affordable and accessible for young people to acquire necessary skills and opportunities regardless of their social class or political stance
- Ensure that venture capital funds, including ones managed by Arab governments, prioritize local, home-grown initiatives rather than invest primarily abroad as is currently the case
- Maintain and defend a free and open internet

Future of Cybersecurity

Ensuring cybersecurity in a digital Arab world

By Alan D. Cohn, Adjunct Professor, Georgetown University Law Center, USA

Cybersecurity is intrinsically linked with the digitization of our world. We all know the list of negatives associated with cybersecurity today: distributed denial of service (DDOS) attacks, data breaches, intellectual property theft, ransomware, and the list goes on. But what does the future hold for cybersecurity in a digital Arab world?

The drivers of future concerns over cybersecurity are becoming clear. Artificial intelligence (AI) will play an increasingly large role on both sides, enabling increasingly sophisticated cyberattacks, but also underpinning more capable defenses. Quantum computing, if it comes to fruition, has the potential to disrupt the use of encryption, a critical piece of data security and protection against threats. Critical infrastructure, whether owned by the public or private sector, may increasingly find itself on the front lines of cyber conflict; no longer seen as civilian infrastructure, but rather as a legitimate target in conflicts between states, or within states. The vast potential of the internet to enable innovation and the formation of new communities of knowledge competes with the range of potentially malicious forces that access to vast amounts of information and computing power can enable.

Within this context, as governments, industry and civil society consider how to move into a new digital world, decision-makers would be wise to consider the following issues, among others, concerning the future of cybersecurity:

AI creates non-artificial challenges and opportunities: Today's machine learning technology has helped to automate an increasing number of tasks, allowing for increased productivity and an ability to process vast amounts of information. That same ability to harness and make use of big data can also lead to information overload, and an inability of human actors to keep pace with threats and challenges. When machines become able to perform basic reasoning for themselves, however, these challenges only become greater.

How can cyber defenders respond? Interestingly, by embracing the same technology themselves. AI-enabled cybersecurity will allow machines to identify and mitigate cyber threats at machine speed, without the need for human involvement. AI-enabled big data analytics tools may also allow cyber defenders to be able to cut through the noise of information overload and focus on those issues on which human judgment will most be needed. The biggest challenge may not be technical but human. How can decision-makers achieve trust in machine processes moving at machine speed?

Quantum computing may change the game: Quantum computing is still largely a buzzword, thought of in many instances as an across-the-board upgrade in computing power. However, if it lives up to its potential, quantum computing will allow machines to conduct focused tasks at levels of power far in excess of current computing capability. For cyber defenders, one of the most troubling applications that quantum computing could be put to is breaking computationally based encryption, including some of the most commonly used encryption protocols in use today.

Cyber defenders need to be ready for a world in which existing methods of computationally based encryption no longer guarantees protection of data. Luckily, there are other types of encryption currency being designed and tested that are not subject to the same decryption risks from quantum computing, and there are other approaches to data and system protection besides encryption. Cyber defenders need to understand the risks to today's encryption protocols and the potential alternatives.

Distribution and decentralization can help: Many of today's cyber threats work because of the way we currently structure networks. Centrally controlled systems with large stores of information that are vulnerable to theft and subject to disruption compound the challenge of cyber defense. Different technologies and technology protocols, including those that allow individuals to retain control of personally identifiable information, that let devices more securely authenticate onto networks, and that distribute and synchronize ledgers across several (if not hundreds, or thousands) of computers, may be better platforms for constructing more secure and resilient information and data networks.

Blockchain technology, the technology that underpins cryptocurrencies like bitcoin, holds the potential to serve as this new type of distributed, decentralized platform. Cyber defenders should understand this critical technology and others like it, and how features like identity verification and validation, device authentication, secure ledger keeping, and other critical functions can be performed on technology platforms better suited to resisting cyber threats.

Ultimately, effective cyber defense will rely on people, processes and technologies adapted to and well suited for tomorrow's cybersecurity environment, not just today's. With attention to workforce development and exposure to emerging technologies, embrace of different concepts of operations and processes for cyber defense, and examination of technologies that allow information systems to function in a more secure and resilient way, decision-makers can help ensure the cybersecurity of a digital Arab world.

Future of Behavioral Economics

How behavioural insights are changing the stakeholder landscape in the Arab world

By Fadi Makki, Head, Qatar Behavioural Insights Unit, Qatar Supreme Committee for Delivery and Legacy, and Founder, Nudge, Lebanon

Nudging, and the application of behavioural insights to public policy challenges, is a recent innovation. Its rise to prominence has been driven by a growing recognition of behavioural economics as a mainstream field of study, thanks in large part to research and writings of pioneers like Danny Kahneman, Richard Thaler and Cass Sunstein, of which the first two have been awarded the Nobel Prize in Economics in 2002 and 2017, respectively. This rise in prominence was also due to the spread of nudge units and behavioural insights initiatives around the world, which started in governments with the set-up of the UK's Behavioural Insights Team in 2010 and continues in academia, NGOs and the social purpose companies.

The Middle East has by and large been on the margins of this new development, but things are starting to change:

1. Nudge units are either being established or underway in many parts of the Arab world and at various levels in government. While Qatar has led this trend through the set up its nudge unit at the Supreme Committee for Delivery and Legacy, Kuwait is setting it up at the General Secretariat of the Supreme Council for Planning and Development. Meanwhile, Saudi Arabia is setting up its nudge unit at the Center for Strategic Development in the Ministry of Planning and Economy. Other countries in the Gulf and the region are also planning similar initiatives at various levels.

2. In some cases, nudge units are being set up as non-governmental organizations working alongside governments on policy initiatives and interventions, for example, Nudge Lebanon and its academic arm, the Consumer-Citizen Lab.

3. Beyond dedicated institutional set-ups, behavioral experiments have been conducted in many public policy areas where stakeholders have realized that many of the challenges they are trying to tackle have strong behavioral roots that cannot be addressed effectively using the classical tools of "command and control" or heavy financial incentive. Often these experiments are conducted as "proof of concept" before setting up a dedicated behavioral insights unit.

The impact of greater use of behavioural insights in the Middle East is likely to be significant as it will help governments in the region tackle some of their policy challenges with behavioural roots. In a recent experiment in Lebanon, nudging households to pay their electricity bills on time using social norms and ego increased collection rate by 13% and 15%, respectively, compared to the control group.

There are numerous lessons that could be learned from applying behavioural tools to public policy challenges while still keeping in mind that "context matters". What worked in other countries – for example, on the use of social to produce higher levels of energy savings – might not necessarily work in the regional context, and hence the need to "test, learn and adapt" to be sure of what works.

At the same time, there are governance-related lessons that could be drawn from other settings that could make the use of behavioural sciences in public policy more positive, orderly and inclusive. Key among these are two: building strong partnerships between governments, academia, NGOs and the private sector; and adopting rigorous ethical standards that promote trust in behavioural initiatives and minimize room for manipulation.

The use of behavioural insights as a tool to address policy challenges is putting pressure on the way stakeholders in the policy domain are and will be operating in the future.

First, the integration of behavioural insights in government operations is not only transforming the way their services are offered, but also fostering a new culture of policy experimentation among government officials to test what works in order to make evidence-based decisions. Sometimes, using simple rules of thumbs to design behavioural experiments – e.g. to make them "easy, attractive, social and timely (EAST)" as the BIT calls it – can be a key success factor for their adoption and scale-up.

Second, the disintegration across many governments, particularly in countries that have experience the so-called Arab Spring, is creating a vacuum in the design and execution of policies and services. This vacuum is being filled by NGOs who are starting to apply behavioural interventions in priority areas such as education, health, humanitarian relief, etc.

Third, for decades, the private sector has been using behavioural insights in the world of advertising, marketing and consumer behaviour. Many private organizations are increasingly aware of the bounded rationality of humans. Indeed, use of behavioural insights is behind the emergence of new job clusters. For instance, the role of chief behavioural officer did not exist in organizations up until recently, but many companies are nowadays hiring for CBOs positions, including Google, Facebook, HSBC and Unilever.

Last, academic institutions in the region are starting to establish closer partnerships with governments via collaborations on field experiments designed to test solutions for the policy challenges that these governments face. One innovation in this regard relates to special courses being offered in universities on behavioural economics and public policy experimentation, a trend that is well-underway in many of the renowned universities in the US and Europe.

Clearly, more reliance on behavioural science has a lot of potential in the region. It is particularly interesting to see how today's jobs will undergo changes in descriptions, functions and requirements as a result of the disruption created by behavioural sciences. Indeed, many jobs in banking and the legal profession are exposed to future automation, which could threaten their very existence. In the Arab world, these changes mark a disruptive innovation that is being taken up by governments, NGOs, academia and the private sector to greater or lesser extents, and in various settings and forms. How to ensure adoption is always for the greater good should now be the focus of concerted effort within the region.

Future of Biotechnology

Preventative medicine in the Middle East must be a collaborative effort

By Habiba Al Safar, Director of Biotechnology Center, Khalifa University of Science, Technology & Research (KUSTAR), and Associate Professor, Department of Biomedical Engineering, United Arab Emirates

The rising tide of precision medicine

Excitement is abuzz, but tempered, around a new paradigm referred to as precision medicine. The US National Institute of Health (NIH) defines this as "an emerging approach for disease treatment and prevention that takes into account individual variability in genes, environment and lifestyle of each person".

An alternate term, personalized medicine, is often used interchangeably. According to the US Food and Drug Administration (FDA), the term personalized medicine is the process of customizing medical treatment to the individual characteristics, needs and preferences of a patient during all stages of care, including prevention, diagnosis, treatment and follow-up. The terms are often used to describe as providing "the right patient with the right drug at the right dose at the right time".

The first human genome project was completed by a collaborative international effort. Still regarded as the most costly experiment in biology, it took 13 years to complete. Since the first human genome sequence was reported, significant advances in sequencing technologies have evolved. Traditional sanger sequencing platforms have been replaced by a range of next generation sequencing (NGS) technologies, which has been consistently breaking down the cost of whole genome sequencing to now less than $1,000 and time to completion of weeks. Arguably, the bottleneck in genome research now, is our ability to analyse and make sense of the data.

Reference DNA sequences have been compiled by a number of populations and has ushered in a new wave of services providing direct-to-consumer DNA-based services, which to date has predominantly used for ancestry analyses. Not commonly known to the consumer, is that the growing amount of information in databases of these services is providing opportunities to mine data that predisposes humans to disease.

During the fossil fuel era, a number of countries in the Gulf Cooperative Council (GCC) have thrived and have built competencies and proficiencies around the financial sector, telecommunication and aviation. These countries have in recent years moved to the technology sector, in anticipation that oil reserves are finite and as the world shifts to renewable energy sources. As these nations seek to diversify their economics and its base of revenues, health projects are taking hold.

The genome era has slowly, but is most certainly, gaining momentum, and has included a number of projects in the Middle East, with national genome efforts commenced in Saudi Arabia, Qatar and Kuwait. Although a predictive test for complex multifactorial diseases such as diabetes and cardiovascular disease will require more work, there are examples where genetic screening is used as a pre-emptive measure to provide alternatives to patients predisposed to particular disease. Specifically, genetic testing is available for many single-gene disorders such as Huntington disease, cystic fibrosis, sickle cell anemia and others.

There is little doubt that DNA testing will continue to contribute to preventative strategies in the health sector. However, for this strategy to take hold in the Middle East, collaborative efforts to improve the lack of genome data available on Arabian populations are essential. In 2017, Popejoy and Fullerton reported on the status of genome data available in the public domain, after completing an extensive audit of databases and discussed how the Arab genome is sadly underrepresented. At 0.08%, it is only better than native populations. This has to change in order for individuals of Arabian ancestry to benefit from this new and improved standard in healthcare.

Quantifying the impact of medical intervention

Despite the practice of precision medicine being in its infancy in the Middle East, there are a number of international examples of the economic and personal benefit, when genetic screening is used to identify disease early in life, allowing for proactive intervention.

Example 1: Genetic testing in neonatal diabetes has been shown to improve the quality of life and produce cost savings.

Neonatal diabetes is a form of the disease diagnosed before 6 months of age. Nearly half the patients have pathogenic variants in 2 genes, KCNJ11 and ABCC8. A cost-utility analysis was conducted to compare routine genetic testing to no testing of children with the disease. Testing was projected to bring about quality-of-life benefits that enlarged over time (0.32 QALYs at 10 years, 0.70 at 30 years) and produced savings in total costs that were present as early as 10 years ($12,528 at 10 years, $30,437 at 30 years).

Example: Screening for risk factors associated with cardiovascular disease.

A systematic review of seven economic evaluations between 2002 and 2015 consistently showed that cascade screening based on genetic testing of relatives of an index case with confirmed clinical or genetic diagnosis of Familial Hypercholesterolemia (FH) is cost effective. FH is a genetic disorder that leads to elevated plasma LDL-cholesterol levels and premature coronary heart disease.

Example 3: Pharmacogenomic screening to allow precise delivery of pharmaceutical treatments.

Pharmacogenomics (PGx) has the potential to personalize pharmaceutical treatments. In a review of the 137 PGx associations in the table held by the US FDA, Verbelen et al (2017) identified 44 economic evaluations, relating to 10 drugs. Fifty-seven percent favored of PGx testing, of which 30% were cost-effective and 27% were cost-saving. If genetic information was freely available, 75% of economic evaluations would support PGx-guided treatment, of which 25% would be cost-effective and 50% would be cost-saving. The reviewers of this study concluded that having genetic information readily available in the clinical health record is useful.

Conclusion

Although quality adjusted life years (QALY) and incremental cost-effectiveness ratio (ICER) data for major disorders (diabetes, cardiovascular disease, cancer) in Middle Eastern countries are not freely available, the international experience, particularly from Europe and North America, can be used as a guide. These studies show significant cost savings (thousands to hundreds of thousands of dollars and GDP), if strategic nationwide genetic screening programmes are implemented. Any proposed genetic programme established in the region should include an interim period to evaluate the cost-effectiveness of such programme. Most importantly, due to the relatively small populations of Arabian nations, combined with the ethnic diversity across the Middle East, collaborative strategies must be a priority.

Future of Computing

How is the future of computing likely to impact the Arab world?

By Ghida Ibrahim, Data Scientist, Facebook, United Kingdom

Computing – the use of computers to process data and perform operations – has been at the core of the Third Industrial Revolution, also called the Digital Revolution, which is believed to have started with the invention of transistors in 1947. Since then, computers have come a long way from the multi-unit machines occupying entire rooms and taking days to perform basic operations like summation or lookup, to the micro-computers in our smartphone or smartwatch performing highly complex operations in order of milliseconds or less. The advances in computing power have been significant.

According to Moore's law – named after Intel co-founder Gordon Moore – the number of transistors per square inch has doubled approximately every 18 months to 2 years since the mid-1960s. As Moore's law faces physical limitations, the focus is shifting from reducing transistors size towards using more efficient and specialized hardware systems. On the other hand, a new form of computing, quantum computing, is progressively gaining more ground, although its practical implementation remains a challenge.

Quantum computers rethink computing by leveraging the strange laws of quantum mechanics. Instead of using transistors designed around binary units that classical computers use, quantum computers employ "quantum bits" or "qubits". Unlike bits, which are limited to being either 1 or 0 at all times, qubits can exist in "superposition", with a probability of being in either state until measured; this enables them to simulate multiple states at the same time. Another property of matter at quantum level, "entanglement", means that multiple qubits can be connected through logic gates. The "superposition" and "entanglement" properties of quantum computing makes it possible to carry many operation streams in parallel both at the level of one "qbit" and many "qbits", thus making a quantum computer more suited to tackle complex computational problems, when compared to a classical computer.

How the Arab world will be impacted

As the world moves in a fast pace towards the Fourth Industrial Revolution, the evolution of computing becomes even more problematic. The Fourth Industrial Revolution is characterized by the explosion of highly diversified data coming from humans, objects and all kinds of digital records, and the rise of machines which will use this data to augment their intelligence in order to perform operations as complex as predicting and diagnosing a rare disease, or driving a car without human intervention.

Machine learning and artificial intelligence rely on computing in the same way computers rely on mathematical concepts and algorithms. In particular, machine learning consists of running iterative algorithms on large chunks of data, operations which cannot be performed with speed and scale without the availability of adequate computing resources.

The Fourth Industrial Revolution is expected to impact every industry: healthcare, transportation, agriculture, education, retail, multimedia, finance, etc. The Arab world is no exception, particularly with the emergence of a strong tech start-up scene in countries like the UAE, Egypt and Tunisia, and the futuristic drive of many local governments; the Dubai government in the UAE being a shining example in this context.

Below is a list of the main impact areas:

- *Healthcare:* Precision medicine refers to the use of a mix of data, including genesis data, lifestyle data from social media and contextual data such as geographic data to predict individuals' odds of getting different types of diseases. Given the volume and variety of involved data, precision medicine is computationally complex to achieve. In an Arab world where free medical coverage is still a privilege granted only for few, precision medicine is likely to set the way for preventing many diseases from happening by simply predicting these, thus reducing associated medical costs and increasing life quality for many.
- *Retail:* With internet penetration exceeding 90% in many Arab countries, the online retail industry is definitely booming in the Arab world. Success stories in this context include UAE-based start-up souq.com, considered one of the MENA region's tech unicorns and recently acquired by Amazon. Machine learning is shaping online retail as it allows enhancing consumers' retail experience based on their online behaviour, through targeted advertising and items recommendation, among other techniques.
- *Transportation:* With Dubai authorities recently showcasing the concept of an autonomous flying taxi, the future of transportation is already happening in the Arab world. Like self-driving cars, self-flying taxis use image recognition and other optimization techniques in order to safely get a vehicle from one place to another while taking into account elements like real-time traffic state. On-demand car booking and car sharing are also booming in the Arab world with start-ups like Careem becoming real tech unicorns in the region. Careem relies on data intelligence to optimize the way it dispatches clients to captains (cars) and to optimize the pricing of its rides.

- *Finance:* Blockchain presents a main disruptor for the financial system as we know it. By building direct trust among businesses and individuals, blockchain is threatening the role of banks as intermediaries. With many Arab citizens struggling to access basic financial services, particularly in rural areas and in refugee camps, blockchain holds the promise of opening the access to transactions such as storing, transferring or borrowing money to the most vulnerable Arab populations. Blockchain consists of building a distributed immutable ledger that documents all the transactions done by different parties and serve therefore as a single source of truth.
- Cryptography is a main enabler in this context, as a key should be coupled to each transaction or record. As quantum computing is likely to render useless many of the cryptography techniques used today, there is a need to find alternative algorithms, so that the trust in blockchain as a concept remains. One of blockchain's main applications revolves around the creation/mining and trading of cryptocurrencies, also called digital currencies of the future, such as bitcoins. With bitcoin, miners use computing to solve complex math problems and are issued a certain number of bitcoins in exchange. As there is a limit for the total number of bitcoins present in the market and as we are approaching this limit, more computing power is needed to generate a bitcoin. Arab start-ups like bitOasis are positioning the Arab world on the map when it comes to bitcoins creation and exchange. The evolution of computing is likely to drive the creation of similar start-ups and to make bitcoin one new currency in Arab financial markets.
- *Education:* As education moves from classrooms to digital spaces, many Arab start-ups already entered the education tech space. Nafham and Little Thinking Minds are successful examples in this context. After digitization, education is tending towards customization where every student will be offered a learning experience that is tailored to his/her learning capabilities and interests. Metrics such as courses viewing time and viewing frequency, time to answer questions and grades can be used to assess the students' strengths and weaknesses, and to recommend them customized learning paths. Detecting these patterns requires sophisticated machine learning models and adequate computing resources underneath.

Future of Transport

The digital underpinning of the transportation revolution

By Marvin Ammori, General Counsel, Hyperloop One, USA

I work at Virgin Hyperloop One, known for its mechanical and electrical engineers designing an autonomous and high-frequency system of passenger and freight pods moving at up to 1080 km/h through low-pressure tubes. Designing that reliably and safely is a mechanical and hardware challenge. It is also, surprisingly to some, a software challenge. You could not have built a hyperloop 10 years ago because you would not have yet had the embedded software systems, sensors and processing of today.

Digital transformation is going to hit the transportation industry over the next 10 to 20 years. Ours is just one of many companies changing transportation through automation, computation fluid dynamics, software-defined design, 3D printing and high-speed data analytics. As much progress as the industry has made, there is still a lot of catching up to do. Transport, travel and logistics industry is only 27% digitized, according to McKinsey & Co., compared to 39% for the media and entertainment business and 44% for telecom.

One of the exciting things about today's transportation revolution is the opportunity to establish new industrial supply chains and services networks around the world. A regional hyperloop network could unlock billions of dollars in incremental economic growth, establish real exportable expertise, completely transform supply chains across the Middle East and create thousands of jobs in manufacturing, services, finance, operations and education. But it will take require real commitment from both the public and private sectors.

Just as many do not realize that the transportation revolution rests on digital innovation, many do not realize that governments can, and should, play a critical role in spurring this revolution. Many in the business community are wrong to dismiss the innovative power of governments or of innovative, long-term visionary governments working alongside disruptive companies. In my role, I have met with forward-thinking governments around the world, and none are more innovative as those in the Middle East.

Take Dubai as an example. As leaders in the Fourth Industrial Revolution, Dubai and the UAE are also leading digital change across many fronts and several business sectors. MasterCard's 2017 Digital Evolution Index placed Dubai among the world's "standout digital economies" along with Singapore, the UK, New Zealand, Estonia, Hong Kong and Japan. Dubai has abundant examples in advanced mobility and logistics, which have been identified as strategic sectors.

Dubai is targeting 5 million autonomous vehicle journeys by 2030 and is updating its taxi fleet with 50 Teslas. The Dubai Metro is already the largest autonomous train route in the world. DP World, the Dubai-based ports operator (and a large investor in our company), runs some of the most innovative and automated container terminals in the world. In September, Dubai launched the maiden flight of a two-seater drone "air taxi" that will ultimately offer 30-minute flights. Dubai also plans to be the first block chain powered government in the world by 2020, using distributed digital ledger technology to streamline services for business and citizens.

Dubai International Airport is banking on biometrics to speed up its security screening. Next year it will deploy "virtual aquariums" lined with giant LED screens and facial recognition cameras. Air travellers will be asked to walk through the tunnel-shaped portal, and as they gaze all around at the screens, they will deliver a high-quality facial and iris print as they pass. The airport is also experimenting with autonomous rolling carry-on caddies shaped like the BB-8 droid in the recent Star Wars movie.

That kind of innovative thinking – wherever it is in the world – will attract private innovation and the leading thinkers in the world. Virgin Hyperloop One has been in an active partnership with many different entities within Dubai, all of which have the same vision and innovative spirit. We have worked with the Roads and Transport Authority, which sponsored our company in an accelerator organized by the ministry focused on the future. DP World is an active investor and partner. A hyperloop in Dubai could be the first leg of a GCC-wide 1080-kph Hyperloop One network for both people and freight.

One often hears that the future is already here – it is just not equally distributed. The same will be true of the transportation changes in the Fourth Industrial Revolution. The future will come earlier to some places, where governments foster an environment for human capital to thrive and experiment. And then the future will radiate out from those places and connect the rest of the world.

Acknowledgments

This white paper was written with the contribution of the following experts, for whom we are grateful:

Marvin Ammori, General Counsel, Hyperloop One, USA
Bader Busbait, Consulting Services Department, Saudi Aramco, Saudi Arabia
Alan D. Cohn, Adjunct Professor, Georgetown University Law Center, USA
Bashir Dabbousi, Manager, Technology Strategy and Planning Department, Saudi Aramco, Saudi Arabia
Imad Elhajj, Professor, American University of Beirut, Lebanon
Habib Haddad, President and Managing Director, E14 Fund, USA
Ghida Ibrahim, Data Scientist, Facebook, United Kingdom
Khaled Kteily, Community Lead, Regional Strategies – Middle East and North Africa, World Economic Forum
Fadi Makki, Head, Qatar Behavioural Insights Unit, Qatar Supreme Committee for Delivery and Legacy; Founder, Nudge Lebanon
Salem Al Marri, Assistant Director-General, Mohammed Bin Rashid Space Center, United Arab Emirates
Tomas Mebrahtu, Technology Strategy and Planning, Saudi Aramco, Saudi Arabia
Nayef Al-Rodhan, Honorary Fellow, St Antony's College, University of Oxford, United Kingdom
Habiba Al Safar, Director of Biotechnology Center, Khalifa University of Science, Technology & Research (KUSTAR), and Associate Professor, Department of Biomedical Engineering, United Arab Emirates
Esra'a Al Shafei, Founder and Executive Director, Majal.org, Bahrain
Ihsan Taie, Research and Development Centre, Saudi Aramco, Saudi Arabia
Frank Tarazi, Professor, Harvard Medical School, USA
Wendell Wallach, Scholar, Interdisciplinary Center for Bioethics, Yale University, USA

Endnotes

1. Arab Business Intelligence, https://intelligence.arabnet.me.
2. Kteily, Khaled and Mirek Dusek, “These start-up are changing the Arab world”, Forum Blog, 20 May 2017, https://www.weforum.org/agenda/2017/05/startups-changing-arab-world.
3. Institute for Economics & Peace. Global Peace Index. 2017. http://visionofhumanity.org/app/uploads/2017/06/GPI17-Report.pdf.
4. Al-Olama, Mohamed and Frank Tarazi. “Middle Eastern cultures treasure the elderly, making Alzheimer’s a complex scourge”, Forum Blog, 12 October 2017, https://www.weforum.org/agenda/2017/10/alzheimers-MENA.
5. “Improving Timely Payment of Electricity Bills”, Nudge Lebanon, https://nudgelebanon.org/experiments/improving-timely-payment-of-electricity-bills.
6. Behavioural Insights Team, EAST: Four simple ways to apply behavioural insights, 2017, www.behaviouralinsights.co.uk/wp-content/uploads/2015/07/BIT-Publication-EAST_FA_WEB.pdf.
7. Benedikt Frey, Carl and Michael A. Osboure, “The Future of Employment: How Susceptible Are Jobs to
8. Computerisation?” Oxford Martin School, September 2013, http://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf.
9. Popejoy, A.B. and S.M. Fullerton, “Genomics is failing on diversity”, Nature, 2016, 538(7624): p. 161-164.
10. Greeley, S.A., et al., “The cost-effectiveness of personalized genetic medicine: the case of genetic testing in neonatal diabetes”, Diabetes Care, 2011, 34(3): p. 622-7.
11. Rosso, A., et al., “The Cost-effectiveness of Genetic Screening for Familial Hypercholesterolemia: a Systematic Review”, Ann Ig, 2017, 29(5): p. 464-480.
12. Verbelen, M., M.E. Weale, and C.M. Lewis, “Cost-effectiveness of pharmacogenetic-guided treatment: are we there yet?” Pharmacogenomics Journal, 2017, 17(5): p. 395-402.

WORLD ECONOMIC FORUM

COMMITTED TO IMPROVING THE STATE OF THE WORLD

The World Economic Forum, committed to improving the state of the world, is the International Organization for Public-Private Cooperation.

The Forum engages the foremost political, business and other leaders of society to shape global, regional and industry agendas.

World Economic Forum
91–93 route de la Capite
CH-1223 Cologny/Geneva
Switzerland

Tel.: +41 (0) 22 869 1212
Fax: +41 (0) 22 786 2744

contact@weforum.org
www.weforum.org