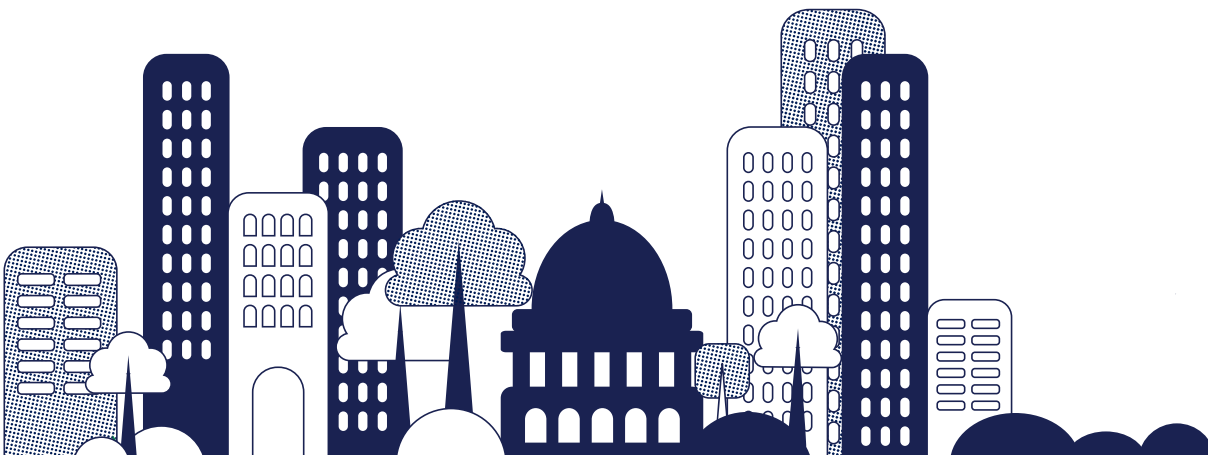




University of Oxford Research

PropTech 2020: the future of real estate



PROPTECH 2020: THE FUTURE OF REAL ESTATE

This report is the successor to our 2017 report **PropTech 3.0: the Future of Real Estate**. It has been compiled using data from Unissu and Crunchbase, while additional data has been compiled from interviews and other external sources mentioned in the acknowledgements and references. We thank all who have contributed to this report; any stated opinions, and any remaining errors, are our own.

The Oxford Future of Real Estate Initiative at the Saïd Business School is led by Professor Andrew Baum and is a collaboration between Oxford academics and industry-leading organisations that aims to advance knowledge in real estate: Arcadis, BCLP, CBRE, EY, Grosvenor, Nuveen, Redevco, The Crown Estate and UBS. Our research is grounded in real-world business questions. To find out more about the Initiative, or to read our other research, please visit our website at: <https://www.sbs.ox.ac.uk/research/oxford-future-real-estate-initiative>.

Any reference to specific companies or organisations does not constitute a recommendation and is included solely for illustrative or case study purposes. We welcome reader feedback and comments, which can be sent to us via e-mail at realestate.reports@sbs.ox.ac.uk

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Notes

Material from interviews is quoted verbatim in the text. Verbatim quotes and materials taken from websites are set in italics. Where interview materials are unattributed, this is at the request of the interviewee. The views are of the interviewees and should not be assumed to be the views of the companies they work for. Andrew Baum acknowledges his personal interest in tech businesses referred to in this report (Proda, Unissu and Reneza). His view of these businesses may not be objective.

Andrew Baum, Andrew Saull and Fabian Braesemann

Saïd Business School
February 2020

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1. Introduction

In this chapter we explain our definition of PropTech, the industry verticals which explain different PropTech activity and the history of PropTech growth

1.1 The fourth industrial revolution

The internet and mobile telephony have enabled a boom in technology platforms applied to nearly all areas of our lives – jobs, homes, education, health, leisure, finance and even romance. The global shift towards the use of digital technology or the ‘fourth industrial revolution’ (Schwab, 2017) has facilitated innovation in three different activities. These are as follows.

Information provision

Wikipedia, the BBC website and on-line newspapers are examples of on-line information engines. Initially, the internet, mobile telephony, social networking and e-mail were all about information, hence the previously ubiquitous use of the term ‘infotech’.

Transactions

Information is the key input into the due diligence phase of a transaction. Shopping on-line was therefore the natural next phase of technology development. PayPal, Amazon and on-line banking are examples of internet and mobile telephony being used as a medium for the exchange of money, goods and services.

Management and control

PCs, tablets and smartphones are potential dashboards for controlling electronic functions. The Internet of Things (IoT) allows objects to be measured (information provision) but also sensed and/or controlled remotely across the existing network infrastructure, creating opportunities to adjust or turn systems on or off remotely. As an example, Google’s 2014 acquisition of Nest to create a Google IoT division was seen at the time as a significant moment. Also, the remote control of driverless cars and delivery vehicles, plus bots offering a range of services, are setting in motion many thought processes imagining the likely future of logistics and retail real estate.

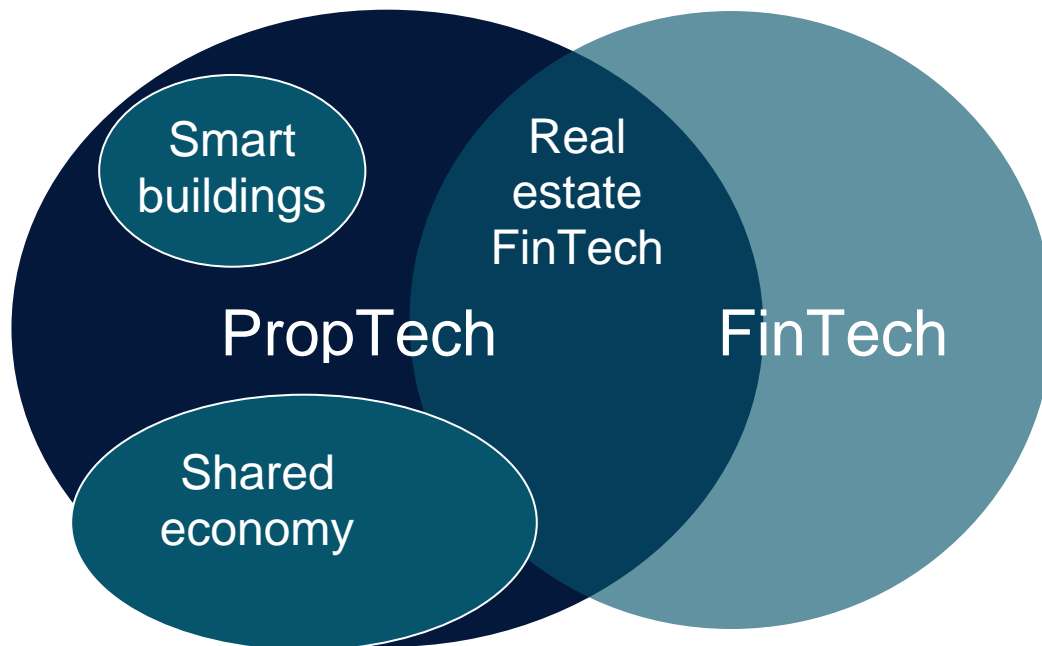
1.2 What is PropTech?

Real estate as an asset and as an industry is not immune to the innovations made possible by the fourth industrial revolution. What has become widely known as PropTech describes the digital transformation that is currently taking place within the real estate industry.

“PropTech is one small part of the wider digital transformation of the property industry. It describes a movement driving a mentality change within the real estate industry and its consumers regarding technology-driven innovation in data assembly, transactions, and the design of buildings and cities” (Andrew Baum and James Dearsley, reported in Davenport, 2019).

In our 2017 report, we suggested that the roots of PropTech lay in three independent movements or impacts. These were Fintech; Smart Building technologies; and the Shared Economy (see Figure 1).

Figure 1: PropTech roots, 2017



Source: Baum (2017)

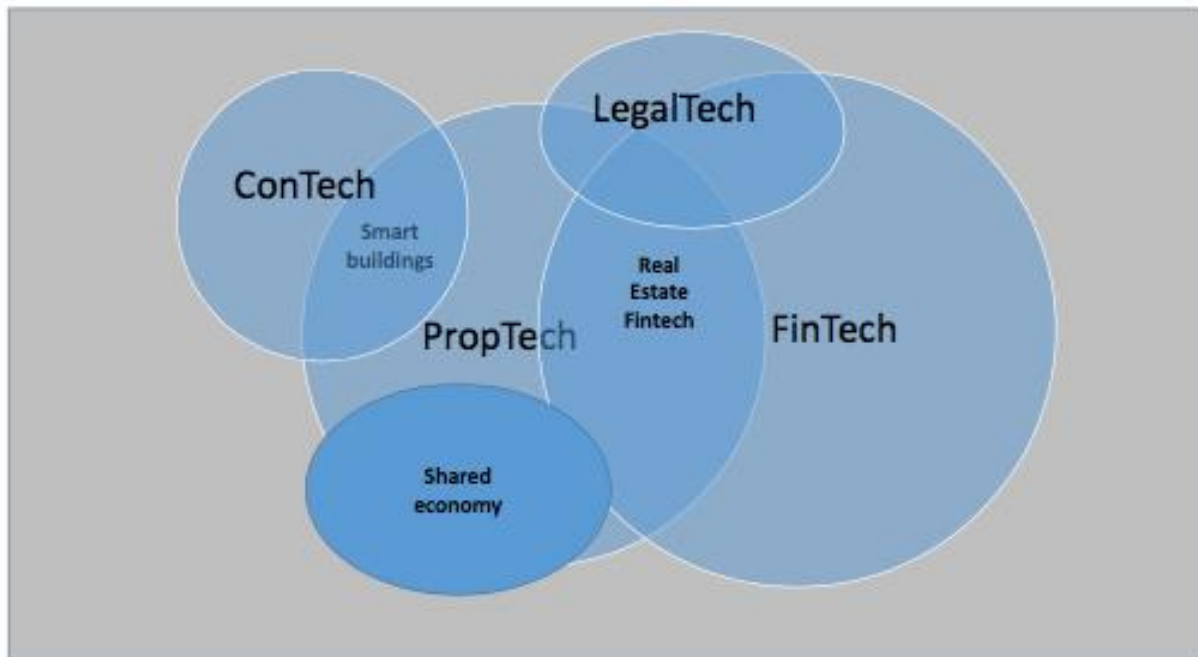
Smart Buildings describes technology-based platforms which facilitate the *operation and management* of real estate assets. The assets can be single property units or entire cities. The platforms may simply provide information about building or urban centre performance, or they may directly facilitate or control building services. This sector supports real estate asset, property and facilities management. We exclude technology which supports the design and/or construction of buildings or infrastructure from our definition of PropTech (this is usually known as ConTech) and discuss this vertical in Chapter 4.

Real Estate FinTech describes technology-based platforms which facilitate the trading of real estate asset *ownership*. The assets can be buildings, shares or funds, debt or equity. The platforms may simply provide information for prospective buyers and sellers, or they may more directly facilitate or effect transactions of asset ownership or leases with a (negative or positive) capital value. This sector supports the real estate capital markets. We discuss this vertical in Chapter 5.

The Shared Economy describes technology-based platforms which facilitate the *use* of real estate assets. The assets can be land or buildings, including offices, shops, storage, housing and other property types. The platforms may simply provide information for prospective users and sellers of space, or they may more directly facilitate or effect rent- or fee-based transactions. This sector supports the real estate occupier markets. We discuss this vertical in Chapter 6.

We can add further influences to this schematic. ConTech, whose origins lie in computer-aided design or CAD, is a strong driver of smart building tech. LegalTech (characterised by smart contracts) is a facilitator of many real estate FinTech applications.

Figure 2 is our updated schematic. In addition to our three initial drivers, we now include ConTech and LegalTech.

Figure 2: PropTech roots, 2020

Source: FoRE

There is also a world of transport technology which will change the way cities work. Smart Cities are somewhat beyond the scope of this report, but will be referred to in several places. Finally, there are many unpretentious digital transformations underway focussed on the storage, analysis and visualisation of data. These data digitalisation activities will have a significant impact on the real estate industry, and the effect will be seen in all areas of PropTech application, including the use of buildings, the operation and management of buildings, and the capital markets.

1.3 PropTech waves

Real estate is not known as an industry which readily embraces change. The nature of the asset class, which comprises large heterogeneous assets traded in a largely private market, is perhaps a good reason for this. Homes may be too important a part of a private portfolio to take any risks with the process whereby it is traded, held or valued. It may also be the case that there is an agency problem: the professional advisors that dominate the transaction process clearly have an interest in protecting their income sources, so chartered surveyors, brokers and lawyers might all be expected to resist tech-driven innovations designed to 'disrupt' their work.

Nevertheless, the real estate industry has undergone two periods of major technological change. In current times we are witnessing a battle for market share between traditional advisors and a discernible second wave of technology-based innovation.

The first wave (PropTech 1.0) took place in the mid-1980s. This was all to do with data and computing power. The invention of computing in the 1930s and 1940s and the subsequent 40 years of development made little or no impact on property markets. The key driver of change was the introduction of the personal computer in the late 1970s/early 1980s. The Apple II and the twin floppy disc IBM PC XT (introduced in 1983) both supported spreadsheet applications (VisiCalc and Supercalc) before Lotus 1-2-3 and, later, Excel became industry

standard platforms for the organisation and analysis of data. Alongside the development of the personal computer (PC), the mainframe computer was becoming more and more efficient and affordable. In the mid-1980s this started to have an impact on property practice.

These waves are likely to correspond to movements in the global financial markets. Frick (2019) describes how a recession encourages the adoption of new technologies. Employers are able to recruit workers with better computer-related skills due to increased unemployment; technology brings transparency into how and where businesses are affected by turmoil; and the opportunity cost of investing in new technologies reduces as the returns from funding regular operations are reduced. The same is suggested by Block and Aarons (2019: 51) who note that the 2008 downturn in global markets led to a boost in PropTech due to the need for real estate companies to find a competitive advantage and maximise savings.

The growth of indirect private fund vehicles with different styles, debt and asset-backed securitisation, the arrival of REITs, the growth of a derivatives market – all of these developments fed on and demanded a much more quantitative and research-focussed approach to performance measurement and investment strategy; and the rapid globalisation of the real estate industry in terms of investors, sources of capital and advisory services substantially reduced the insularity of the industry and brought increased demands for a more research-led product. Growing data availability enabled more finance-grounded quantitative modelling, and valuation software and property and portfolio management systems became computer and technology based.

Alongside these parochial developments, e-commerce had become increasingly popular in the wider world in the 1980s, followed by the internet and e-mail in the 1990s. By this time the rapidly-adopted technologies of internet and e-mail (see Table 1) had begun to facilitate mass data storage and analysis.

Table 1: Traffic on US internet backbones, 1990 - 2000

1990	1
1991	2
1992	4.4
1993	8.3
1994	16.3
1995	not known
1996	1,500
1997	2,500-4,000
1998	5,000-8,000
1999	10,000-16,000
2000	20,000-35,000

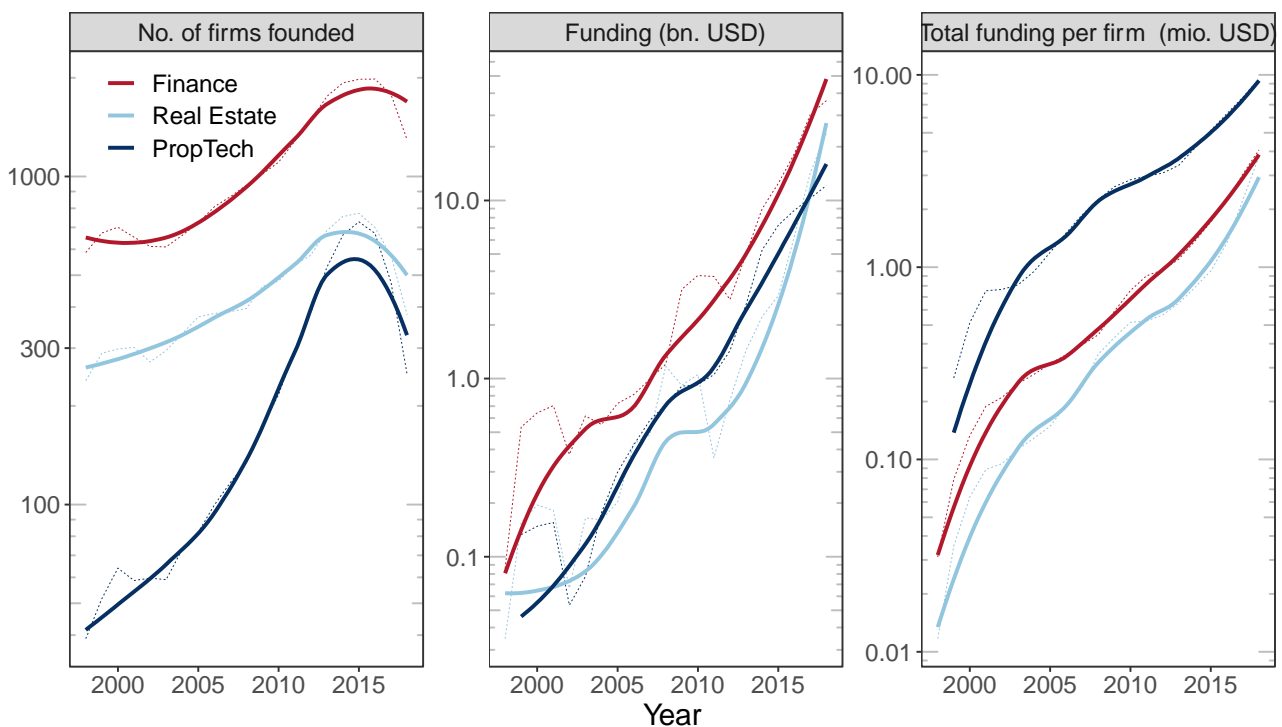
Source: Coffman and Odlyzko, 2000

What we call **PropTech 1.0** began in the mid-1980s, driven initially by the rise of the personal computer and the associated software. Microsoft Excel became the essential tool for real estate analysts, and regression modelling became standard. The peak of the start-up and investment activity associated with the dotcom boom was around the year 2000. A lot of money invested in PropTech 1.0 was lost in the ensuing crash.

In the construction technology world, 1982 saw the launch of Autodesk, an American and now multinational software corporation that makes software for the architecture, engineering and construction, industries employing computer-aided design or CAD. Argus, which has become a leading global provider of software and solutions for the analysis and management of commercial real estate investments, was first established in the mid to late 1980s. Yardi, another leading provider of software solutions for the real estate industry, was established in 1984. CoStar, a provider of information, analytics and marketing services to the commercial real estate industry in the United States, Canada, the United Kingdom, France, Germany and Spain, was established in 1987. These companies established market leading positions which (after several bumps in the road for some, and much consolidation of competitors) they continue to hold in 2017.

These dominant technology-based businesses established themselves by providing apparently comprehensive closed-form enterprise services, often requiring significant and expensive customisation by the client. They were not open source, or collaborative. The dotcom and telecom collapse of the early 2000s – triggered by investors realising that the transmission capacity in place and under construction greatly exceeded the demand for traffic - allowed the hoovering up of failed competitors and the growth of market share.

Figure 3: Start-up foundation, 1998-2018



Source: Crunchbase, Unissu, FoRE

Figure 3, left hand graph (the dotted PropTech line), shows the rise and fall in the number of PropTech firms founded compared with finance and more broadly defined property firms (with some overlap between firms allocated to the PropTech and Real Estate sectors). The number peaked in 2000, fell in 2001-2003, and resumed its growth in 2004. (Note that growth has been so great over the period shown that we use a logarithmic scale.)

The bridge between PropTech 1.0 and PropTech 2.0 appears to be driven by the on-line residential market sector. For example, in the UK Rightmove was started in 2000 by the top

four UK estate agencies at the time (Countrywide, Connells, Halifax and Royal and Sun Alliance). It survived the crash, and Zoopla launched in 2007, followed by OnTheMarket in 2015. In the US, Trulia was founded in 2005 and Zillow launched in 2006; Trulia was acquired (for \$2.5bn) by Zillow in 2015.

The exponential growth that characterises **PropTech 2.0** began around 2008, where growth in the series takes off again. Exogenous technologies such as cloud computing, mobile internet, leaner coding and broadband helped drive huge revenue growth in the late stage 1.0 companies Rightmove, Zoopla, Trulia and Zillow. By 2010, the loss in faith in traditional processes caused by the global financial crisis of 2007/8 and the rise of the smart phone and the multi-platform world, facilitated through open application programming interfaces (APIs), enabled creation of the 'app'. This facilitated consumer access to a wealth of instantaneous real estate information at zero cost. New business models such as Airbnb and WeWork (both of which quickly became unicorns) emerged as the winners of this second wave of innovation, best able to offer enhanced customer experience and offering an alternative to major institutions in the wake of the GFC.

2014-15 sees a peak in this activity followed by a significant fall. This may partly be a data issue - there may have been a lag in registration of new companies. However, it does appear that we are witnessing a massive consolidation of companies and the end – or maturity - of PropTech 2.0.

While there was exponential growth from 2007/2008 until 2014/2015, there has been a clear fall in the number of new PropTech firm foundations in 2016, 2017 and 2018 (and a much bigger decline than is seen in the Finance and Real Estate sectors). By 2018 the number of new firm foundations is back to the level of 2009, and the big boom which was PropTech 2.0 seems to be over. However, as the central graph in Figure 3 shows, total funding is still increasing, though with a noticeable lower rate of growth for PropTech than Finance or Real Estate. The right hand graph of Figure 3 shows that the amount of funding per firm has continued to rise exponentially, so this is not yet a bust. The 'garage business' PropTech boom is over, but the market has continued to grow and mature into a consolidation phase, with more Series A, B and C rounds recently and fewer seed and angel backed start-ups.

This is backed up by Table 2, detailing the technology to technology mergers which have occurred in the PropTech industry from 2015 to early 2019. The year on year growth in PropTech M&A activity clearly visible in the deal counts provided by GVA (2019) in Figure 4.

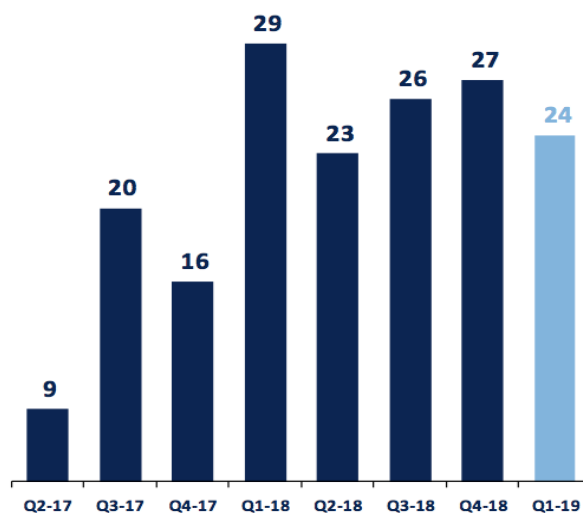
The decline in start-up activity is inevitably in advance of a third major wave of PropTech, the timing and magnitude of whose peak is impossible to predict, its causes less so. **PropTech 3.0** will probably be driven by the global pressures of climate change and rapid urbanisation and enabled through the maturing of exogenous technologies including the Internet of Things, Machine Learning and Artificial Intelligence and Blockchain.

Table 2: PropTech market consolidation, 2015-2019

Acquiror	Target	Year	Valuation	Segment
States Title	Captive Title North America	2019	Undisclosed	Title company analytics platform
Amazon	Eero	2019	Undisclosed	Tech e-commerce
News Corp	OpCity	2018	\$210M	Broker/buyer intermediary
RealPage	ClickPay	2018	\$219M	Property management and payment platform
Siemens	Comfy	2018	Undisclosed	Smart buildings
Autodesk	PlanGrid	2018	\$875M	Construction productivity software
Knotel	42 Floors	2018	\$10.35M	Office leasing data and technology
RealPage	Rentlytics	2018	\$57M	Real-time leasing data analytics
RealPage	LeaseLabs	2018	\$117M	Go direct marketing suite
RealPage	On-Site	2017	\$250M	Lease and property management integration
CoreLogic	Mercury Network	2017	\$153M	Data analytics and valuation technology management
RealPage	Lease Rent Options	2017	\$300M	Property and revenue software platform
Oracle	Aconex	2017	\$1.2B	Cloud software construction platform
View the Space	Hightower	2016	\$300M	Cloud based leasing and portfolio data
Zumper	Padmapper	2016	\$10M	Residential search platform
Ritchie Brothers	Iron Planet	2016	\$785.5M	Platform to buy, list, sell construction equipment
Roper Technologies	ConstructConnect	2016	\$632M	Integrated applications and project information
Oracle	Textura	2016	\$663M	Cloud software construction platform
Expedia	HomeAway	2015	\$3.9B	Hospitality
AltiSource Portfolio Solutions	Rentrance	2015	Undisclosed	Market intelligence platform
AltiSource Portfolio Solutions	Investability	2015	Undisclosed	Mortgage data platform
Zillow	Dotloop	2015	\$108M	Online database and e-signing service
Zillow	Trulia	2015	\$3.5B	Online real estate database

Source: Goodwin, 2019

Figure 4: Quarterly PropTech M&A activity by deal count, 2017-2019



Source: GVA, 2019

2. The PropTech Market

In this chapter we measure the size of the PropTech market, trace the sources and scale of the investment which has powered this sector and describe geographical variations in PropTech activity

2.1 Sizing the market

Attempting to generalize the digitally driven political, economic, environmental and social transformations happening within an industry under one umbrella term is inherently fraught with danger. Yet the term 'PropTech' has seemingly managed to fulfil this role for the real estate industry.

Baum (2017) defined PropTech as a series of verticals that facilitate Information, transactions/marketplace, or management/control, offered through the industry horizontals of Real Estate FinTech, Shared Economy and Smart Real Estate.

There are three PropTech sub-sectors (verticals), and three drivers (horizontal). Not all segments seem likely to be populated (see Table 3).

Table 3: PropTech verticals and horizontals

	Real Estate FinTech	Shared Economy	Smart Buildings
Information	yes	yes	yes
Transactions/marketplace	yes	yes	
Management/control			yes

Source: Baum, 2017

Based on a sample of over 600 companies (applicants to the PI Labs accelerator, Table 4), Baum found that 51% percent fell into his Real Estate FinTech vertical and 62% were focused on his transactions horizontal. 38% of all PropTech companies surveyed were transaction-focused Real Estate FinTech start-ups. that is technology platforms which facilitate the trading of real estate asset ownership and leasing. This analysis included construction technology (ConTech), to include the planning, design and building phases of an asset.

Table 4: Pi Labs applications – analysis by segment

	Real Estate Fintech	Sharing Economy	Smart Buildings	Contech	Total
Information	12.9%	0.6%	0.9%	3.1%	17.5%
Transactions	38.3%	16.6%	3.4%	3.4%	61.7%
Control/management	0.0%	2.5%	15.0%	2.1%	19.7%
Total	51.2%	19.6%	19.3%	8.6%	98.8%

Source: Baum, 2017

Unissu, which manages and offers an online PropTech database, take an alternative approach to categorizing the PropTech marketplace, based around an asset's lifecycle. Their sample of over 7,000 companies includes ConTech, but does not consider 'shared economy' to the same extent as Baum's methodology. Eddie Holmes, co-founder of Unissu explains: *"We have always worked on the principle that a PropTech business is first and foremost a company supplying technology to be used in relation to the underlying property asset lifecycle, from build to demolish and everything in between. For this reason, WeCompany and other Space-as-a-Service operators are not included in our figure. While flexible workspace providers are one of the biggest innovators in the property industry they are, at the end of the day, themselves property companies."* (Faraudo, 2019a).

CRETech, another PropTech data provider, classifies real estate and property technology companies as private companies in the general field of real estate, or in the fields of software-as-a-service, hardware-as-a-service, and real estate-as-a-service.

Global real estate firm CBRE recently released its client portal #TechCBRE, which attempts to classify PropTech not by its target sector, its position in the asset lifecycle or by its service offering, but by which of five identified market inefficiencies it is attempting to resolve. Under this framework, PropTech refers to any real estate company using technology to increase efficiency, visibility, experience, flexibility and productivity (CBRE, 2019).

From an investment angle, Metaprop, a US venture capital firm directly targeting PropTech, bucket each start-up into one of 8 value-chain functionalities: analysis and financing, space identification and listing, site selection and negotiation, diligence, development and construction, process automation, space usage and management, and payments and services (Block and Aarons, 2019).

2.2 Investment activity

The metric of success used by most established companies is profit. However, in the technology world, where growth is the best indicator of future value, more investment means higher valuations and more chances of investor payback. So, how much money gets poured into an industry is often seen as a sign of health (Faraudo, 2019a). Accordingly, most attempts to size the PropTech market look at the year on year funding growth obtained. Widely varied classifications of PropTech mean that measuring the size of these investments can be highly problematic.

Investment in PropTech start-ups has been coming from several directions. These include traditional venture capital funds with diversified portfolios; specialist PropTech funds and accelerators; and real estate companies.

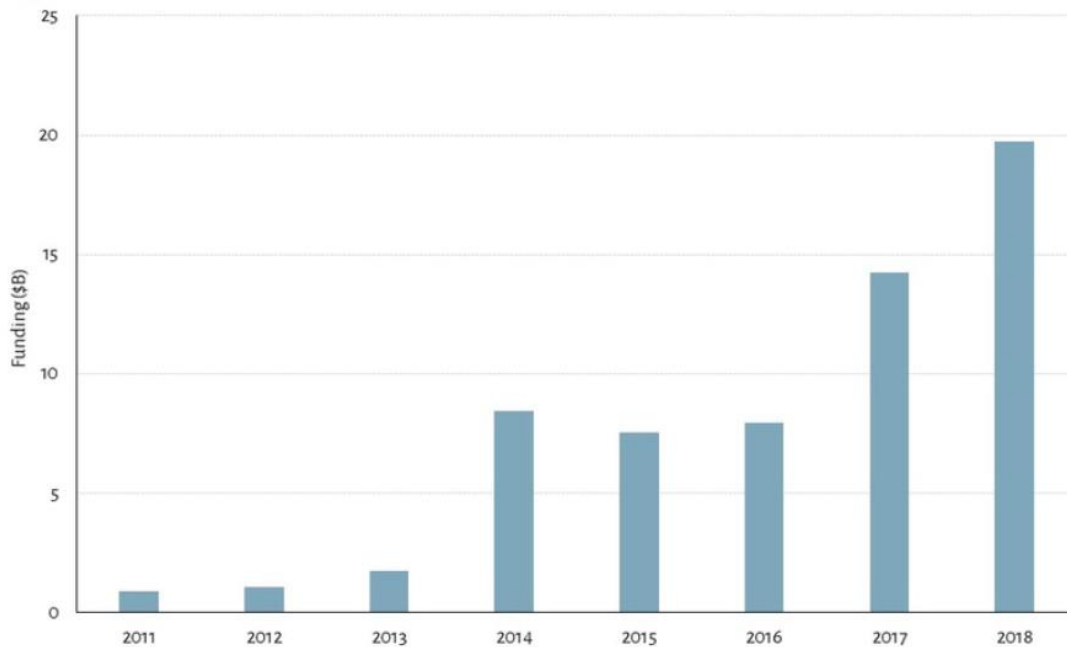
Venture capital

Different research organisations currently report hugely varied estimations of total funding amounts, sometimes retrospectively altering their own data. As an example, Venture Scanner measure in excess of \$20bn having been invested in PropTech businesses over the period 2014-2018; CB Insights is less optimistic, at around \$10bn.

Unissu's estimate of funding achieved in calendar year 2018 was close to \$15bn across 898 global PropTech funding events, not including flexible lease or 'space as a service' operators. If they were to include only WeCompany, the then market-leading space-as-a-service

operator, this figure would have exceeded \$21bn (Faraudo, 2019a). CB Insights report 2018 PropTech funding at \$3.95bn (Faraudo, 2019a) and CRETech (2019) released a report that recorded commercially-focused PropTech funding at \$9.6bn for the same period. If one thing is clear, it is that there is a lack of clarity over definitions of the PropTech universe.

Figure 5: Venture Scanner PropTech funding analysis, 2011-2018



Source: Venture Scanner

However, all commentators are agreed that PropTech funding has risen year on year. Putting together the findings summarised in Figure 3 (a declining number of start-ups) and Figure 5 (increasing aggregate investment), the size of each individual investment has increased significantly over time.

While variations exist over what exactly constitutes PropTech and therefore the size of the market, there can be no confusion as to the high levels of funding activity that has taken place in recent years. According to research firm CREtech (Obando, 2019), investment in PropTech companies globally hit \$14 billion in the first half of 2019. That is more than during all of 2017, which saw a record \$12.7 billion in PropTech investment, and a 309 percent increase from the first half of 2018.

Arguably the most transformative of this activity is the increase in venture capital entering the PropTech arena with some VCs able to deliver huge capital sums to a single investment. The most influential of these is SoftBank's Vision Fund, a partnership of many investors including Saudi Arabia's Public Investment Fund, Foxconn, Qualcomm, Daimler and Apple (Crunchbase, 2019), flush with nearly \$100b from the world's biggest exit in the form of Alibaba's IPO.

Since 2017, Softbank has invested around \$10b in the WeCompany, the flexible office company pushing its valuation to a high of \$47b before their well-documented IPO troubles. With \$400m invested in each, Softbank is also the lead investor in residential iBuying platform Opendoor and residential software company Compass, valued at \$2b and \$4.4b respectively. It has invested \$200m in Clutter, a tech-led storage business that picks up and delivers stored

items as well as providing the storage space itself, and further \$867m in construction start-up Katerra. With Softbank's minimum investment limit at \$100m. It is also reported that intelligent window manufacturer View secured \$1.1bn and Indian hotel chain OYO received \$1bn (Phillips, 2019a; Griffith, 2018; Vander Capital Partners, 2019).

Justin Wilson, Investment Director at Softbank's Vision Fund, spoke of their motivation to enter the PropTech market: *"There are plenty of studies which show you that real estate and its associated segments account for about 17-20% of global gross domestic product, and the real estate sector is larger than the securitised debt and equity market globally. So we wanted to take the time to explore that sector. We are one of the world's largest funds, so the sector gives us the opportunity to deploy capital at scale."* (Phillips, 2019a).

However, Softbank is far from alone in targeting the PropTech market. Numerous funds have been raised attempting to identify the next sure thing. Table 5 charts the PropTech investment activity of the 14 most active VC funds in the US, 2008-2018 and the 10 most active VC Funds in Europe from 2014-2018, based on the total number of deals secured. This data omits Fifth Wall, reported to have raised the biggest PropTech fund to date at \$500m.

Venture Scanner (2019) shows very different figures for similar companies in their analysis of the largest global PropTech investors by deal flow up to December 2018 (Figure 6), most probably (once again) due to differences in classification.

Table 5: The most active VC investors in US and European PropTech

VC Fund	Investments	Target
500 Startups	28	US
Thrive Capital	20	US
Founders Fund	16	US
Y Combinator	15	US
MetaProp NYC	15	US
General Catalyst	14	US
Greylock Partners	14	US
Khosla Ventures	14	US
Felicis Ventures	13	US
Andreessen Horowitz	12	US
SV Angel	12	US
Global Founders Capital	12	Eu
Navitas Capital	11	US
Resolute Ventures	11	US
Right Side Capital Management	11	US
Pi Labs	11	Eu
Seedcamp	11	Eu
Seaya Ventures	7	Eu
Bpifrance	6	Eu
HOWZAT Partners	6	Eu
Passion Capital	6	Eu
LocalGlobe	5	Eu
Picus Capital	5	Eu
Piton Capital	5	Eu

Source: Olsen, 2018; Hodgson, 2018

It seems agreed that PropTech investments have seen a dramatic increase in recent years as a percentage of all venture capital investments (Figure 6).

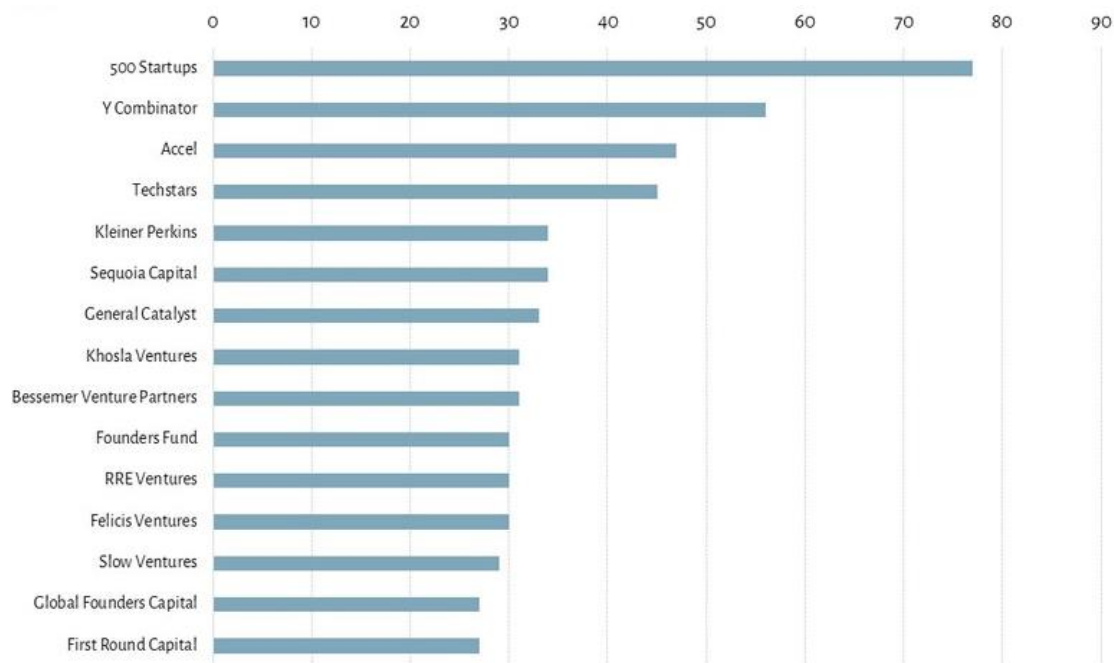
Table 6: PropTech’s VC market share (\$bn)

	2015	2016	2017	2018
VC in PropTech	1.80	4.20	12.60	11.15
Total VC	83.00	77.20	83.00	130.90
Proptech/VC	2.2%	5.4%	15.2%	8.5%

Source: Vander Capital Partners, 2019

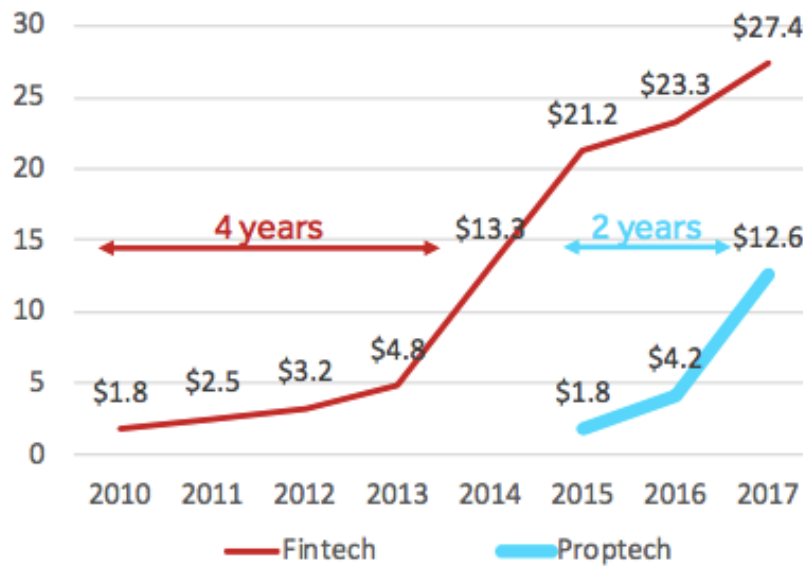
While the percentage seems to have dropped between 2017-2018, it appears that VC spending on PropTech grew by over six times its 2015 amount in two years. This acceleration in funding is twice as fast as the older, mature FinTech market according to analysis from Concrete Ventures (2019), shown in Figure 7. Whether this funding will generate returns for its investors is an open question, given that a typical VC expects to write off 80-90% of its investments, and that ‘success’ is often defined in terms of achieving more funding rather than profitability. Everyone, it seems, is looking for the next unicorn (see Table 9).

Figure 6: Largest global PropTech investors by total deal flow through to December 2018



Source: Venture Scanner, 2019a

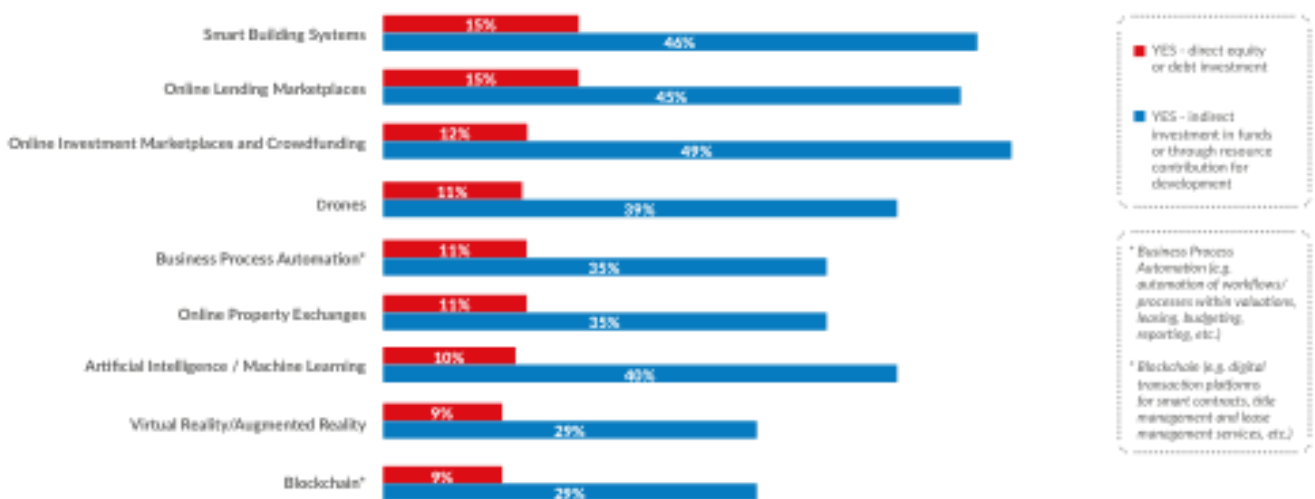
Figure 7: VC Investment in FinTech and PropTech (\$bn)



Source: Concrete Ventures, 2019

Traditional real estate companies are also highly active in this field. With revenue streams under threat from alternative business models such as the WeCompany, the industry is turning towards technology to maintain competitive advantage. According to Altus Group (2019), 53% of 400 major real estate companies surveyed are directly investing in at least one type of PropTech firm. Their breakdown of this investment activity can be seen in Figure 8.

Figure 8: CRE investment in PropTech firms



Source: Altus Group, 2019

Much of the indirect investment shown in blue in Figure 8 has come through the activity of corporate venture capital funds, set up by consortiums of traditional real estate firms. Vander Capital Partners (2019) compiled a list of the most prominent of these within the US market, shown in Table 7. While by no means exhaustive or indicative of size and activity, this list

seeks to illustrate a few of the more progressive real estate firms embracing the role that technology will play in the future of real estate.

Table 7: Corporate venture funds targeting PropTech

<u>Fund name</u>	<u>Corporation</u>	<u>Location</u>
1. Brick & Mortar VC	Bechtel	San Francisco, CA
2. Brookfield Ventures	Brookfield	Toronto, CA
3. Caterpillar Ventures	CAT	Peoria, IL
4. CEMEX Ventures	CEMEX	Monterrey Mx
5. JLL Spark	JLL	San Francisco, CA
6. Lennar	Lennar	Miami, FL
7. Second Century Ventures	Nat. Assoc. of Realtors	Chicago, IL
8. Stanley Ventures	Black & Decker	Atlanta, GA
9. Strategic Capital Ventures	Prologis	San Francisco CA
10. Simon Ventures	Simon Property Group	New York, NY
11. Creator fund	The We Company	New York, NY
12. Westfiled	Westfiled Corporation	Los Angeles, CA

Source: Vander Capital Partners, 2019

The most notable absentee from this list is Fifth Wall Ventures, which launched its first fund in 2017, with half of the \$240m in commitments coming from the real estate industry itself including CBRE, Lowe's, Brookfield, Equity Residential, Hines, Host Hotels and Resorts, Lennar and Prologis, making it the perhaps the closest thing to a real estate industry research and development consortium currently available.

PropTech funds and accelerators

It was recently announced that Fifth Wall has raised the largest ever PropTech targeted fund at \$503m, which closed in July 2019. It is clear the investments of this new fund will have significant impact on the PropTech landscape.

Dedicated or specialist PropTech funds and accelerators represent a major investment source of PropTech investment. Accelerators focus on early stage start-ups, offering not only capital but also premises, business guidance and expertise. Often, an accelerator will need to add venture capital funding to maximise the value of its early stage support.

There are probably at least 40 other significant PropTech funds and accelerators. A selection is shown in Table 8.

Table 8: PropTech venture funds and accelerators

ADAPT Accelerator	Malaysia
AREA	Unknown
Asia PropTech	Hong Kong
Blackprint Booster	Germany
Brick and Mortar Ventures	US
Brigade REAP	India
Charter Hall Accelerator	Australia
Colliers PropTech Accelerator	Canada
Concrete Ventures	UK
ConstruTech Ventures	Brazil
Design X (MIT)	US
Dreamit Ventures	US
Elmspring Accelerator	US
Fifth Wall	US
Geovation	UK
IFCA Accelerator Programme	Malaysia
IMPACT	Spain
ING Real Estate Lab	UK
INhab RE Tech Accelerator	Hong Kong
iStartHub PropTech	Unknown
JLL Spark	US
MetaProp NYC	US
MITHUB	Brazil
PI Labs	UK
PIRE Labs	Argentina
Plug and Play	US/Global
Propell Asia	Singapore
PropTech Capital	EU
Proptech Ventures	Germany
REach	US
RElab accelerator	UK
Structura	UK
TheFactory PropTech Accelerator	Norway
The We Company Labs	US
UrbanLab	China

Source: Vander Partners, FoRE

Property companies

Major real estate companies have also been active investors in or acquirors of tech firms. Buyers have included Prologis, CoStar, Brookfield, JLL (via the venture arm, JLL Spark), Industrious, CBRE and Accor.

Baum (2017: 83) predicted that for the Real Estate FinTech market (technology platforms which facilitate the trading of real estate asset ownership and leasing) “*consolation is certainly on the way, and we can expect to see traditional broking and advisory businesses cherry-*

picking the best ideas and moving into the space currently occupied by the more thoughtful start-ups. Property owners will Hoover up tech firms and combine high return service operations with low risk ownership.” This is a feeling echoed by many, including Goodwin (2019): “*As fundraising has become increasingly competitive due to the acceleration of the number of PropTech assets in the market, small and mid-sized start-ups are combining to build more valuable and attractive real estate technology platforms.*” It is safe to say that both of these predictions are being fulfilled – see Chapter 1 - and that we have entered a period of industry consolidation.

PropTech Unicorns

All of the activity in the PropTech market has produced a handful of Unicorns, defined as a privately held start-up company valued at over \$1bn. All but two of these (OYO in India and Revolution Precrafted in the Philippines) are located in either the USA or China, as shown in Table 9 and Figure 9. This is likely due to the fragmented European real estate markets each offering different cultures, languages, standards, industry processes and legislation, making it more difficult for start-ups to cross borders. Several others are now publicly traded and therefore no longer considered as start-up unicorns. This select club includes Redfin, Zillow, GreenSky and American Homes 4 Rent (Vander Capital Partners, 2019).

Table 9: PropTech Unicorns

Company	Valuation, \$bn	Location
WeCompany	47	USA
AirBNB	29	USA
Lianjia	6	China
OYO	5	India
Compass	4	USA
Houzz	4	USA
Fangdd	4	China
Ucommune	3	China
Ziroom	3	China
Procore Technologies	3	USA
View	NA	USA
ESR Cayman	2.8	China
OpenDoor	2	USA
Katerra	2	USA
Tabatu	2	China
Tujia	1.5	China
Nextdoor	1.5	USA
Kr Space	1.3	China
Iwjjw	1.3	China
Revolution Precrafted	1	Philippines
MoFang	1	China
Xiazhu	1	China
VTS	1	USA

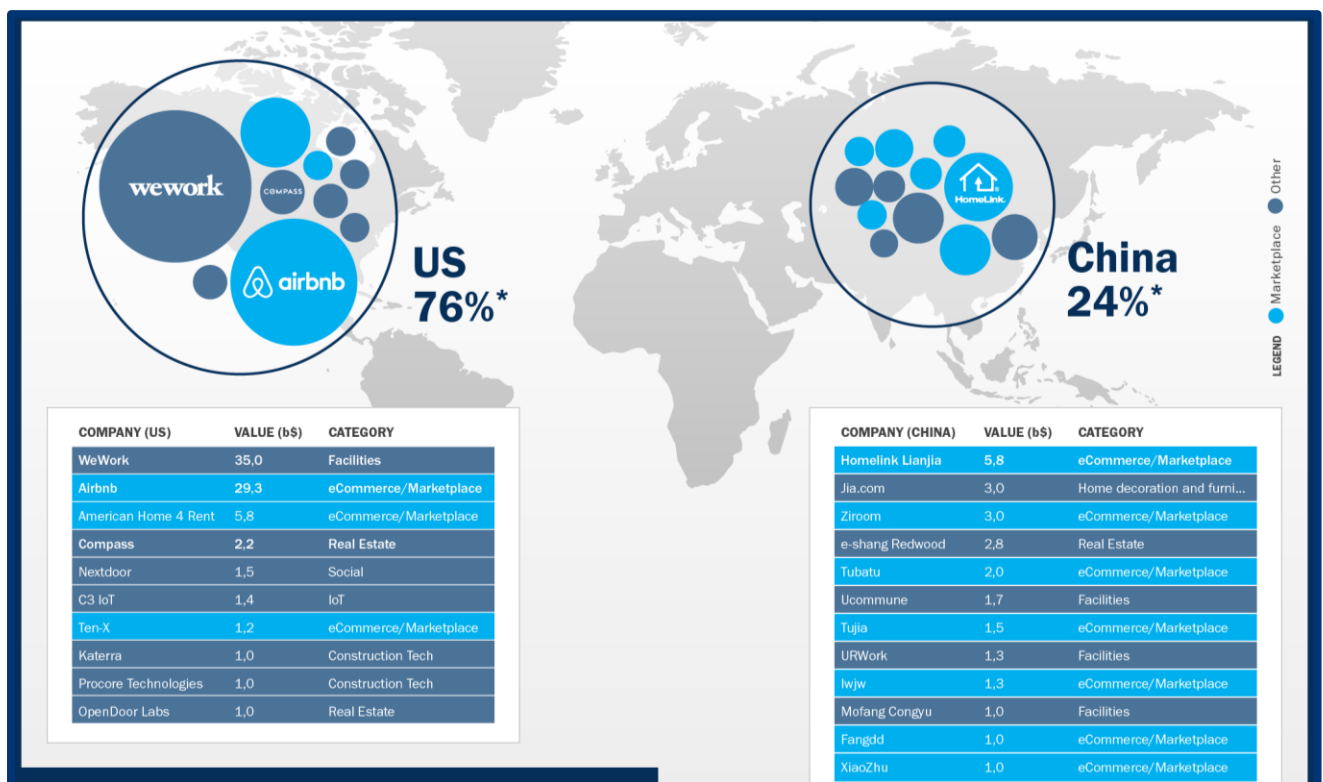
Source: adapted from Vander Capital Partners, 2019

2.3 Geographic dispersion

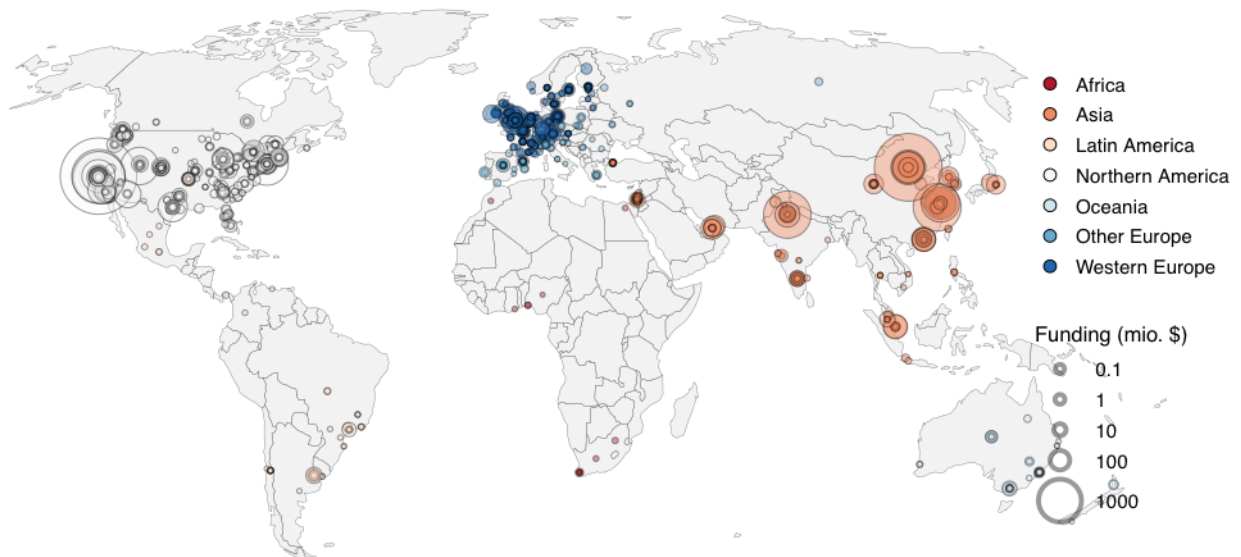
PropTech is a global phenomenon. As Figure 10 (in which each dot represents a PropTech firm, while the size of the dot corresponds to the funding the firm has obtained) shows, PropTech start-ups are distributed all over the world. However, they clearly cluster in specific regions. Hotspots of the PropTech industry are California, the US east coast, Western Europe (in particular the UK), and metropolitan areas in Asia (Delhi, Shanghai, Beijing, Seoul, Singapore). Compared to these places, most other regions of the world have much less well developed PropTech sectors.

The US is a global property and PropTech powerhouse. New York City and San Francisco represent the nation’s two major tech hubs and both cities are enjoying generous amounts of private investment and interest, both domestic and foreign. The world’s leading 10 tech companies are Microsoft, Apple, Amazon, Google, Facebook, Alibaba, Intel, Oracle, Samsung and Baidu. Seven of these call America home, while three are based in Asia. As a result, China and in particular the US have a disproportionate amount of influence over the future of technology.

Figure 9: The location of PropTech Unicorns, June 2018



*Share of total PropTech Unicorn valuation (\$104.8bn)
Source: Célérier, 2018

Figure 10: The global distribution of PropTech firms

Map based on locations of 6,428 PropTech firms

Source: Crunchbase, Unissu, FoRE

Spotify is by far Europe's most highly valued tech company. The Swedish music streaming service is valued at around \$16 billion, and is one of three European tech companies to be valued at more than \$10 billion. Alibaba, meanwhile, is estimated to be worth between \$150 and \$200bn, while Apple and Amazon have hit values of over \$1tr and Microsoft and Alphabet (Google) are not far behind. The US offers a large domestic market and investment comes in far bigger sums, and its influence on PropTech is likely to increase.

While the US and China have a disproportionate amount of PropTech unicorns, there is a lack of representation in Africa (Kejriwal and Mahajan, 2018). Hughes (2019), in his analysis of regional real estate markets digital transformation 'preparedness', finds that the US and European real estate markets are vastly more prepared to thrive in the digital era than those of Asia, Africa and South America.

This perceived 'unpreparedness' is perhaps dispelled by Crouse (2018), further supported by a similar analysis from JLL (in Baatar, 2018) detailed in Figure 13. It is clear that Asia is also a major global hub of PropTech activity, dominated by brokerage and leasing start-ups as well as property management platforms.

The US

Unissu has a database of around 7,000 PropTech companies. Just over 2,000 of these are based in the U.S., where there are currently six PropTech firms for every million people. 53% of those companies are working in the residential sector, 38% in the commercial sector, and 9% in retail. Companies such as Zillow and Realtor are leading the way in portals and online agency, while companies like Module and Blokable are working to improve the accessibility, affordability, and sustainability of American homes.

The commercial side of the US PropTech industry is also busy changing the way in which we place value on property. US company WiredScore has, for example, found great success in measuring the digital connectivity of commercial property and assigning graded certificates based on the results. The US (with China) continues to lead the world in retail innovation:

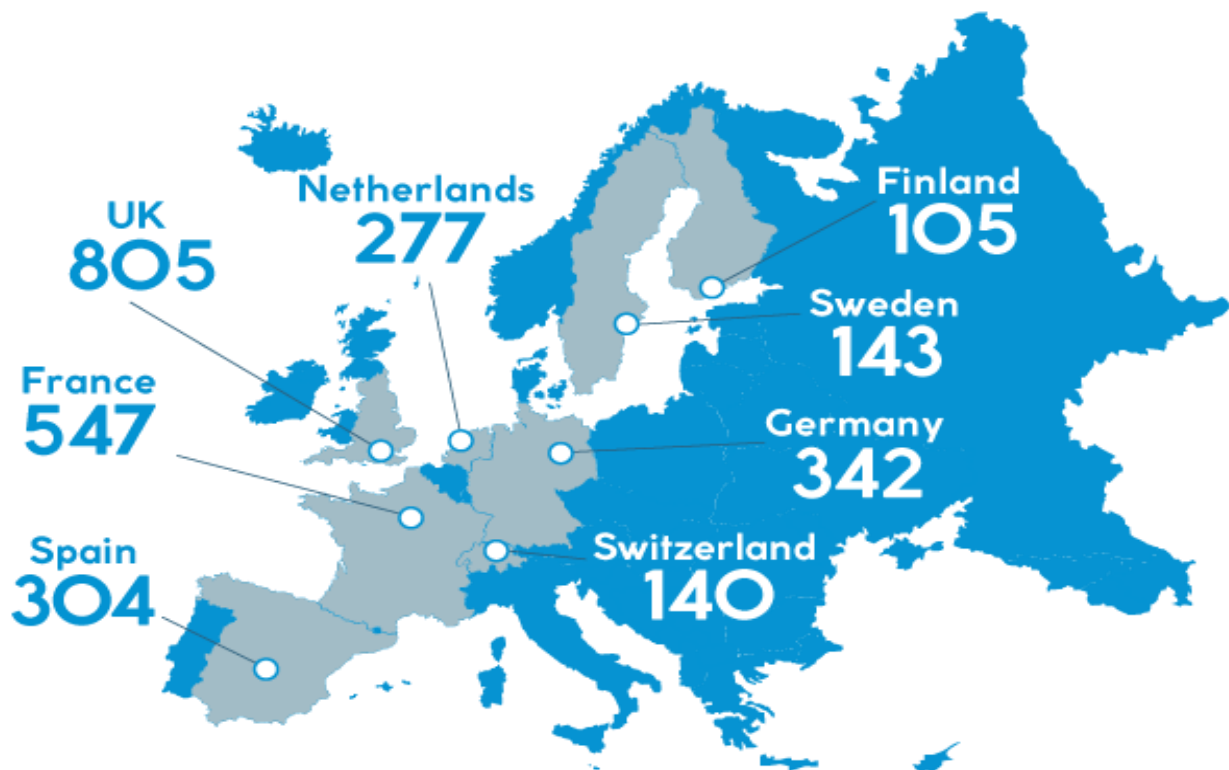
Amazon Go, the retail giant's unstaffed grocery stores, is challenging our view of what a 'shop' must entail, and many US companies are pushing the boundaries of what is starting to be known as 'experience-led retail' - physical shopping experiences which offer something that online retail simply cannot.

Europe and the UK

Unissu lists 3,219 PropTech companies located in Europe. Eight countries are home to 100 companies or more.

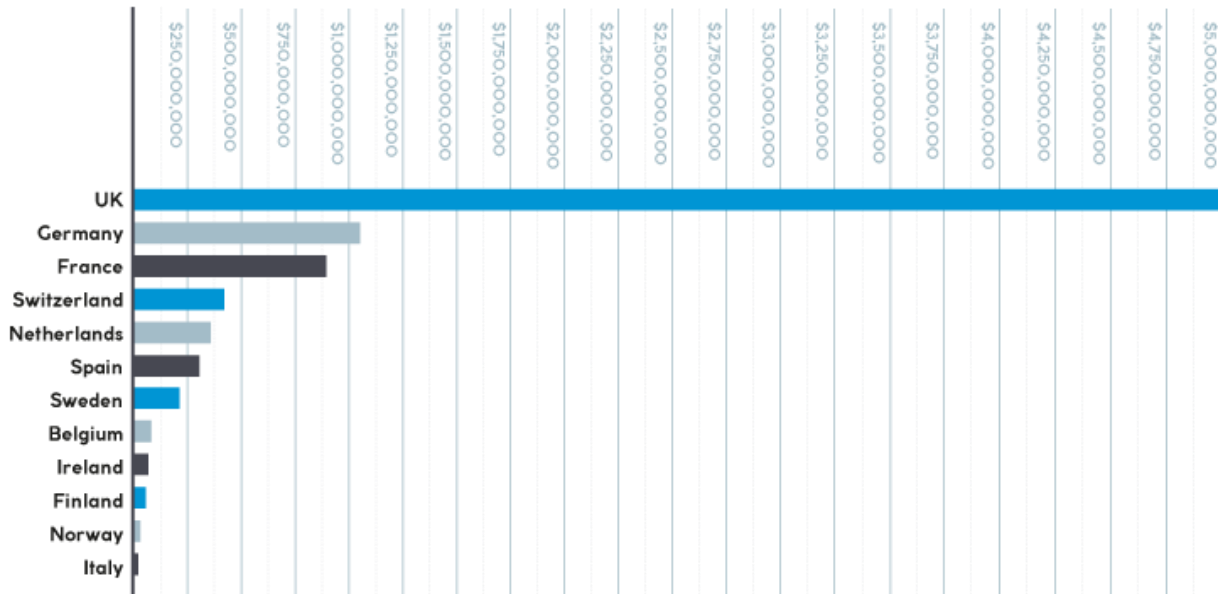
The UK once again leads the way when it comes to European PropTech funding, receiving considerably more funding than any other European nation. Germany's \$1 billion+ has been raised over just 58 recorded funding events, whereas France has raised less money over 148 events. France's funding has supported younger, less well-established start-ups while German investors have demonstrated great confidence in local companies.

Figure 11: PropTech companies in Europe



Source: Unissu

Figure 12: Total PropTech funding for leading European countries



Source: Unissu, 2019

Asia

There are now over 550 PropTech companies operating from Asia, with China, India, and Singapore boasting the highest numbers with 144, 170 and 84 respectively. However, this figure which places India above China is highly misleading when we considered the total amount of funding each nations start-ups have received. Figure 14 highlights this disparity, dtialing how across 50 individual events India has bought in just under \$1.5 billion. Chinese companies, with 53 individual funding events, has raised just over \$10 billion.

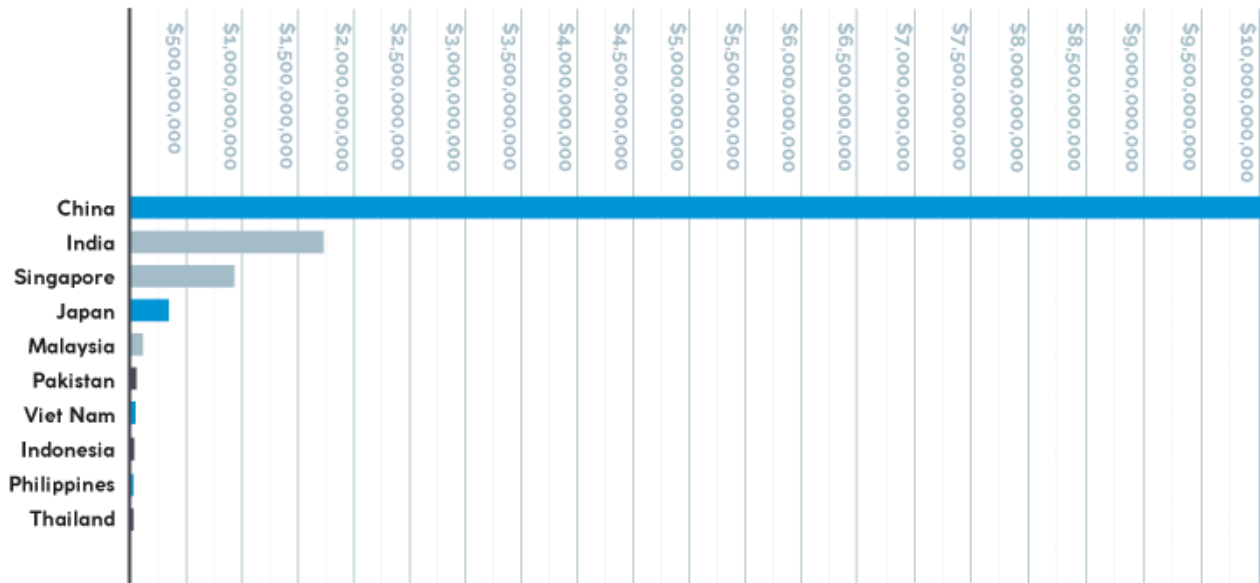
Over the next 5-10 years, Asia holds huge potential to rise to an equal footing with the USA and Europe as leaders of the PropTech world. India’s real estate industry is expected to have a market value of \$1trn by 2030,while it is also estimated that by 2025 the industry will contribute an estimated 13% of the country’s total GDP. The opportunity for PropTech in such a vibrant market is clear to see. Meanwhile technological advances being made in China have made it the world leader in 5G technology, set to play a crucial role in the development of innovative PropTech and perhaps even entirely new smart cities, reaping the rewards from all the economic, environmental and social benefit this concept is expected to unlock . If China continues to drive this sector, it could find itself in an influential position moving forward.

Figure 13: PropTech investments in Asia Pacific, 2013-2017



Source: JLL, reproduced in Baatar, 2018

Figure 14: Total PropTech funding for leading Asian countries



Source: Unissu, 2019

While many high-income countries host relatively mature PropTech sectors with many firms and funding per company, many low-income countries have huge development potential to establish firms that offer innovative property technologies to solve the most urgent problems of the local real estate markets. Given the significant imbalance, it stands to reason that most of the smaller PropTech firms from the developing world will find it hard to compete against better funded competitors in the global competition to offer platform-based PropTech solutions.

3. Technologies

In this chapter we describe the broad or exogenous technologies which have made the PropTech revolution possible

“People rarely need to know what a system, software or platform actually is – and by that I mean how it is put together and its inner workings. It is all about knowing what it does, and jargon has scared off potential adopters and converts. If any of us had to get our heads around the inner workings of our mobile phones before actually using them, very few of us would have one.” Emily Wright (in Block and Aarons, 2019: 94)

Underpinning business change and innovation are the major technologies driving the fourth industrial revolution. These are:

- Websites and Smart Phone Apps
- Application Programme Interfaces
- Data Analysis and Visualisation
- The Internet of Things
- Artificial Intelligence and Machine Learning
- Blockchain and Distributed Ledger Technology (DLT)
- Sensors
- Virtual and Augmented Reality
- Geospatial and 5G technologies
- Cloud computing
- Transport Tech: Drones and Autonomous Vehicles
- Other technologies

The biggest shift currently under way is the move from digitised to digitalised real estate systems. Digitisation is the means through which we convert paper hard copies into unintelligent digital soft copies; data held within digitised documents are unable to be extracted through computer programmes and require human interpretation. In practice, digitisation can be thought of as scanning a page, uploading a photo, or creating a pdf, so as to have a digital copy of an original document.

By contrast, ‘digitalisation’ is the act of converting anything into a digitally readable format. Digitalised data enable computer programmes to automatically execute tasks without the need for human intervention. In practice, this means completing forms online to enable software processes to act upon the machine-readable, ‘intelligent’ information.

Many PropTech companies currently offer digitalised platforms which purport to streamline processes used by the property industry. However, most of the transformative technologies we highlight in this chapter constitute ‘exogenous technologies’, meaning those not specifically designed for PropTech and real estate applications. The real estate industry has generally been slow to adopt these new technologies and to make full use of technologies which automate current manual procedures. For this to occur, a step beyond digitisation must prevail and the data upon which the industry runs must be digitalised.

3.1 Websites and smartphone apps

The interface between the supplier of services and goods and the customer has been transformed by digitalisation, expressed through the user interface (UI) and focussed on the user experience (UX). The efficiency of the process is informed by data collection and

analysis used to deliver increasingly accurate predictive models, primarily by websites, including social media sites, and smart phones.

According to mobility data provider GYANA, a smart phone's location data is sent to a nearby communications tower approximately 20 times a second. While GDPR laws prevent EU citizens' personal data being used against their will, most of us deliver anonymous aggregated data this way. We hand over many of our data protection privileges upon acceptance of terms and conditions when downloading Apps and using online services.

Mobile location analytics provides unprecedented visibility into consumer behaviour (Zvi, 2019), and the use of smart phone data helps understand the individual within the city (Paulos et al., 2008: 1) and enables new systems of 'smart' urbanism including tenant experience apps. The value generated by being able to track the behaviour of users of space is being captured by many PropTech start-ups, while a new industry of data brokers facilitates the trade of such information.

3.2 Application Programme Interfaces (APIs)

Given that much of the data needed to increase the efficiency of the real estate market can be and is captured, the innovative PropTech application needs to gain access to it. An Application Programme Interface, or API, is a set of functions and procedures that allows the creation of applications which access the features or data of an operating system, application or other service. These links can be built into software platforms which enable others to export data for use in their own systems. Open-access APIs have made it possible to aggregate real estate data in real time from different sources without large implementation costs, informing valuations and investments through a deeper understanding of a property.

However, much of the real estate data needed is held privately and contained within analogue documentation, and is not so easy to aggregate or access. Many data providers and exchanges are aiming to become the sole provider of real estate information to facilitate greater market transparency, while making financial gains through charging third party organisations for use of their API. There will be many losers.

3.3 Data analysis and visualisation

Those who are using digitalised systems are most likely doing so through generic software, with 60% of executives saying their firms are still using spreadsheets as their primary tool for reporting, 51% for valuation and cash flow analysis and 45% for budgeting and forecasting (Altus, 2019; see also RICS, 2019). This impedes access to so-called 'big data'.

Data are pieces of information that can be used for reference and analysis. As of 2017, around 90% of the world's data had been produced in the previous two years (IEA, 2017). *Traditional real estate data* includes the size, location, amenities and market conditions upon which we would base an offer for a single property on any given day. *Alternative data* is any data which is being used for anything than its primary collection purpose, and so sits outside of the realm of traditional data. If the local crime rate is being used to decide the price a person may offer for a property, this makes local crime statistics alternative data sets. *Big data* is traditionally defined through 'the three Vs': information which is produced with high velocity, variety and volume. Within real estate, big data can be thought of as that which is being produced in near real time, and too voluminous for traditional regression and

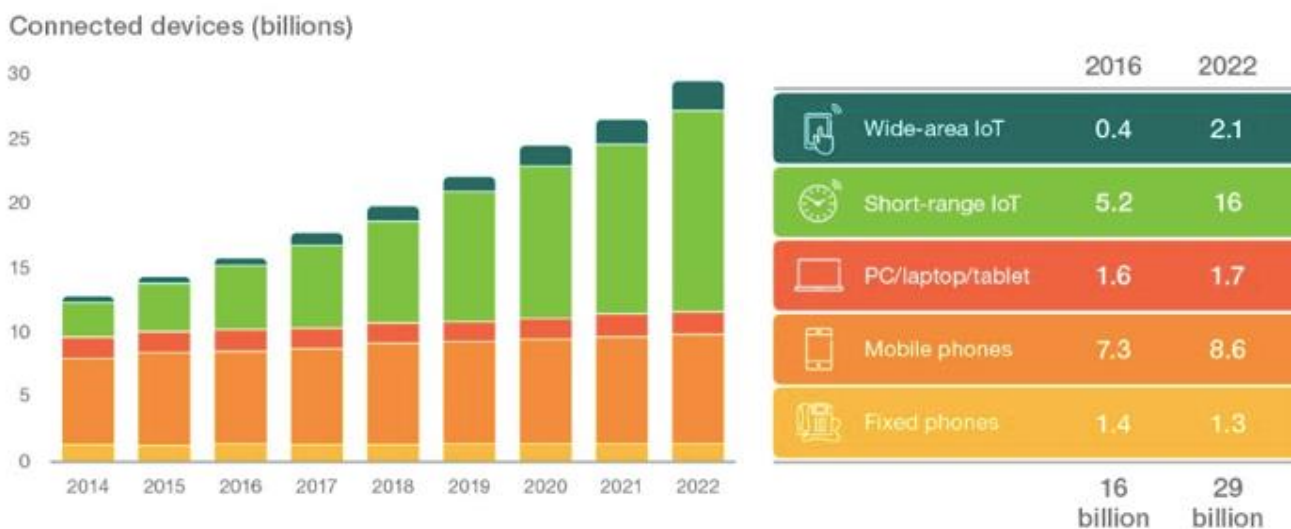
spreadsheet models to interpret. This could be social media activity, credit histories, trip advisor reviews for the local neighbourhood, phone location data and so on.

The reason for the recent ‘data buzz’ is due to the rapidly increasing power of machine learning, a set of self-refining computer algorithms able to find correlation in disparate data sets (see 3.5). Increasing power has been brought about by the exponential development of microchip processors. This breakthrough has suddenly made the analysis of alternative big data sets possible in the world of real estate, a revolution that is fuelling the rise of increasingly intelligent PropTech offerings. To fully understand cities, there is a requirement to “reason from the particular to the general, rather than the reverse, to seek ‘unaverage’ clues involving very small quantities, which reveal the way larger and more ‘average’ quantities are operating” (Jacobs, 1961: 440)

Start-up residential loan company Propportunity claims to offer more competitive loan terms than traditional companies based on their ability to predict the future value of a residential property they lend against through the analysis of alternative big data sets. Macaulay (2018) writes of some of Propportunity’s more novel methods: “Analysis of police arrests and the chemical compounds in sewers that people flush down their drains shows that when the use of crack cocaine drops gentrification could soon arrive, but when the crack is replaced by cocaine, gentrification may already be complete”. This highlights the methods now at the disposal of PropTech innovators, thanks largely to the growth of big data collection and analysis.

3.4 The Internet of Things (IoT)

Figure 15: Internet of Things predicted growth, 2016-2022



Source: Ericsson, 2017

The Internet of Things or IoT refers to any device that can connect to the Internet. Estimates put this number of devices at 29 billion by 2022 (see Figure 15; also Wiggers, 2019).

Advanced analytics are already being provided by the ‘big data’ collected by numerous individual electronic devices (sensors, switches, light bulbs, phones, cameras, fridges and so on), powering smart buildings, and, ultimately, smart cities.

IoT also enables the development of Building Information Modelling (BIM) technology, which is a digital simulation or model of a property, currently associated mainly with new developments. BIM is increasingly being used throughout a building's lifecycle, and IoT devices will help to drive this.

3.5 Artificial intelligence and Machine Learning

Artificial Intelligence (AI) and Machine Learning (ML) are broad terms covering the analytics engine that could power many real estate applications. AI involves coding a machine to perform as desired, while Machine Learning enables a machine to refine its code over every iteration through an inbuilt feedback loop (a Neural Network), increasing its efficiency over time. *“In short, the best answer is that: Artificial Intelligence is the broader concept of machines being able to carry out tasks in a way that we would consider “smart”. And Machine Learning is a current application of AI based around the idea that we should really just be able to give machines access to data and let them learn for themselves”* (Marr, 2016).

This technology's predominant use case is in predictive analytics, producing increasingly accurate algorithms to find increasing sense in the newly-available swarms of big data. Automated valuation models (see Chapter 5) would be an ideal application of machine learning techniques.

The current model through which Machine Learning takes place is known as a *Neural Network*. The development of neural networks has been key to teaching computers to think and understand the world in the way we do, while retaining the innate advantages they hold over us such as speed, accuracy and lack of bias. Welcome to the world of (decision) trees and (random) forests!

A Neural Network is a computer system designed to work by classifying information in the same way a human brain does. It can be taught to recognize images, and classify them according to elements they contain. Working on an advanced system of probability based on the data fed to it, a computer programme is able to make statements, decisions or predictions with a degree of certainty. The addition of a feedback loop enables 'learning'. Through validation or rejection of whether its decisions are right or wrong, the software can modify the approach it takes in the future. These are increasingly being used in real estate analysis and prediction, finding correlations beyond what is possible through traditional regression models.

Another field of AI based around Machine Learning techniques known as *Natural Language Processing* (NLP) has also emerged. NLP applications attempt to understand natural human communication, either written or spoken, and to communicate back to us using similar, natural language. ML is used to help machines understand the nuances in human language, and to learn to respond in a way that a particular audience is likely to understand. While this is particularly important for use in chatbots and lease information extraction technologies, it is currently most evident in home assistants such as Alexa which have entered the residential market over the past few years, changing the way people engage with their household utilities and entertainment systems. While these are only just beginning to be used in commercial space (with JLL releasing their employee voice assistant JiLL in June 2019), real estate companies will also need to understand how to market their products and services in a world of audio and voice search.

A third field of AI development is *computer vision*. Enabling computers to gain high-level understanding from digital images or video has been in the headlines for all the wrong

reasons, with facial recognition scandals at Sidewalk Labs in Toronto, Government intervention on ethical grounds at Kings Cross in London, and Huawei banned in the US. While this technology is heavily used in China, European and US privacy laws could restrict its deployment over data security and data manipulation fears. Despite these problems, there is no denying that this technology could have a huge impact on real estate. The development of facial recognition technology will foster the understanding of space utilization and enable personal preferences to be adjusted in any one space. It will also allow retailers to better understand the customer within the store or shopping centre and to personalize shopping experiences accordingly.

The capacity of neural networks grew 60 times over three years between 2013 and 2016. The error rate for computer vision in 2015 was 3.5% compared to the human error rate of 5% for certain closed tasks, while by 2017 the error rate of voice recognition had dropped below the human level of 5% (Slumbers, 2019a). However, the speed at which AI has been developed has outpaced our ability to regulate its use of personal data, a void that has long been exploited by major technology providers: *“Many of the practices associated with capitalizing on these newly perceived opportunities challenged social (privacy) norms...and are contested as violations of rights and laws”* (Zuboff, 2015: 85). These practices enabled power to be seized by technology providers, while use of their services became a requirement for social participation.

3.6 Blockchain and Distributed Ledger Technology (DLT)

A distributed ledger (also called shared ledger) is a consensus of replicated, shared, and synchronized digital data spread across multiple sites, countries, or institutions. There is no central administrator or centralised data storage.

Blockchain is a DLT-based technology and business practice built on peer-to-peer transaction data held in a packet of information (a block). This allows systems to create and develop a permanent ledger of historical transactions and power a current ownership register.

Distributed ledger technology or DLT is a limited form of digital transaction facilitation. Blockchain is a wider system implying the collation and storage of more (even non-digitalised) information in a decentralised database. Recent advances in this technology mean that one open source, public system will facilitate private transactions where the details of the parties involved can be hidden from all but those who need to know (this is known as a shield contract). Blockchains have been too slow and power hungry in processing transactions, but both of these issues are likely to be solved through batch processing.

Blockchain is associated with Bitcoin, its first application, and more generally with cryptocurrency. Facebook’s announcement of a new crypto-currency called Libra could signify a major revolution, and could lead to a whole new methods of transacting, recording, pricing and owning real estate. Additionally blockchain could offer a repository through which personal data protection is more easily enforced, as is evidenced by a similar (but different) cryptographic system used for the e-Estonia national identity system.

Technology strategists Gartner (2019b) highlight the 5 key components of blockchain (see Figure 16).

Distribution: Blockchain participants are located physically apart from each other and are connected on a network. Each participant operating a full node maintains a complete copy of a ledger that updates with new transactions as they occur.

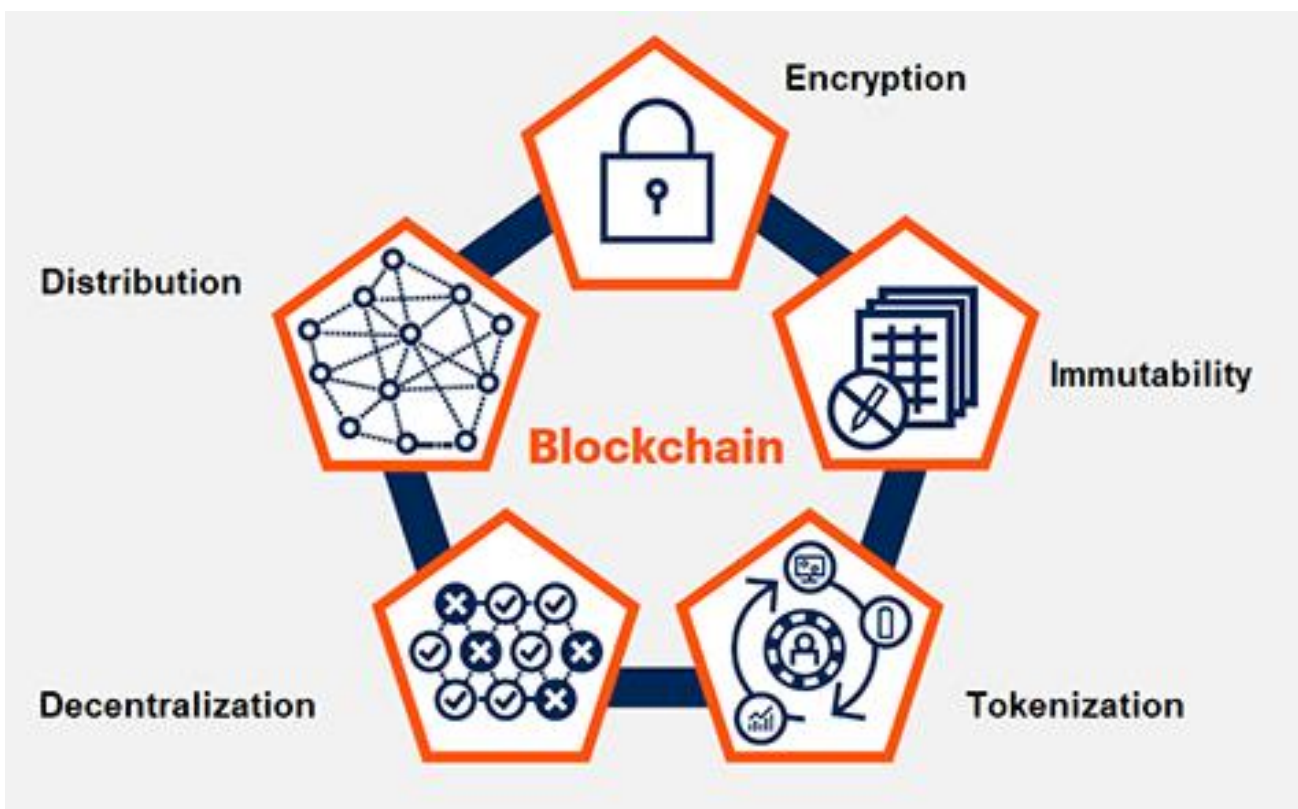
Encryption: Blockchain uses technologies such as public and private keys to record the data in the blocks securely and semi-anonymously (participants have pseudonyms). The participants can control their identity and other personal information and share only what they need to in a transaction.

Immutability: Completed transactions are cryptographically signed, time-stamped and sequentially added to the ledger. Records cannot be corrupted or otherwise changed unless the participants agree on the need to do so.

Tokenization: Transactions and other interactions in a blockchain involve the secure exchange of value. The value comes in the form of tokens, but can represent anything from financial assets to data to physical assets. Tokens also allow participants to control their personal data, a fundamental driver of blockchain's business case.

Decentralization: Both network information and the rules for how the network operates are maintained by nodes on the distributed network due to a consensus mechanism. In practice, decentralization means that no single entity controls all the computers or the information or dictates the rules.

Figure 16: The 5 components of blockchain



Source: Gartner, 2019b

Smart Contracts are used for the automated movement of funds, data and agreements. They are contracts written in computer code which can react to information sent to them from a

DLT-based storage system. Smart contracts can be self-executing and self-enforcing, meaning that a contract can enforce a pre-determined outcome once the required criteria are met. They can be standard, multifaceted, multi-party or tailored to individual needs and can eliminate timing differences by making an exchange simultaneous. Currently, Smart Contracts do not have a legal status and are used as a guide to protocols of exchange. However, like eDocs and eSignatures, they will eventually acquire legal status and be able to enforce these protocols in the future, most likely working in tandem with traditional, paper-based legal practices where human judgement will still take precedence.

Blockchain is not, unfortunately, foolproof. Garbage can be maliciously uploaded – collaborative consensus is needed to push it out. The identity of the uploader of garbage is known, and any upload can be disputed and changed so that eventually there is a consensus, but there is no third party arbitration and the system relies on trust and collaboration. In practice, this may reduce to a reliance on professional advisors participating in the system and acting effectively as arbiters.

3.7 Sensors

Micro-sensor technology provides the toolkit with which emerging PropTech companies have begun to record data and offer operational efficiency gains.

With the development of ever smaller, cheaper and smarter sensors, potentially located within other devices (even lightbulbs: see for example, the Gooee system), the real value for the real estate industry comes in the connectivity between the individual sensors and platforms able to record their output. This connectivity between devices and sensors of any sort has already been referred to as IoT. Market Research Engine (2018) estimates that the global IoT sensor market will reach US\$8 billion by 2024.

Figure 17: A wireless IoT sensor



Source: Disruptive Technologies, 2018

Modern IoT sensors are able to report on a wide range of environmental indicators including Temperature Sensors, Pressure Sensors, Humidity Sensors, Flow Sensors, Accelerometers, Magnetometers, Gyroscopes, Inertial Sensors, Image Sensors, Touch Sensors, Proximity Sensors, Acoustic Sensors, Motion Sensors, Occupancy Sensors, Image Processing

Occupancy Sensors (IPOS), Intelligent Occupancy Sensors (IOS), CO2 Sensors, Light Sensors and Radar Sensors (Market Research Engine, 2018).

PropTech companies in this field range from Disruptive Technologies, who have built the world's smallest wireless IoT sensor which can be discreetly placed around an office to measure energy usage or desk availability (Figure 17), to Demand Logic, whose platform delivers real time building facilities management analytics.

The most widely used sensor in PropTech is the smartphone. In the near future, the role of the smartphone in human monitoring will be replaced by wearable or embodied trackers which are better able to monitor biological indicators of productivity and sentiment such as stress levels, tiredness levels and heart rate, in order to inform the design of the 'smart workplace'.

3.8 Virtual and augmented reality

Virtual and augmented reality (VR and AR) offer a new way of using artificial intelligence to visualize what would previously have been two-dimensional floor plans and photos, offering an interactive three-dimensional video model of a piece of real estate which is capable of being accessed remotely and cheaply. Combined with BIM, VR and AR are enabling architects to provide a near-real interpretation of their designs and can help to eliminate wasted trips and site visits, while also being increasingly used to virtually design and furnish a fit-out prior to commencement.

Figure 18: Virtual reality viewings



Sources: Morley, 2017; Augment, 2016

Perhaps the largest breakthrough in AR will come with the mass roll out of 5G. The increased processing power enabled by this latest generation of digital connectivity will encourage the widespread adoption of 'smart glasses'. The consequences of this could change how users perceive and interact with any given space. Smartphone users are already beginning to use filters to augment the environment around them through applications such as Snapchat and Instagram. This overlaying of digital augmentation upon the real physical world could be greatly enhanced through the introduction of smart glasses.

Personalisation and variation of experience will become easier to deliver, so that no two individuals will have the same visual experience of the spaces they occupy. We can imagine a meeting room with blank walls and chairs, where presentations are preloaded onto a shared set of smart glasses, enabling dynamic and interactive charts, videos and virtual inspections to take place.

3.9 Geospatial and 5G technologies

Geospatial technologies are those that use satellite and mobile phone masts in order to provide a spatial analysis of real assets and the movement of people between them. Sometime called digital mapping, applications like Google Maps and GPS are increasingly used to identify plots of land for development, feeding big data analytics about regions and buildings, and revealing plot boundaries to which legal documentation can be tied.

Geotagging, 'proximity solutions' and beacon software enable digital data to be sent to users of an app within a specified physical location which is given away by their smartphone. This technology is already being used across social media including Foursquare, mainly for targeted advertising in shopping centres. While the world of real estate marketing has fallen behind, it is not difficult to envisage a world where a prospective house buyer receives the marketing brochures of available properties as they walk the streets of a neighbourhood. Alternatively, a simpler solution is to place a QR Code (a unique digital barcode) on the sales board, allowing a smartphone user to scan the marketing board and be re-directed to the online marketing brochure.

Figure 19: A 5G small cell signal router



Source: Vaughn, 2019

The development of 5G, the newest form of mobile data connectivity, offers increasingly accurate positioning of individuals within a building, as well as the positioning of autonomous vehicles relative to one another and the cityscape within which they operate. The higher frequency of 5G bandwidth means that there is far less interference with its signal, creating pinpoint precision in measuring a device's location. However, the downside is that it is unable to broadcast across large distances. As a result, 5G routers will need to be deployed in and around the existing urban infrastructure in order to fulfil their promise (Figure 19) producing another revenue opportunity for real estate owners.

It is estimated that the rollout of 5G could result in creation of £173bn of incremental UK GDP over a ten-year period from 2020 to 2030 (Vaughn, 2019). However, the rate of development of new technologies means that the risk of obsolescence is difficult to avoid: as an example, the University of Oulu in Finland has published a white paper for the rollout of 6G internet connectivity (Smart Cities World, 2019).

3.10 Cloud computing

Perhaps the most mainstream of the technologies underpinning PropTech, cloud computing is the practice of using a network of remote servers hosted on the Internet to store, manage and process data, rather than using a local server or a personal computer. This means that files previously held in an individual business location can now be accessed by anyone with permission, anywhere in the world, on a multitude of compatible devices. Accordingly, cloud servers clustered in huge data centres (another real estate revenue opportunity) have become indispensable, with mobile access to data driving this adoption. Virtual data rooms have replaced physical documents for due diligence enhancing transparency and security; collaborative software applications have become standard; and digital workflows help with the transparent and time-optimized execution of standard processes. Knowledge workers have been freed to work from anywhere within range of a good wireless signal, changing the nature of office work and design.

Perhaps the most common use case for cloud computing has come with the development of software-as-a-service solutions. This means that the pace of technology development has increased as software upgrades are continuously delivered. Platforms are being created that allow real estate owners to manage their properties in the simplest way possible. Further efficiency gains are expected with software companies Microsoft and RIB developing a cloud solution for BIM modelling (PWC, 2018).

3.11 Transportation tech: drones, autonomous vehicles and hyperloop

Advances in mobility will undoubtedly have a significant impact on the future of urban landscapes and building design, and thus on the real estate industry. The impact of Elisha Otis' invention of the commercial elevator helps us to understand the impact that transportation has upon office building design, occupation and efficiency, and on the shape of cities. The introduction of the steam engine, the motor engine and more recently the jet engine have led to logistic networks that affect the location value of every single building. One cannot easily disentangle transportation from real estate.

The real estate industry is currently the second biggest user of commercial drones (after photography). Currently these are used in due diligence and site inspections. *“Drones can survey potential sites and conduct inspections quickly, increasing the efficiency of site selection, inspections, regular maintenance and more. They can also reduce risks by ensuring all parties have more comprehensive and thorough information about a property.”* (Welles, 2018).

Figure 20: Marketing footage derived from a drone

Source: Drone Dispatch, 2017

Flying vehicles are not just being touted for their use in photography and logistics, but flying passenger vehicles are also due to begin trials. While start-ups such as Skyportz (Australia) aim to develop the infrastructure for vertical take-off and landing aircraft within urban locations, another start-up called Skyports (UK) has begun to option flat commercial rooftops on the premise that these currently unutilised spaces will fetch a high premium in such a scenario. (See also Skyscape, which offers to unleash the value of rooftops via rooftop analytics.)

Companies are now trialling land-based drones for use in last mile delivery, while autonomous (self-driving) vehicles have been well documented as potentially removing the need for parking spaces, thus freeing up redundant parts of the urban landscape. All in all, the impact on real estate could be dramatic; all current assets contain or require some form of on or off street parking. What will become of purpose built, multi-level car parks under such a scenario?

There will be less congestion and the rise of a new sharing economy to minimise any redundant vehicle capacity. Logistics can operate around the clock 24 hours a day, with no drivers requiring breaks. London office buildings such as 22 Bishopsgate already require associated fulfilment centres to accept parcel deliveries which are then re-routed to the mother site at specified times of the day. A company called Embark aims to develop cargo transfer hubs on the outskirts of major US cities specifically for the transfer of loads from a manual local truck onto a driverless truck.

Hyperloop is a new highspeed, underground shuttle system for private motor vehicles currently under development in Los Angeles. While this in itself will not impact global real estate to any significant extent, similar increases in the speed of private horizontal travel, subterranean or not, will re-define the way in which future cities and their transport infrastructure are designed, most likely with a large increase in low emission and pedestrianised city centres.

3.12 Other technologies

The *3D printing* process builds a three-dimensional object from a computer-aided design (CAD) model, usually by successively adding material layer by layer, which is why it is also called additive manufacturing. Its applications to building construction and engineering, and the design flexibility this technology offers, are being explored.

The introduction of ‘*wearables*’ into the built environment will enable real time location statistics, as well as user wellbeing and productivity information, to be recorded. In using IoT enabled smart watches or fitness trackers, the occupiers of space can educate their environment enabling the dynamic systems within a building to adjust daylight, fresh air, and temperature in order to increase occupant wellbeing. This data could also be used to adjust building design in the long run if it is proven that any particular building feature significantly improves biological indicators of stress, satisfaction and wellbeing.

Quantum computing is a long way from commercial viability and is in its early stages of development. While it is too early to understand how and where this may change real estate, it is important to be aware of the enhanced computing power (derived from theories of quantum mechanics and multiple universes) supposedly achievable by these machines and how they may be able to almost instantaneously solve previously impossible mathematical equations. Such capacity threatens to rebuild the digital ecosystem as we know it today, and even the most advanced cyber security could be undone in a matter of seconds. It is thought by some that the required breakthrough in big data analytics and smart city functionality will only be unlocked by the rollout of such machines.

Climate change pressures have led to ever-more ingenious breakthroughs in *environmentally friendly building materials*. There now exists paint which is able to reduce levels of carbon in the room, and perfectly transparent photovoltaic glass, able to turn any window into a solar panel. As the further development and reduced pricing of these technologies make them more attractive, we can expect buildings which are carbon neutral and then buildings which are able to create renewable energy to help power the grid.

3.13 Applications

In the following three chapters we employ our tri-sector taxonomy (Baum, 2017) to disentangle the many PropTech innovations being developed from these technologies by around 7,000 start-ups financed by a minimum of \$20bn of VC investment (Chapter 1).

Figure 2 in Chapter 1 is the relevant schematic, and our taxonomy is built on the three horizontals and three verticals described in that chapter. PropTech businesses (i) **offer information provision**; (ii) **support transactions and build marketplaces**; and **offer management and control systems**. These are the horizontals.

The verticals are **Smart Real Estate**, which describes technology-based platforms which facilitate the *operation* of real estate assets. The assets can be single property units or entire cities. The platforms may simply provide information about building or urban centre performance, or they may directly facilitate or control building services. This sector supports real estate asset, property and facilities management. We discuss this vertical in Section 4.1. Our definition of PropTech excludes ConTech, meaning technology which supports the

design and/or construction of buildings or infrastructure, but ConTech is clearly very closely related to smart real estate, so we touch on this vertical in Chapter 4.

Real Estate Fintech describes technology-based platforms which facilitate the trading of real estate asset *ownership*. The assets can be buildings, shares or funds, debt or equity, freehold or leasehold with a (negative or positive) capital value. The platforms may simply provide information for prospective buyers and sellers, or they may more directly facilitate or effect transactions. This sector supports the real estate capital markets. We discuss this vertical in Chapter 5.

The Shared Economy describes technology-based platforms which facilitate the *use* of real estate assets. The assets can be land or buildings, including offices, shops, storage, housing and other property types. The platforms may simply provide information for prospective users and sellers of space, or they may more directly facilitate, or effect, rent or fee-based transactions. This sector supports the real estate occupier markets. We discuss this vertical in Chapter 6.

4. Innovations: Smart Real Estate

In this chapter we describe PropTech innovations in the Smart Real Estate sector, which facilitates the operation of real estate assets

Poster Children: EDGE Technologies, ProCore, Autodesk, Johnson Controls, Katerra

4.1 Introduction: ConTech and smart real estate

Smart Real Estate describes technology-based platforms which facilitate the *operation* of real estate assets. The assets can be single property units or entire cities. The platforms may simply provide information about building or urban centre performance, or they may directly facilitate or control building services. This sector supports real estate asset, property and facilities management.

Since PropTech 3.0, the scope of definitions surrounding what makes a smart building has shifted somewhat. Smart building development has been driven by sustainability, but a clear division needs to be made between ‘green buildings’ which facilitate environmental sustainability and ‘smart buildings’ which now increasingly facilitate social sustainability criteria such as occupant wellness, productivity and satisfaction, as well as economic sustainability criteria such as space utilisation. Having said that, an increasing body of research linking environmental factors such as air quality to social factors such as wellness and productivity means the broad scope of smart buildings is now re-connecting smart buildings with the green building movement.

“A smart building (i) stabilises and drives a faster decarbonisation of the energy system through energy storage and demand-side flexibility; (ii) empowers its users and occupants with control over the energy flows; and (iii) recognises and reacts to users’ and occupants’ needs in terms of comfort, health, indoor air quality and safety as well as operational requirements. The most fundamental requirement of any smart building is that it is energy efficient and provides a healthy living and working environment for the occupants” (De Groote, Volt & Bean, 2017: 8)

In addition to green initiatives, the origins of the Smart Real Estate industry lie in ConTech. The funding of construction technology start-ups grew from \$730 million in 2017 to more than \$3 billion in 2018 (including large funding rounds for two companies raising \$1.96 billion). This is somewhat less well funded than the PropTech sector, but ConTech bumps into and at the same time underpins PropTech and the two industries can be difficult to disentangle.

ConTech is increasingly a defined area for investment by VC firms such as Brick and Mortar Ventures, which closed a \$97.2 million targeted fund in August 2019. The first unicorn in this area, ProCore, and newer firms such as Plangrid, Holobuilder, Micello, Kahua and Rhumbix, focus on data-driven efficiencies across the construction process, such as recording and benchmarking productivity, facilitating the exchange of information between main and sub-contractors, sharing plans and simply replacing paper-based reporting in a huge industry whose IT spend is believed to be below 1% of total costs.

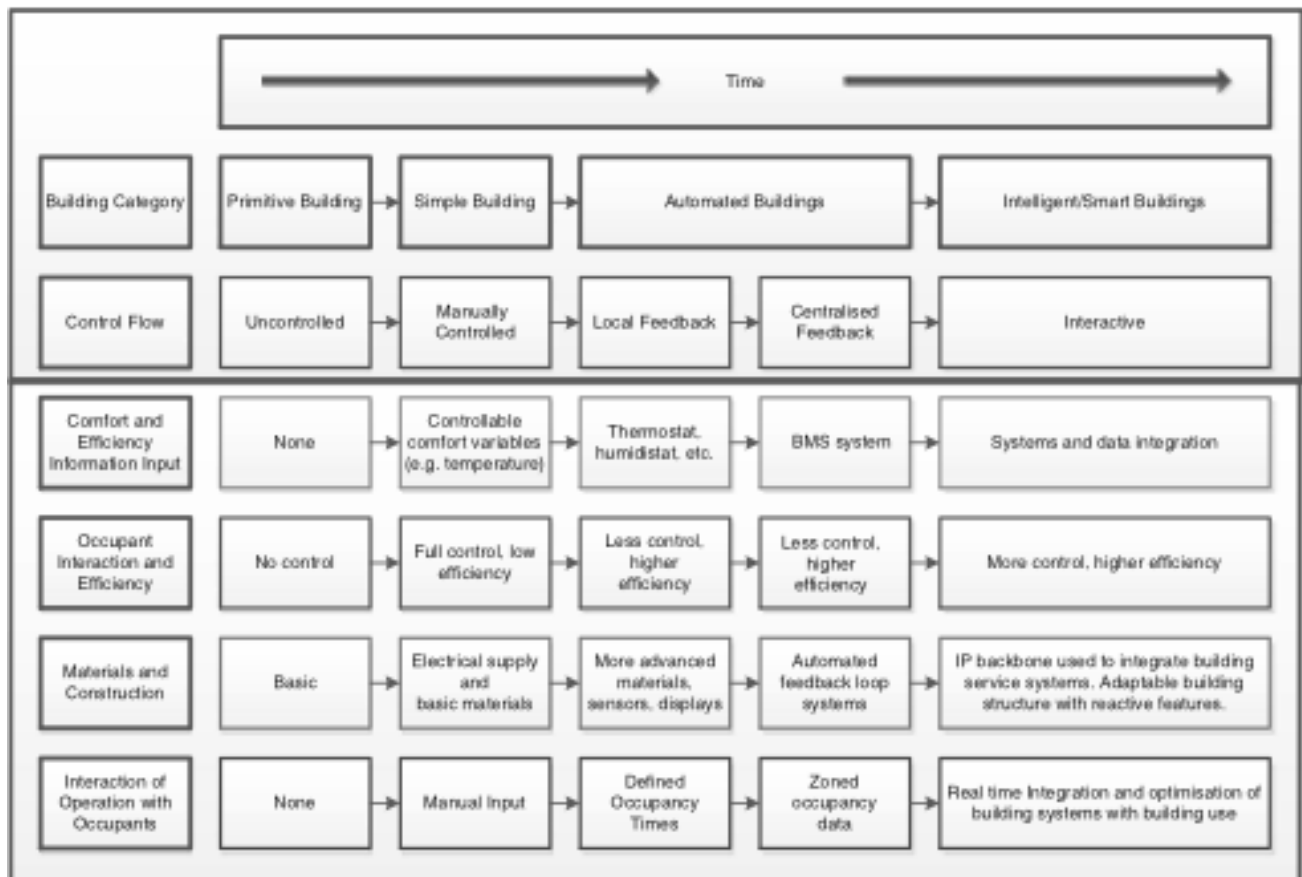
The technology used in the construction industry is increasingly important when it comes to understanding the full lifecycle of an asset and amassing relevant lifecycle data. Advances in ConTech will also have a large influence on the way we finance, transact and occupy real

estate, particularly residential. With both a global climate emergency and a global housing shortage, any increase in the efficiency of production in this sector is likely to be supported.

4.2 Smart buildings

Buckman et al. 2014 summarise the components of a smart building (see Figure 21).

Figure 21: The elements and functionality of a smart building



Source: Buckman et al., 2014: 95

WiredScore has created a unique certification system to benchmark the digital connectivity within a building. Competition will come from the new Intelligent Building (IB) Index, due to be launched in 2020 and developed in partnership with Microsoft, Investa Property Group, Willow, University of Technology Sydney and EG.

In the IB system, the criteria for ‘intelligence’ are based on six pillars:

- project delivery;
- instrumentation,
- devices and applications;
- control, monitoring and management;
- economic and fiscal impact;
- social and behaviour impacts; and
- environmental impacts.

The existence of these benchmarks could begin to drive a value premium which an intelligent building should command. However, as with all numerical measurements, many factors are difficult to quantify, and benchmarking a dynamic quality such as building intelligence based on assumptions which can be quickly outdated is inherently problematic.

4.3 Building Information Modelling (BIM) and digital twins

Altus (2019b) surveyed the opinions of 417 individuals at real estate development firms as to their views about the impact of emerging technologies on their sector. The top three technologies which respondents believed were likely to cause maximum disruption were smart building technologies, pre-fabrication (modular construction) and Building Information Modelling. **Building Information Modelling (BIM)** technology can be thought of as “a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition” (National BIM Standard, 2014).

Figure 22: The impact of emerging technology on development

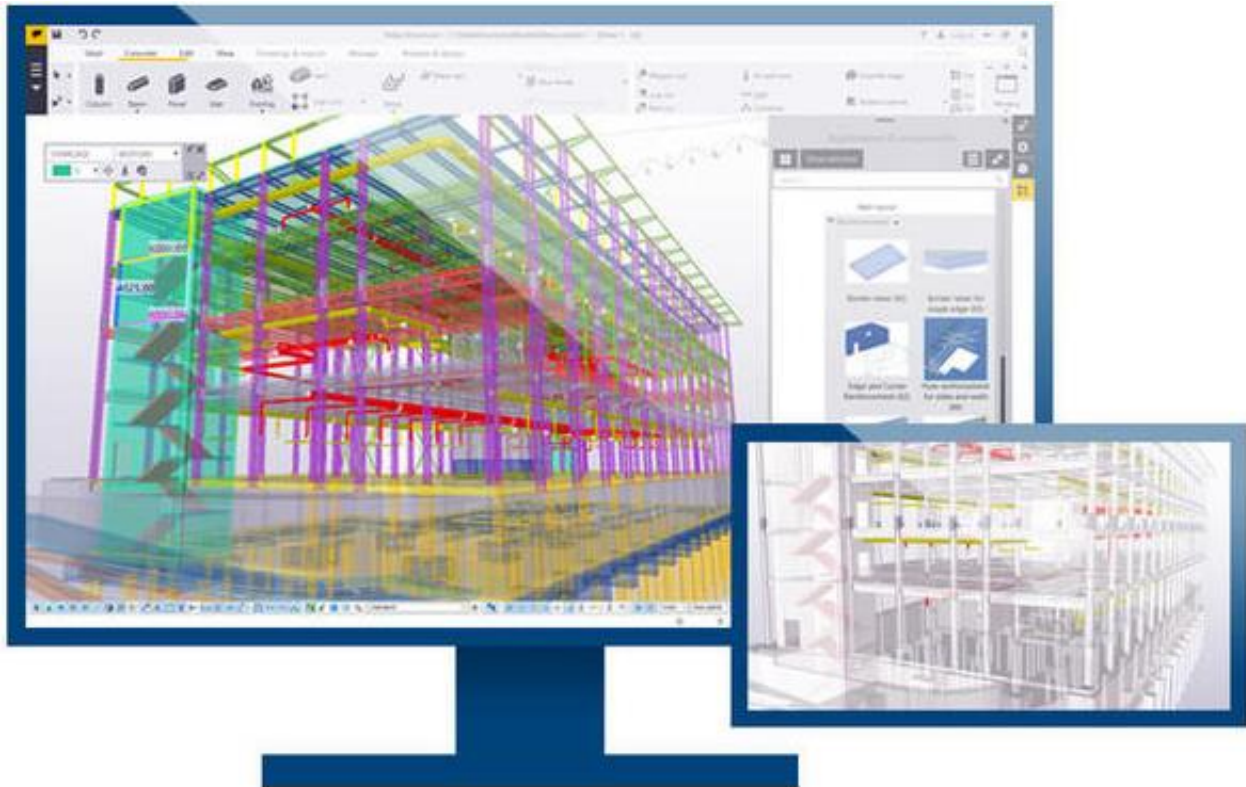
	NO OR ONLY MINIMAL IMPACT ON DEVELOPMENT INDUSTRY	POTENTIAL FOR SIGNIFICANT IMPACT ON EFFICIENCIES AND HOW DEVELOPMENT IS CONDUCTED	WILL CREATE MAJOR DISRUPTIVE CHANGES IN THE DEVELOPMENT INDUSTRY
Smart Building technologies	8%	42%	49%
Pre-fabrication	16%	34%	49%
Building Information Modeling (BIM)	10%	42%	47%
Construction site robotics	32%	32%	34%
Intelligent building design (using Artificial Intelligence + Machine Learning)	30%	37%	30%
Drones	36%	36%	28%
Process automation (Contracts, Workflow, Proformas/Feasibility, Procurement)	56%	22%	22%
Connected job sites	54%	26%	20%
Augmented reality/Virtual reality	45%	34%	20%
3D printing	65%	19%	16%

Source: Altus, 2019b

In essence, BIM can be thought of as a digital simulation for any property that is able to be modelled, currently associated mainly with new developments. Pioneered within the architecture and construction industries as a Contech application, it is increasingly being used throughout a building’s lifecycle.

“Today, the creation of digital assets, such as an avatar of a building, will provide better control management and data. This will help lower costs and risks during the construction and lifetime of buildings since it will require less rework (and fewer) change orders and errors on site.” (Melki, 2018).

“Stakeholders in a project will not need to guess or verify if they have the most recent version of a survey, floorplan or time schedule. All of these facets of a project will be integrated in real time and be accessible to all parties.” (Archambault, 2018).

Figure 23: BIM

Source: Tekla, 2018

At present, while commonly-used software such as Autodesk Revit exists, there is no dominant BIM system. Instead, every party in the design and development of a building will add to the model using their own software. The data model is created by a specialist software company, usually instructed by the developer. At each stage of planning and construction this model will be passed to the necessary contributor to add their expertise to its growth.

“Before a project begins, there will be a BIM for the project that is capable of running operational data through the model in real time, including traffic, utility use, temperature control or movement of people through the building. It will also include all details of structure, MEP (mechanical, electrical and plumbing) and space volume. As each stage is completed during construction, drones and other equipment with scanning sensors can scan and record each phase to verify it meets design plans and code.” (Archambault, 2018)

While BIM is used to provide a user interface, the development of **digital twins** offers additional simulation and control (BCO, 2018). The digital twin is based on the collection of real time data via sensors and IoT devices embedded during construction which feed an AI-powered digital model.

“A digital twin is a detailed virtual copy of a building (in some instances as a part of a larger network of buildings and services) and its systems. The model can be created during the design stage and continue to be updated using post-occupancy data. The twin can be used for intuitive real-time monitoring of a building and will also then act as the cloud-based controller for the building systems. In addition, it allows the building owner to simulate future scenarios to test possible methods for improving performance.” (BCO, 2018)

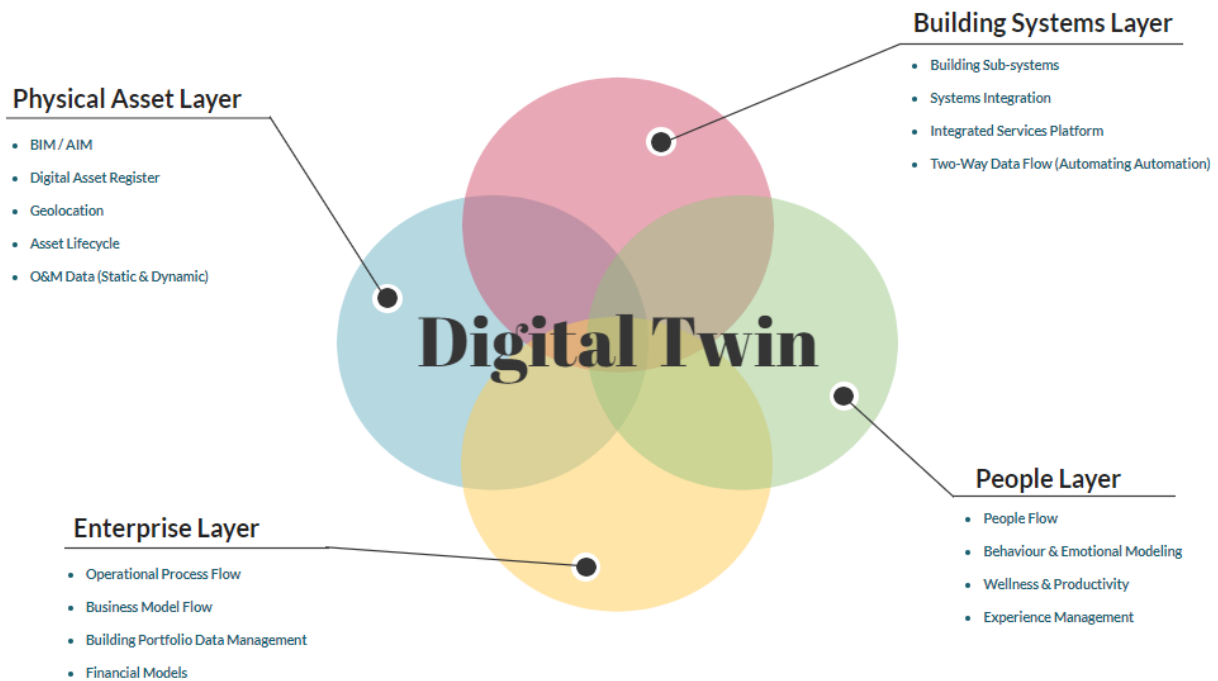
Figure 24: Applications of BIM for differing users during a building’s lifecycle



Source: NBS, 2013

“The digital twin has three components: the virtual replica, the physical asset and the connection in real time between the two. The purpose of the virtual replica is to be a digital equivalent of the asset throughout its lifecycle with the ability to create, test and build a physical asset in a virtual environment to avoid wastage or loss, (and to) optimise performance. The virtual replica gathers all data and specifications in relation to the various stages of the asset, which can be used for all aspects in regard to operations and maintenance” (Savian, 2019)

Digital twins could drastically impact the management of cities. For example, VU.CITY has recently released a model of Greater London (among 7 other major cities) which covers over 3.3m dwellings, including over 6 million trees, all accurate to 15cm. Currently this offering is aimed towards town planners, architects and developers for virtually designing new projects within the existing landscape. However, as more and more information becomes available and complementary technology advances, such a ‘smart city’ model could begin to incorporate numerous BIM and digital twin models, as well as government searches and planning, land titles and lease information. Such a comprehensive digital twin of an urban region would dramatically change the way the real estate industry plans, invests, develops and transacts (ABI Research, 2019).

Figure 25: Digital Twin functionality

Source: Roper, 2019

4.4 Modular construction

Several innovative start-ups have identified complex procurement processes as being in need of disruption. These firms are moving toward a manufacturing-like system of mass production, relying on pre-fabricated, standardised components that are produced in a factory and shipped on a flat-bed truck to the construction site.

Modular construction can involve the assembly of large, standardised blocks. These may be empty boxes, fitted out on site, or complete with flooring, built-in appliances, etc. (Koones, 2019). This offers efficiencies of scale and time in planning, design and construction, enabling homes to be produced faster and more cost effectively.

Start-ups include Katterra in the US, which has raised \$1.2bn to date, and Urban Splash in the UK, which secured £90m, the largest-ever investment from a Japanese firm by a UK business, from construction giant Sekisui House. Future competition may come from outside the world of construction with IKEA, the Swedish furniture prefabrication specialists, also poised to enter the affordable housing market. This is just one of many examples of external threats to the real estate and PropTech industries.

A novel approach to the delivery of prefabricated homes is offered by start-up Ten Fold Engineering and their fold out home concepts. Resembling motorhomes, these buildings are towed into position on the back of lorries before lever technology allows the buildings to expand into structures in less than five minutes.

4.5 3D printing and robotics

In the United Arab Emirates, Dubai's municipal authorities have mandated that 25 per cent of all new builds will be constructed using 3D printing technology by 2030. They believe the technique could have the potential to reduce the amount of labour required by 70 per cent,

overall project costs by 90 per cent, and duration of construction by 80 per cent (Pi Labs, 2019).

Companies such as WinSun claim to be able to construct 10 homes in under 24 hours using 3D printing techniques. Many companies are reporting total costs of construction of around \$4,000 per home, making 3D printing substantially cheaper than any other method (Hay, 2019).

Figure 26: A residential home 3D printer



Source: Morris, 2018

In April 2018, Japanese contracting firm Shimzu announced that it had developed robots which can carry materials, work on floors and ceilings and weld steel columns autonomously. This progression from the stationary mechanical arm is just one of many tasks currently being automated in the construction of buildings. Others include robotic brick layers, and strength-enhancing human exoskeletons (Pi Labs, 2019).

4.6 Smart materials

Some start-ups are improving existing building materials by reconstructing their chemical composition to make them more sustainable. High-profile examples include recent unicorn View, whose dynamic windows improve human health and wellness by preserving unobstructed views, automatically letting in the optimum amount of natural light and greatly reducing heat and glare, cutting the building's energy consumption by up to 20 percent. Going one step further is Physee, whose fully-transparent photovoltaic glass transforms windows

into solar panels. A similar power-generating solution in the form of solar roof tiles has been developed by Tesla.

Other novel breakthroughs include self-healing concrete, titanium dioxide tiles that break down smog when exposed to UV light, carbon take back paint, and reinforced timber frames, allowing wood to now be used in the construction of much larger structures.

4.7 Green buildings

One major stimulus for the smart building revolution was the need to reduce the built environment's impact on carbon emission, primarily through reducing the wasteful consumption of electricity. Globally, the largest source of greenhouse gas emissions is energy consumption, and 40% of this energy is consumed within buildings, which contribute one-third of the world's emissions (Ahmad et al., 2018), a greater amount than is created by both industry and transportation (Pérez-Lombard, Ortiz and Pout, 2008). A small decrease in the energy consumption buildings could have a big environmental impact.

Labeodan et al. (2015) find that the combined HVAC (heating, ventilation and air conditioning), and lighting systems in a typical office building account for around 70% of energy consumed. It is no surprise, therefore, that many PropTech companies are targeting efficiencies in commercial building energy management systems.

In most cases, current commercial building HVAC systems run on fixed schedules and do not employ controls based on detailed occupancy information (Agarwal et al., 2010; Klein et al., 2012; Dong et al., 2018; Ekwevugbe et al., 2017), leading to the current building stock over-conditioning rooms through assuming maximum occupancy rather than being adjusted according to usage, causing a significant waste of energy (Erickson and Cerpa, 2010; Erickson, Carreira-Perpiñán and Cerpa, 2014; Dong et al., 2018). Labeodan et al. (2015: 304) state that “*a substantial number of commercial buildings still make use of coarse-grained occupancy information, assumed occupancy profiles, and schedules with little or no consideration at all of the energy implications and savings accruable at periods when spaces are partially occupied or unused*”.

However, this is now beginning to change with the help of increasingly-connected sensor technology. The real breakthrough will be driven by the increasing ability of AI systems to make sense of the building data collected. AI-powered ‘smart’ Building Management Systems (BMS) will be able to perform numerous autonomous tasks, producing a more energy efficient outcome: “*occupants cannot be completely trusted to exercise energy-conscious behaviour, particularly in large commercial buildings where they are not directly responsible for the cost implication*” (Labeodan et al., 2015: 305).

Such autonomous energy-saving actions undertaken by a smart BMS include:

- *Operating systems based on actual use.* If someone is not in the room, the lights and HVAC can be switched off. If a certain number of people are in the room, more or less CO₂ will need to be removed and differing quantities of fresh air need to be used to replace it.
- *Operating systems based on predictive use.* Over time the smart BMS will be able to learn which areas of a building are used at various times and condition the space in advance, to avoid unnecessary system stress and spikes in energy demand.

- *Operating systems based on ambient factors.* If there is an abundance of daylight at certain times of the day, the system can detect this and dim the lights. If the weather is predicted to change, the forecast can act as an input to the predicted demand for heating/cooling.
- *Predictive maintenance.* A smart BMS is able to learn the energy consumption requirements of individual units in a system. If one unit comparatively shows a temporal or spatial anomaly, this can be a sign of imminent malfunction and works can be undertaken to resolve the issue.
- *Reducing building energy consumption* during a regional demand surge, lowering stress on the national grid.

Legacy BMS typically present an increased opportunity for energy savings. Retrofitted smart BMS can yield reductions in whole-building energy consumption of over 30 percent (MGE, 2019), while the UK Department for Business, Energy and Industrial Strategy (2016) finds that over a third of the measures that will reduce energy use in commercial buildings will use measures with an investment payback of three years or less.

Evidence that energy efficiency is becoming incorporated into market pricing has been elusive, but is now emerging (see, for example, Fuerst and McAllister, 2011 and Zancanella, Bertoldi and Boza-Kiss, 2018). Initially, the drive for sustainability and energy efficiency was a burden which was held by the public – it was a matter for public concern that was not transmitted into market pricing. This is because the consideration paid by a tenant to a property owner for a traditional lease is for the space (and not the utilities). The utility bill was the responsibility of the tenant, and energy waste in inefficient buildings is usually externalised.

As an example, an interviewee identified a package delivery depot which was using significantly more electricity than others, and found that this was explained by staff failing to switch off lights at night because the light switches were hidden. This issue is decreasingly likely given technology enabling the automatic switching off of lights when rooms are not in use, and now the use of sensors to gather information enabling the subsequent automatic adjustment of energy use.

It took quite some time for consciousness about building energy efficiency and the resulting cost to be incorporated in the corporate real estate decision process. This process was accelerated when larger companies were driven to publicise their CSR (corporate social responsibility) policies in order to protect their share price. When this began to be the case, landlords and developers had a motive for producing energy-efficient buildings. Now a lower energy cost could be used to negotiate higher rents and deliver better returns for investors.

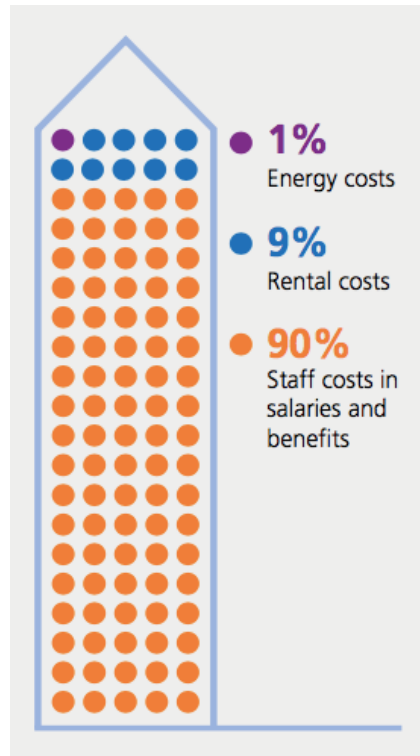
If the developer/owner can generate power within a building and cut out the middleman (the utility company), a much more efficient market for space and energy will develop. However, the landlord will now be concerned to limit the amount of energy used by the tenant. So we will need to be able to develop a system where the benefits of energy saving pass directly to the market participants. This requires intelligent monitoring of energy use through control and monitoring devices, and the efficient transmission of data between the user of the building and the supplier of space and energy.

This theory is supported by Saull (2019), who warns of a landlord-tenant split-incentive problem inhibiting the use of green building technology under typical lease structures. This problem is reduced under more flexible or managed space lease structures under which the

landlord has full control and accountability of the energy efficiency within their tenants' demise.

4.8 Increasing occupant wellbeing

Figure 27: Typical business operating costs



Source: World Green Building Council, 2014

The current drive towards the inclusion of smart building technology has been accelerated by the success of space-as-a-service operators, including in particular WeWork and Spaces. Their flexible leasing model relies on customer retention. For conventional real estate owners whose business model relied on long leases, the need to put user experience at the core of operations was somewhat alien. For years science has told us what we should put in our bodies; only now has interest turned to what we are putting our bodies in.

The World Green Building Council (2014) states that a typical business' operating costs are 90% staff, 9% building rent and 1% energy bills (Figure 27). Even a small improvement in employee health, productivity or satisfaction is likely to represent a significant financial gain for employers, far above that of any savings on energy cost. This is further backed up by a report by the British Council for Offices (2017) which suggests that an effective strategy for delivering a productive workplace is likely to be the single most important contribution that property professionals can make to the success of their organisations, noting how a business could legitimately increase its property costs by 10% if this delivered a 1% improvement in employee productivity (BCO, 2017: 9).

The adjustment of a building's operating systems according to personal preference and individual need, thereby offering a bespoke occupier experience, is slowly becoming possible through the use of occupancy monitoring technologies. However, measuring any uplift in

subjective indicators such as occupant happiness, health and productivity is not straightforward.

Currently, the way we typically try to understand the wellbeing of an individual in a space is through self-reporting. Traditionally, this has occurred through occupier surveys such as the Leesman Index, which is based on surveys asking individual employees to rate the quality of their surroundings and amenities, and to report on how productive they feel. Krekel, Ward and De Neve (2019: 13), used one of these surveys to conduct a study which included over 1.8m employees from over 82,000 individual firms to find that customer loyalty, employee productivity and firm profit were positively correlated with employee satisfaction, while staff turnover and employee satisfaction were negatively correlated.

Single platforms enabling efficient communication channels to be brought into a digital format are currently being pioneered by Tenant Experience (TeX), Apps HqO, District Technologies, Equiem and Locale. These systems allow tenants to book and cancel their own meeting rooms, allow visitors to obtain a digital QR code for signing in and out, and help cleaning to be procured based on a space usage basis. Network Control Group aims to integrate IoT devices using a modular smart workplace platform to *“open the doors to improved wellbeing and enhanced productivity for all”*.

4.9 Increasing space utilisation

Given flexible leases, the reduced utilisation of space through occupancy monitoring can lead to lower costs for building occupiers. A typical workstation in Central London costs £17.5k annually, yet the average desk utilization rate is only 45%. In an office containing 500 workstations, occupancy monitoring enabling 100% desk utilization could save as much as £5m a year in rent alone (Stanton, 2019).

The current race to offer wellbeing amenities such as break out areas, crèches or gyms will soon slow as data reveals which of these provisions are ‘essential luxuries’ and regularly used by employees, and which are not. This data will be reflected in price as the productivity effects of a positive user experience within a space becomes further understood and an analysis of the return on investment of these facilities becomes possible.

The dynamic pricing models introduced by travel and hospitality operators also offer an opportunity to drive more efficiency. Systems gathering usage data will be able to offer a lower price when utilisation is low (Fridays) and a higher ‘surge price’ when demand for desk spaces are high. This will ensure fuller optimisation of the asset and drive higher returns. This idea is increasingly closely connected with the shared economy - see Chapter 6.

4.10 Smart retail

The concept of smart retail has developed as a reaction to online marketplaces such as Amazon and ASOS competing with high street stores or shopping centres. How can the store operators fight back?

Online marketplaces have built, and utilise, large datasets to better understand the customer. Disaggregated retailers are at a disadvantage and need to learn how to pool data resources. Indoor mapping coupled with occupancy monitoring sensors can provide insights into the customer journey both within individual stores and in large shopping centres. The collection of data on average dwell times and the routes taken between shops supports more effective

store and shopping centre layouts, while data describing the adverts a customer is shown and the offers they receive, correlated with sales data, support targeted advertising and offers which are unique to each shopper.

This type of data-driven, experience-focused approach has been used by corporations such as Disney since 2013 to *“increase the time guests spend with them, thus improving the opportunity to extract additional cash along the way,”* according to Disney’s former CFO, Jay Rasulo. The more individual data they can extract, the more Disney are able to tailor services and gain a head start in selling those services (Beckerman, 2019).

These tactics are more easily deployed in shopping centres, where the developer has a vested interest in the success of each individual store in their building. Westfield Stratford, Europe’s largest shopping centre, recently trialled a real time ‘Trending’ pop-up store. The shop was designer-agnostic, using algorithms to stock and sell 100 garments and accessories based on predictions of what was trending on social media channels.

While this is not easily replicable on the high street, platforms such as JoinJo are emerging to offer a single data repository for independent retailers in the same location, creating an enhanced experience for the customer who is, as a result, better able to search and compare products across stores and plan a trip, while facilitating the collection of consumer journey data to better aid the independent retailers. This smart city ‘software as a service’ offering will lower the cost of entry for smaller retail stores, offering them insights previously reserved for large department stores and shopping centres and facilitating targeted advertising.

Further benefits may include the ability to make optimal location decisions, develop mutually beneficial logistics operations and regional comparisons. (Developing truly digitalised bus timetables would also help to make the high street a more attractive destination.)

Online marketplaces are also beginning to understand the importance of physical presence. AmazonGo stores use occupancy tracking and computer vision software to allow a registered shopper to walk in, pick items off the shelf and leave, with automatic payment settled upon exit. This frictionless shopping is likely to grow over the coming years as machine learning software becomes more intelligent and efficient (Slumbers, 2019b).

The merging of digital data and physical retail environments will continue to evolve. This view is backed up by the International Data Corporation’s (IDC) latest Artificial Intelligence Systems Spending Guide, which finds that the global retail industry is set to spend \$5.9 billion/£4.45 billion on AI systems in 2019, more than any other industry (Stevens, 2019a).

We also expect further growth in the use of AR and VR to allow customers to try products before they purchase them in-store. VR experiences will also help customers use in-store technologies to help them gauge the fit of apparel or different looks without having to go to the store, as well as to see which furniture and interior design trends will work in their homes (Stevens, 2019b).

4.11 Smart logistics

According to Savills (2019), the future of logistics will be increasingly urban, driving the repurposing of old buildings to meet the new, environmentally-friendly demands of inner city transportation. For example, a former car park in central London has become parcel delivery company DPD’s first all-electric distribution centre. From this 464 sq m facility, 2,000 parcels

a day will be delivered by all-electric vehicles to the capital's SW1 postcode area. The site also includes a pick-up shop allowing customers to collect and return parcels. The company expects to open seven more micro all-electric units across the city and a second London depot, in Shoreditch, has already been secured.

As noted in Chapter 3, London office building 22 Bishopsgate requires an associated fulfilment centre to accept parcel deliveries which are then re-routed to the mother site at specified times of the day, while Embark aims to develop cargo transfer hubs on the outskirts of major US cities specifically for the transfer of loads from a manual local truck onto a driverless truck.

4.12 Smart residential

Smart home technology is perhaps the largest growth market for PropTech in recent years, dominated by home voice assistants. The smart speaker market grew by 55.4 per cent over the second quarter of 2019, seeing 26.1 million devices sold and shipped. Amazon (Echo), Baidu and Google (Alexa), the three market leaders, sold 6.6million, 4.5 million and 4.3 million units respectively over the quarter (Stevens, 2019c).

MIT robotics spin-off Ori recently received funding from Alphabet and Ikea to develop affordable motorised furniture which can convert a wardrobe into a bedroom, or a sofa into a dining table in a matter of seconds. Given the increasing demand for flexible space, dynamic furniture could be one development which could find its way into the commercial realm.

4.13 Emerging sectors

The 1980s created a new property sector. High tech (or hi-tech) buildings were initially the mixed use office/industrial buildings which formed the component parts of a science park. Hi-tech described the operations carried on within the building rather the building itself; but now the term has migrated to describe the building.

High tech – another variant of smart buildings - also describes new buildings (and whole new property types) which support technology-based platforms. These include data centres, specialised logistics such as on-line distribution hubs, click and collect stores, Amazon locker sites, co-working space designed for tech companies requiring very fast broadband, and others which we may not have seen yet such as autonomous car charging stations, drone hubs and others too futuristic to describe credibly.

Mega data centres, typically also known as 'hyperscale data centres' and operated by large service providers, are on the rise globally. According to Cisco, global data centre IP (internet protocol) traffic within hyperscale data centres quintupled between 2015 and 2020.

Every day, nearly two billion photos are shared on Facebook services. This produces a huge demand for data storage or cloud facilities. In 2010, Facebook announced plans to build its own data centre in Prineville (Oregon). Since then it has completed three other data centres in Forest City (North Carolina), Altoona (Iowa), and Lulea (Sweden). To support its growth from acquired platforms such as Instagram, WhatsApp and Messenger, Facebook has started construction in two new locations in the U.S. and two more in Europe in Clonee (Ireland) and Odense (Denmark). Facebook has commissioned a new build averaging a million square feet every year in the last seven years.

An industry tracking publication, Datacenter Knowledge, estimated that Facebook was running about 60,000 servers in 2010. Given the scale of Facebook's completed sites, thousands of new servers will come online each year. This is not surprising with the explosion of applications available from the cloud, and the expectation from users for any app to not only work, but also to process any transaction instantaneously. For a company like Facebook, building its own cloud facility is essential.

Connectivity is a main pillar for such mega data centres and their locations must meet the latency (the time interval between request and response) requirements of the applications they are serving. In the last year, Facebook has announced partnerships to help lay trans-oceanic cable from the U.S. between the East Coast and Europe and similarly from the West Coast and Asia. (It is interesting that the trading routes from several centuries ago mirror the fibre optic routes of the digital age.) However, the changing nature of the internet's global information flow is challenging and taxing existing network points, so new ones must be built, sponsored by the likes of Microsoft, Alphabet and/or Facebook.

Deloitte (2018) states that across all sectors investors are most likely to increase allocations in data centres (67 percent) and healthcare facilities (55 percent) followed by mobile towers (49 percent).

4.14 Smart city applications

Digital twins are discussed earlier. However, the idea that digital twins could be held on a single platform to aid city governance has only recently come into consideration. While necessary developments in technology and regulation make this idea still far from a reality, platforms such as VU.CITY offer a glimpse into what such a system could look like. A full city digital twin is becoming possible.

However, smart city solutions are plagued by a lack of digital infrastructure and a severe absence of sufficient national and regional government funding, at least in the US and UK. This poses a large question: do we want to out-source the development of city governance structures to tech providers (such as Google subsidiary Sidewalk Labs in Toronto's eastern waterfront) or other major corporations?

As the development of technology begins to outpace regulation, issues of data ethics and cyber security arise. Confusion and opposing objectives have occurred through a lack of clear guidance on how systems operate and how public data ownership should be managed for the common good.

Further threats exist over the increasing use of IoT devices in buildings which can be used by cyber-criminals as a gateway to wider building systems and employee databases. In Austria, hackers attacked the electronic key system of a four-star hotel in 2017, locking guests out of their rooms and leaving the hotel unable to create new keys until a ransom was paid. In the same year a US casino lost 10GB of data siphoned out through an internet-connected fish tank (Kang, 2019). How would such a risk be mitigated in this age of ubiquitous connectivity if a smart city network, including hospitals, schools and military bases, was constructed on data fed from so called intelligent buildings?

With the world's population set to double by 2050, and with 90% of that growth predicted for Asia and Africa, there is huge potential for the development of smart city technology which is able to aid in the planning, ownership, and operation of informal settlements. This is arguably

a far more urgent need for the focus of technology start-ups than the already developed and functioning city centres of Global North economies. While each region will require its own bespoke solution, whoever is able to piece together this puzzle will certainly help to define not only the future of real estate, but also the future of shelter and sustainable urbanism.

5. Innovations: Real Estate FinTech

In this chapter we describe Real Estate FinTech, meaning the enterprise sector which supports (sale or leasing) transactions of real estate assets

Poster children: Zillow, Zoopla, LendInvest, Opendoor, VTS, CoStar, Leverton, Kira, HighQ, Chromaway

5.1 Introduction

Real Estate FinTech is a PropTech vertical which supports (sale or leasing) transactions of real estate assets, by which we mean buildings, shares or funds, debt or equity, freehold or leasehold, with a (negative or positive) capital value. Real estate FinTech platforms may simply provide information for prospective buyers and sellers, or they may more directly facilitate or effect transactions.

According to Savills (2016) and the World Bank, the global real estate market is worth \$217tr, 75% of which is residential property. Annual real estate trading has averaged \$683bn annually since 2007 and reached \$900bn in 2015. This represents turnover of around 0.3-0.4% of the capital stock. Inventory turnover in the average S&P 500 company averages around 15 times; this is a multiple of approaching 5,000 compared to global real estate. The global real estate market is huge – making up more than half the value of all mainstream assets in the world - but it is horribly illiquid (Baum, 2017).

The concept of liquidity is multidimensional. It not only encompasses the time taken to sell an asset, but the probability of a sale and, critically, the costs associated with transacting (IPF, 2004). The efficient transfer of ownership requires transparency (Schulte et al., 2005) so that market participants may access the necessary information to be able to make a rational decision, thus minimising the adverse factors of illiquidity and accelerating transaction speeds. However, real estate transactions currently occur within highly opaque information systems, often without relevant information publicly distributed through official sources (Juneja, 2019). Accordingly, not only are current transactions inefficient, but this information asymmetry also allows for market actors to involve themselves in insider trading, leading to false market equilibrium (Kurlat and Stroebel, 2015).

During the current global shift towards a reliance on digital technologies, many innovations are emerging which propose to increase the transparency of the real estate market and overcome these issues of asymmetric information and illiquidity. This chapter will seek to expose some of these innovations, explaining how and where they propose to increase market efficiency.

Activity in the Real Estate FinTech category has largely been driven by growth in the supporting FinTech market, which has led the way in reducing transactional friction, the need for market transparency being most obviously satisfied within both residential and commercial real estate sectors through emerging real estate digital data providers such as Zillow, Rightmove, CoStar and others. These PropTech portals or platforms not only ensure that more factors are now considered within an investment decision, but also provide data in a digitalised format, enabling machine learning programmes to execute investment decisions with greater accuracy. The coupling of a strong FinTech ecosystem with an ever-growing pool of available digital residential real estate data has lowered the barriers to digitalisation in this particular sector and, accordingly, much of the Real Estate FinTech innovations

discussed in this chapter are centred around this market. While websites drove residential PropTech 1.0, the key technology driving residential PropTech 2.0 appears to be AI/machine machine-learning. This powers automated valuation models (AVMs), which in turn can drive automated house-purchase enterprises (see below). HouseCanary uses AI/machine learning to value residential property in real time, while 'iBuyers' such as Opendoor and OfferPad use AVMs to guarantee an offer price and quick completion on a property.

“Data science will continue to play an increasingly huge role in predicting home prices for companies like OpenDoor and Knock. Zillow already has a dominant brand - Zestimate - to help home sellers better understand their home values.” (Yardley Ip, Trulia)

In most developed markets, the current end-to-end home buying/selling process is long and cumbersome, generally takes several months and involves seemingly endless fees and paperwork. Can technology make a difference?

5.2 Online residential brokers

Online estate agents have been grabbing market share from the traditional version, with a reduction in the number of estate agents widely anticipated. Zillow, Trulia, Rightmove and Zoopla are all successful tech-enabled information providers or portals in UK and US residential real estate, late stage PropTech 1.0 players who are now relatively mature players with a straightforward information aggregation proposition. These businesses began with residential sales and have more recently moved into lettings: for example, Trulia launched its rental brand in 2017. In the US, Zillow recently bought its close competitor Trulia; in the UK, Zoopla bought Hometrack; in China, Fang, Sina and Juwei (for international property) are dominant; in Australia, the main players are Property.com and Domain. Now, 90% of residential sales are generated by portals and only 5% by estate agents' shop windows. Virtual estate agents led by Purple Bricks have had mixed success based more on cost cutting than on technology.

In the UK, estate agents have traditionally operated on a 'sole agency' basis, and are reliant on instructions to sell properties on behalf of the owner for a fee of around 1%-3% of the purchase price. In the US, sole agency is less common than the pooling of instructions across groups of brokers through what is known as a multiple listing service. This is a collection of services that real estate brokers use, to share information about properties with other brokers who may represent potential buyers; to establish contractual offers; and to accumulate and disseminate comparable information to enable appraisals. The listing data stored in a multiple listing service's database is the proprietary information of the broker who has obtained a listing agreement with a property's seller. Broker fees can as a result of this sharing model be as much as 6%, although the broker also facilitates exchange of contracts and legal professionals are less involved, saving fees elsewhere.

In most developed markets, where debt is used in the majority of house purchases, the bank or lending party commissions a valuation by a qualified professional. This inevitably takes time – form filling by the buyer, processing of the application by the lender, commissioning of the valuation, setting up the inspection, preparing, writing and returning the valuation and processing the information received – which can eat into a large proportion of the 100 days.

Uncertainty over the value of the property can also delay the initial sale process, risking gazumping and a long drawn out negotiation. The HouseCanary proprietors believe that they can develop intelligent AI algorithms which can be accurate for the vast majority of US homes

to within a 2% error range. If this thesis were to be accepted by market participants and lenders for a slice of the current combined total of 11% of the price of the house which is spent by both sides in fees and taxes, perhaps half of the 100-day lag can be taken out of the process. So we can imagine a world in which prospective house buyers can go to one site where all houses on the market are listed, with an independent and public valuation discoverable by the seller, the buyer and lenders. The transaction process would be faster, and the liquidity of this huge asset class would greatly improve (see Section 5.8).

The residential letting process is also characterised by risk and inefficiency. Landlords risk letting to inappropriate and untrustworthy tenants; tenants risk paying out deposits and rent to unsuitable landlords; and a disparate pool of available rentals is matched by a disparate pool of prospective renters. PropTech developments include Rentberry (US), Houzen (UK) which rates letting agents using customer feedback, Reneza (Eu) and TiPi which connect residential landlords and tenants directly via an app, and others. (For more examples, see Baum, 2017; for an update on residential portals, see Delprete, 2018.)

5.3 Automated Valuation Models (AVMs) and iBuyers

Automated Valuation Models (AVMs) utilise Machine Learning to make predictions about the price of any individual (initially residential) property based on publicly-available real estate, economic and spatial data. Through feeding accessible big data and relevant alternative data into a Machine Learning algorithm, AVMs enable the prediction of price for any individual asset within a sample region for which sufficient data is available. This has given rise to new models of both real estate investment and mortgage lending, reducing the time needed to sell and purchase a property.

Much of the alternative data input to these models can be accessed through ‘*scraping*’ relevant websites. *Scraping* is a term used in data science to describe the act of using a computer code to systematically extract relevant information from a third-party website for use within another model or database. For example one could ‘borrow’ the information from Zillow or Zoopla relating to each individual home which has ever been listed on their webpage, such as price, size, location, energy efficiency etc., to be used to inform a predictive model for the fair price of any given residential asset. The legality of this practice is currently debatable. However, open data sets require no permission for such use in which case information can be scraped and updated in real time, enabling a machine learning-based AVM to refine the accuracy of future predictions. Crucially, these models might avoid the stale valuation problem, as a relationship with stock and bond markets (for example) might be established so that a fall in the financial markets might indicate a fall in house prices even in the absence of comparable transaction evidence. If this produces more realistic asking prices, this would clearly improve liquidity.

Residential property

In the UK, Zoopla already offers AVM-derived valuations of UK houses; other tech start-ups have AVM-driven propositions under development. Dijkstra (2017) suggests: “*If [property] information is correct and up to date, the whole due diligence process may change ... since all transaction history and information of properties is available, valuations can become automatic.*”

We shall focus more closely here on Zillow, the largest of the residential portals. Their mission is to increase transparency for home buyers in an industry that is characterised by

fragmentation, opacity, and localisation, through being “*dedicated to helping homeowners, buyers, sellers, renters, real estate agents, mortgage professionals, landlords and property managers find and share vital information about homes, real estate, mortgages, and home improvement*” (Oberoi, 2018). Generally, home buyers rely on agents with imperfect information, biases and preferences, resulting in varied outcomes that generally disadvantage home buyers. Zillow offers home buyers and renters the ability to search a database of over 100 million homes listed by agents and owners (listings include unavailable and ‘for-sale-by-owner’ homes) in order to fully understand market prices and availability (Alsadi, 2015).

Over 80% of homes in the US have been viewed on Zillow and in Q3 2018 the company’s web traffic peaked at over 195 million unique users across their apps and website (Zillow, 2019). 96% of Zillow’s revenue, (approx. \$1.3 billion) comes from selling ads, CRM tools and qualified leads to real estate agents who rely on the site for a sales funnel of potential homebuyers (Zillow 2019b). As described by Van Alstyne et al. (2016), Zillow has leveraged network effects to control the ecosystem for the residential marketplace in the US. A multiplier effect is observed when user numbers increase, leading to more listings and ad revenues that expose the product to a wider audience of agents, buyers and sellers. This continues to drive up user numbers, listings and ad revenues as this cycle continues (Perez, 2019).

Despite the ongoing success of Zillow and other online residential brokers, their business models have recently come under threat by a new group of PropTech 2.0 companies who (as anticipated in our 2017 report) both *list* and *buy* property, through leveraging urban big data and AI to drive increasingly accurate Automated Valuation Models (AVMs). Dubbed ‘iBuyers’, their machine learning proposition has forced a shift in Zillow’s strategy, with the recent launch of Zillow Instant Offers, based on their proprietary AVM the ‘Zestimate’, which enables users to look up the market value of any home in the United States in real time (Zillow, 2019c).

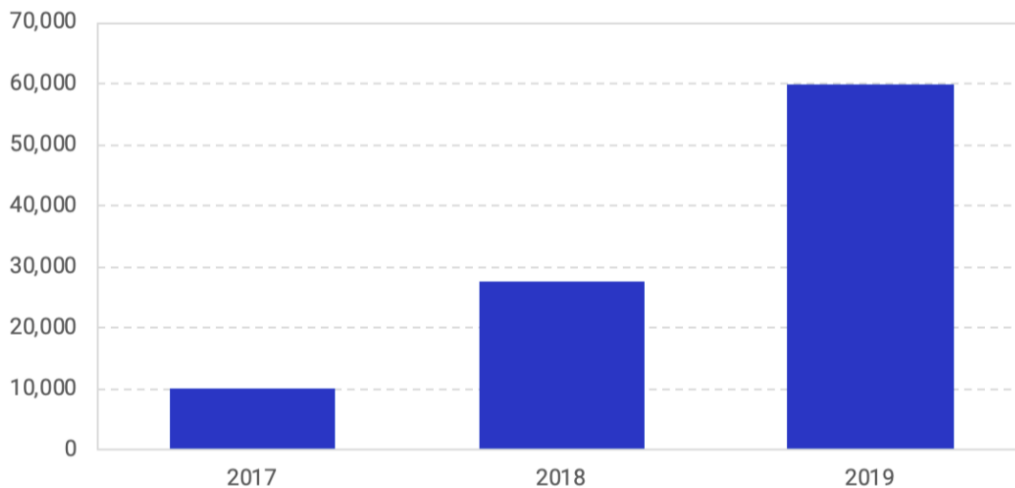
US market leaders in the iBuyer space include Opendoor and OfferPad, with the former recently achieving Unicorn status thanks to a recent US \$400m investment from Softbank’s Vision Fund. These online companies will guarantee an offer price and quick completion on a property, usually within 7 days. They plan to resell the properties at a higher price after a minor refurbishment, further maximising profit margins selling fees and a buyer’s fee, while also charging a service fee of around 7% of property value. The top four iBuyers (Opendoor, Zillow, Offerpad and Redfin) doubled their collective market share in 2019, reaching 60,000 total transactions and spending over \$8.7 billion on the homes they purchased, representing an average purchase price of \$260,000 (DelPrete, 2020).

The intended attraction of these companies goes beyond the instant offer, as they purport to leverage the power of technology to deliver an excellent customer experience. Utilising the Internet of Things, Opendoor allows prospective residential purchasers to enjoy unaccompanied, any time of the day, viewings. Once registered through their app, geolocation technology will guide individuals to the property before remote access is granted via an electronic door lock. A system of remote security monitoring is enabled by the installation of motion sensors coupled with the client’s mobile phone location data. Transparent demand statistics regarding the number of viewings, and thus the level of interest, are able to be published in real time.

AI is also being used to identify prospective sellers prior to the listing of a property. Through targeted marketing strategies, companies are reducing the time taken for marketing and

capturing the selling agent commission. Additionally, AI aids in identifying the best capital market structure available at the time of an iBuyer purchase, facilitating the subsequent bundling of properties into portfolios that will optimise their debt financing options. The success of iBuyers in the US, and the continued rise of companies such as Nested and Propportunity in the UK and Casavo in Italy, would suggest that AVMs are slowly changing the way residential real estate is transacted, and that they will get stronger and more accurate with the proliferation of data currently being produced.

Figure 28: US iBuyer total home purchases by year



Source: DelPrete, 2020

Such is this perceived threat to the traditional model of buying and selling residential property through a local agent, and such are the margins for profit for those with the most accurate AVMs, that market incumbents have begun to follow suit. As already mentioned, Zillow recently made the controversial shift to iBuying in Q2 2018 - controversial because Zillow Offers will become a direct competitor to its main customer, real estate agents. The new and improved Zestimate uses the power of machine vision to scan property photos and identify high and low end fixtures and fittings to adjust its price accordingly. For homes listed for sale, the error rate is now less than 2%, meaning half of all Zestimates fall within 2% of the home's eventual sale price (Zillow, 2019).

Figure 29: US iBuyer competitive advantage comparison

Firm	Key Competitive Advantage
Zillow	Zillow has been collecting home data on a massive scale for much longer than any other competitor, and they will have zero customer acquisition costs because they already own the largest userbase of buyers and sellers. They also benefit from a smaller network of Premier Agents who are "local experts" in their communities and can help train their AVM as well as provide additional leads.
Opendoor	Opendoor has first mover advantage and a foothold in key markets like Pheonix and Houston. The firm also sticks very closely to their AVM and their formula for homebuying (in terms of home type and price) and as a result has seen steady returns on their investments. They have forced incumbents like Zillow and Redfin to react and refine their iBuying models to compete.
Redfin	Redfin's AVM has been proven to be the most accurate at predicting a home's sale value. This is essential to a successful iBuyer as the only way to make a profit in this business is to sell the home for more than you bought it for. They already employ a team of realtors working off a 1% fee across the country enabling transaction volume and they are using technology like advanced virtual home tours to make sales more quickly and cheaply.

Source: Perez, 2019

Critics of the iBuying business model cite the risks involved in holding a large amount of stock during an unforeseen market downturn. How the businesses fare in such a scenario is yet to be seen.

Shared ownership and equity loans

Start-ups offering private shared ownership schemes include StrideUp, Unmortgage, HoP, Heylo Housing, Your Home, ZeroDown and others. These are private market shared ownership products through which no debt is used in the house purchase but a minority owner, who is also an occupier, co-invests with a particular capital source or with a pool of capital which in turn charges a rent for their commitment. This is useful for intending homeowners with insufficient deposits, but has been undercut at the lower end of the market by government Help to Buy equity loans.

We have also seen the emergence of equity loan providers such as Ahauz, Propportunity and others. These organisations will provide cash to bridge the deposit shortfall in return for a minority equity position. Shared ownership and equity loan products have all struggled to achieve scale, although some have managed to raise Series A venture capital funding.

Despite these innovative financial instruments, perhaps the biggest shift in the residential rental market could be cultural. With the rise of the sharing economy comes the proliferation of 'co-everything', and co-living has certainly not escaped this phenomenon. We will discuss this concept further in Chapter 6.

Commercial property

The requirements for commercial property valuations are significantly different and many believe that an accurate AVM will prove difficult to achieve. GeoPhy is attempting to dispel this assumption. The GeoPhy website claims that their current model has a median absolute prediction error of 7.9%, meaning their average predicted asset value is 7.9% higher or lower than the eventual transaction price (GeoPhy, 2018).

The closest one can currently get to an instant purchase of a commercial asset is through a property auction website. Companies such as BidX1 and Clicktopurchase operate in exactly the same way as a traditional property auction but use the internet to market properties and to host all relevant legal documents before inviting interested parties to place remote bids. 41% of BidX users do so through their smartphones (BidX1, 2019).

This development has been recognised by Rightmove, which is currently trialling the Clicktopurchase technology on the Rightmove website, a move which has caused concern within the industry and which provides evidence of the tension within the online brokerage industry given a perceived need to innovate in the threat of iBuyer disruption.

5.4 Instant mortgages

Having the ability to accurately determine a property's value can also aid mortgage lenders and banks in establishing the amount they are willing to loan. The advantages of using AVMs over traditional asset appraisals are that they can reduce the cost and time employed in valuing a property – and they do not offer the risk of fraud potentially associated with the occasional self-seeking appraiser.

UK based company Hometrack, the data provider behind Zoopla's property valuation report feature, are also selling their AVM as a service to mortgage lenders. Hometrack's website states that 12 out of 15 of the UK's largest mortgage lenders use their AVM, which is accredited by all of the major rating agencies, to *"give lenders lower costs and faster time to yes, without increasing risk"* (Hometrack, 2018).

From this foundation, Her Majesty's Land Registry in the UK is exploring how it might assist in the development of instant mortgages as part of their Digital Street Initiative, exploring how geospatial technology can improve the land buying and registration process. While they are not developing this idea in house, the goal is to understand what is technologically possible and to reverse engineer data systems to enable access to the right information from the right sources earlier in the process, and thus facilitate a more streamlined home buying process (Tombs, 2018). The Land Registry's willingness to co-operate with anyone with instant mortgage capabilities will enhance the strength and accuracy of any underlying ML based system.

Kurilyak (2018) compiled a list of further potential applications within the residential real estate industry for data-driven technologies, which include automated underwriting, predicting the expected time of closing a home purchase, report generation and others.

5.5 Commercial real estate data

The importance of data has been stressed throughout this report, in particular with regards to improved analytics using machine learning models and the resulting disruptive business models. Any true disruption to the commercial real estate industry will only come once there is the availability of standardised, accurate, real time, digital data and whoever is the first to reach critical mass will hold a very powerful market position.

With the existence of a strong pool of digital data comes enhanced Machine Learning and AI applications. Skyline.ai, for example, partners with real estate organisations with the goal of establishing investment vehicles augmented by AI. Proda uses AI to extract and update non-digital tenancy schedules that would otherwise be manually retyped.

The CoStar Group is a public company, a conglomerate comprising the CoStar Research platform, Apartments.com, LoopNet and a significant number of other property marketplaces. With a market cap of over \$21bn, this company is more valuable than WeWork and with almost a billion page views per month has established itself as the go-to research and listing tool for commercial properties (Faraudo, 2019c). However, their data is collected through analogue formats, with an army of researchers frequently calling businesses for leads, information and up to date market data. This is in contrast to CoStar's emerging digital data driven rival, VTS.

Accounting and lease management software platform VTS is able to crowdsource much of its data through motivating users to input private cash flow information in return for the offer of an enhanced business accounting experience. Their first anonymised, aggregated data offering comes in the form of MarketView, launched early in 2019. Updated daily, the platform provides near real time insights into industry benchmarks and market trends to users who agree to contribute their asset or portfolio performance data to the existing pool, thus further strengthening the product's accuracy. The VTS merger with Hightower, a \$300 million combination of two cloud-based leasing and portfolio management data platforms, exemplifies the benefits that can be realized in PropTech M&A, including increased market

share and efficiencies from cost savings. The synergies resulting from the merger included a customer base of more than 28,000 real estate users and a portfolio of more than 7 billion square feet.

Combining each company's key investor bases, including data from Blackstone, OpenView, Bessemer Venture Partners and Thrive Capital, resulted in more access to capital (Liggio and Kim, 2019). VTS have since gone on to form a partnership with comparable data provider CompStak and are already servicing one third of the US commercial market while building a presence in the UK market (Business Wire, 2018). The true value of the data they continue to accumulate will become apparent once scale enables them to move away from insights and towards prediction, offering one possible route towards a commercial AVM.

The popular phrase that 'data is the new oil' is never more obvious than in the world of commercial data brokers. As in the political arena, many wars have recently been fought over this 'oil'. In December 2016, CoStar successfully sued Xceligent, its then main competitor, for copyright infringement. In the 34 months since CoStar filed its lawsuit against Xceligent, its stock has nearly tripled from \$183 per share to \$572 per share. More recently, CoStar has acquired hospitality data provider STR for \$450m, while VTS acquired retail brokerage marketing platform PropertyCapsule. It appears that the two are betting big. Will a real estate data monopolist emerge?

5.6 Legal processes and PropTech

Legal Technology is underpinning and transforming much of the real estate transaction (sale and leasing) process. In addition to the opportunity to speed up transactions through smart contracts (see 5.7 below), other LegalTech developments include lease information extraction and cloud-based data rooms. AI is also being used by companies like Proda to digitalise tenancy schedules.

Lease information extraction

Currently the real estate industry is plagued by differing data formats held within unstandardized lease documents and un-interoperable software systems. However, advances in artificial intelligence combined with machine learning protocols has generated a new era of image recognition software able to identify specific data sets in handwritten and scanned documents. These software systems then extract the relevant data to populate digitalised databases which are able to be used in automated systems. The increased processing power of machines over humans also enables them to handle large data sets in a fraction of the time, streamlining this otherwise arduous data entry challenge.

In the conveyancing industry, software platforms such as Leverton, Kira and HighQ are widely available and in use. These programmes are taught to extract, compile and digitalise all the relevant data from a scanned paper document. However, the accuracy and capacity of these systems still needs much improvement. With no standard industry-wide language or lease format used, there are many outliers which the self-taught technology has not previously encountered and is not able to decipher. These current lease data extraction platforms also have difficulties interfacing with other commonly-used software systems across the conveyancing and real estate industries.

Cloud based data rooms

A data room is a single portal that connects the parties to a transaction and their advisers, and has clear applications within commercial conveyancing. Data rooms have been made possible through advances in cloud computing, freeing clients and advisers from the need for expensive and complex in-house hardware. Within a cloud-based data room using APIs, it is possible to share information between the various parties involved in the transaction.

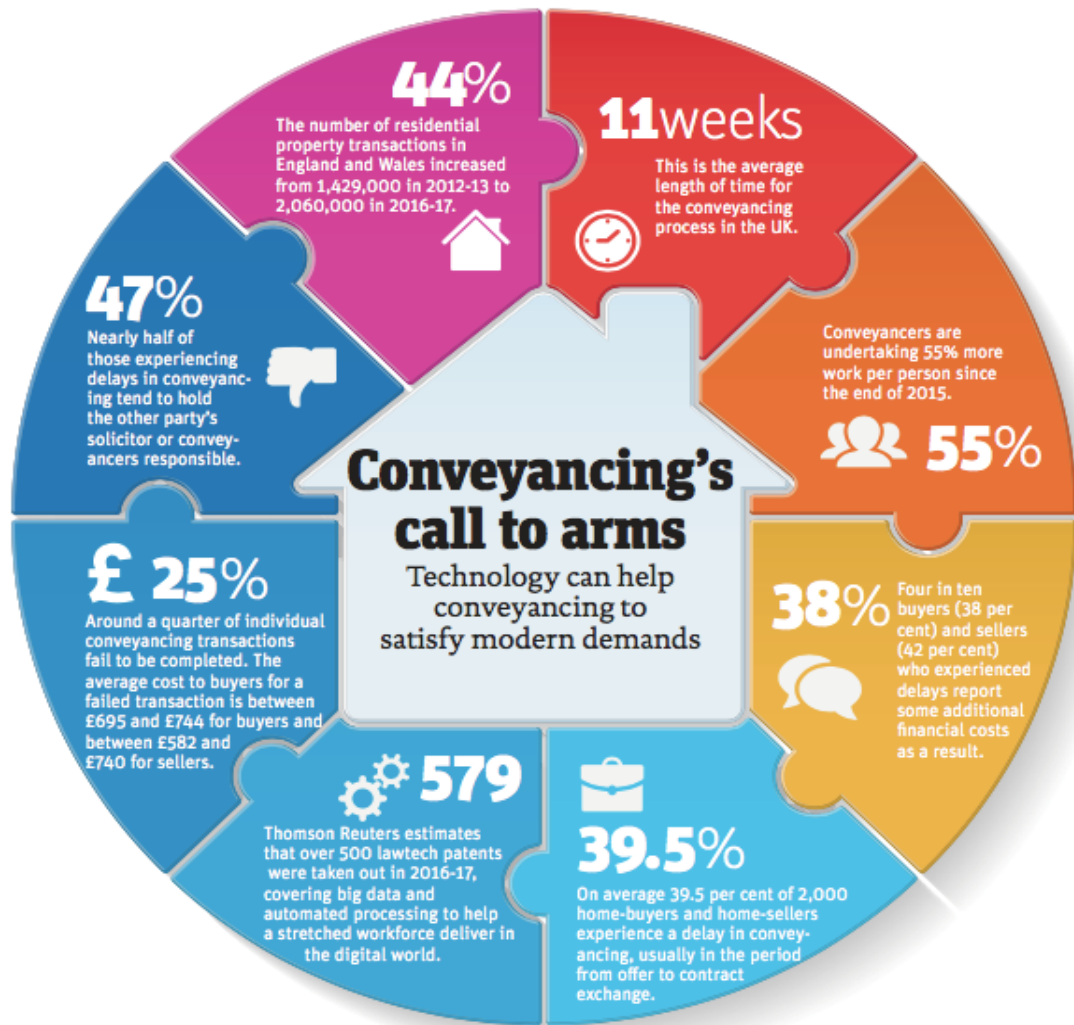
5.7 Real estate transactions

In the pursuit of efficiency, it is important to ensure that the systems by which real estate is registered and conveyed are transparent, secure and quick. Those economies best able to harness the economic and social benefits which come with a high quality of land administration and transference have simple fast-track procedures, low transfer taxes, fixed registration fees, digital registries and time limits for administrative procedures.

PropTech has the ability to bring increased market transparency, liquidity and bring lower transaction costs. This should positively impact the value of investment assets. The digitalisation of both data and processes is evident within the emerging technologies attempting to embed themselves into the transactions process.

At its most ambitious and radical, the technology world imagines a single, distributed system of recording real estate ownership and transactions - the blockchain world – as the ultimate solution. However, we can easily expect too much. The blockchain world is probably a decade away, and may never happen unless it is mandated by regulation and/or supported by industry groups. In the current real estate market, there is very little protection for the buyer in the discovery of undisclosed defects, beyond either title insurance or an upfront structural survey (*caveat emptor*, or buyer beware). Accordingly, buyers instruct lawyers to undertake lengthy due diligence to provide a trusted 'guarantee' of the pre-sale information, and avoid issues of overpaying and unwanted liability. Rapid property transactions are some way away.

Figure 30: Conveyancing delays, UK



Source: New Statesman, 2018

Property passports

The idea of a property passport is a simple one: to store all the information relating to an individual property in its own unique digital data file, to be maintained by the owner, tenant or real time technology and transferred along with the title. Providing an openly accessible, single pool of up to date, standardised property information could solve many of the causes for delay in the transaction process (Saul and Baum, 2019).

The British Property Federation and Future Cities Catapult (2018) cited the establishment of a property passport as one of the key drivers to foster innovation within the real estate industry: *"This would be a data standard for core information to be generated and maintained throughout the property lifecycle and for different users. This might include core asset, financial and building performance information, and could build on recent BEIS consultation on standards for smart systems and a flexible energy system. Our recommendation is for the property industry and government to work together to set up a property passport with common data standards for core information."*

Many believe any such a system will come to fruition with the normalisation of blockchain technology, offering a single immutable repository for all building information and linked

accounts. *“The relationship between Blockchain and real estate has not yet been proven in practice. It is expected to develop further in the form of registering transaction processes and the DNA passport of a real estate (asset).”* (Veuger, 2018).

While blockchain offers transparency and auditability of information contained within a property passport, it is not technology essential to its creation. Dijkstra (2017) suggests that creating a solid, trustworthy and reliable digital identification of a building is inevitable for the future transaction process, but digitalisation does not need blockchain. A property passport which sits at the nexus of many new technologies, combining official land registry title documentation additional ‘smart building’ data from technologies such as the Internet of Things and Building Information Models, could create a ‘digital twin’ of both the functioning and rights over an asset. Companies working on similar solutions include Architrave, Chimni, Home Owner’s Passport, Nimbus Maps, Orbital Witness, Property Made Liquid, Property Log Book, Search Acumen and Sprift.

In the most optimistic minds, a complete property passport serves to warrant a higher asking price at re-sale, providing a motivation for owners to keep information correct and up to date. However, the key remaining problem is: how can we provide a guarantee that the information contained within a passport is accurate and trustworthy? Saull and Baum (2019) conclude that any property passport must come with an insurance backing in order to obviate duplicated diligence and maximise liquidity.

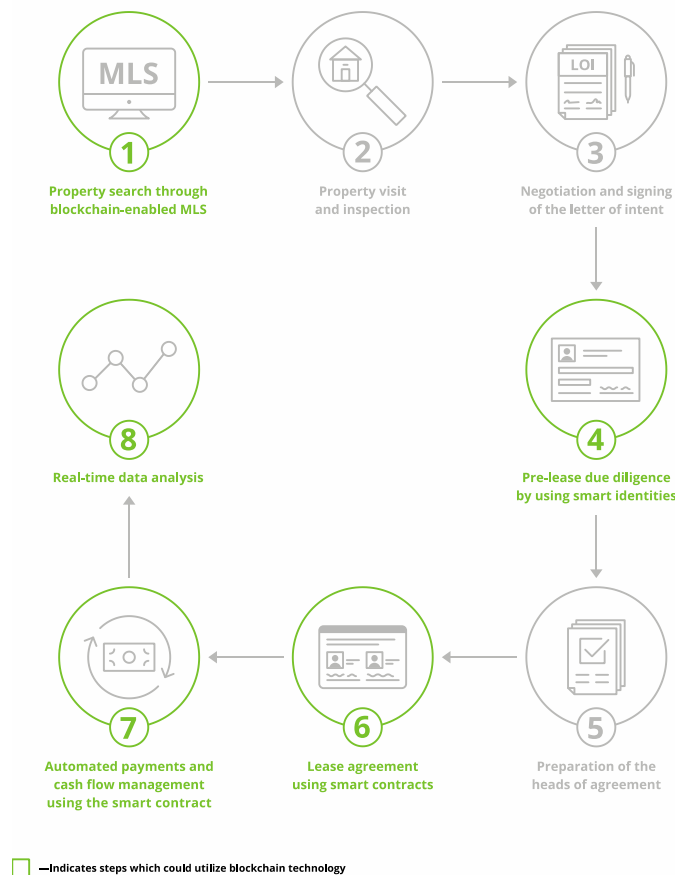
Smart contracts

A ‘smart contract’ is the name given to a piece of computer code that is capable of monitoring, executing and enforcing an agreement (Szabo, 1996). Smart contracts, in conjunction with distributed ledger technology, could be a way of revolutionising real estate transactions. For example, a smart contract could simultaneously transfer funds from buyer to seller while registering the buyer as the new real estate title holder, once all contracts had been digitally signed, exchanged and validated. Deloitte (2017) hypothesise how a new blockchain based model of transacting real estate could function, shown in Figure 31.

Residential-focused smart contracts are being piloted to varying degrees of success by start-ups ChromaWay in Sweden, and Propy, predominantly in the USA, but also facilitating cross border transactions. In March 2019, participants from established organisations such as Ashurst, Baker McKenzie, Barclays, Clifford Chance, AXA XL and the Royal Bank of Scotland, based in 23 major real estate markets and spanning five continents, gathered for the first global blockchain real estate transaction, facilitated by The Instant Property Network, who claim that *“the first transaction conducted in the trial took just 36 minutes from start to finish, thus proving that when participants work together in a collaborative way, the process can really become smarter, simpler and faster”*.

We do not doubt that blockchain technology has the ability to execute a transfer in 36 minutes, but the key factor behind its emergence into the market will be the requirement for *“participants [to] work together in a collaborative way”*. The difficulties facing the adoption of emerging transaction technologies, of which blockchain plays a key role, is fully explored in Saull and Baum (2019). In this report, the numerous operational, regulatory and social barriers to blockchain adoption are detailed, with no clear path to their removal currently available. These include the lack of standardised, digitalised real estate data, the need for a critical mass of users, and the lack of current regulatory framework.

Figure 31: Blockchain applicability in a commercial transaction



Source: Deloitte, 2017

Digital mapping

Given that most land registries in developed markets are non-digital, and/or (as in the UK) based on the principle of ‘general boundaries’, can private sector innovation produce an incentive for all landowners to accurately and digitally map their landholdings and agree the boundaries? Will adequate government budgets be made available to cope with a likely torrent of disputes? Will the legal and property professions find a way to create an institutional approach to the digitalisation of ownership records? Will you and I engineer democratisation by taking responsibility for maintaining our property data?

Saull and Baum (2019) conclude that the answer to all of these questions is the same – the capability of the technology will easily outpace the capacity of the system to employ it, and radical change will be slow.

5.8 Crowdfunding and peer-to-peer lending

Capital raising in the private markets remains a vital, difficult activity. Raising equity may be very appealing, but it is generally more time consuming to raise equity than debt. Hence, we can observe tech-driven entrepreneurial activity in the raising of equity. Real estate crowdfunding has captured the imagination of young entrepreneurs and SME developers.

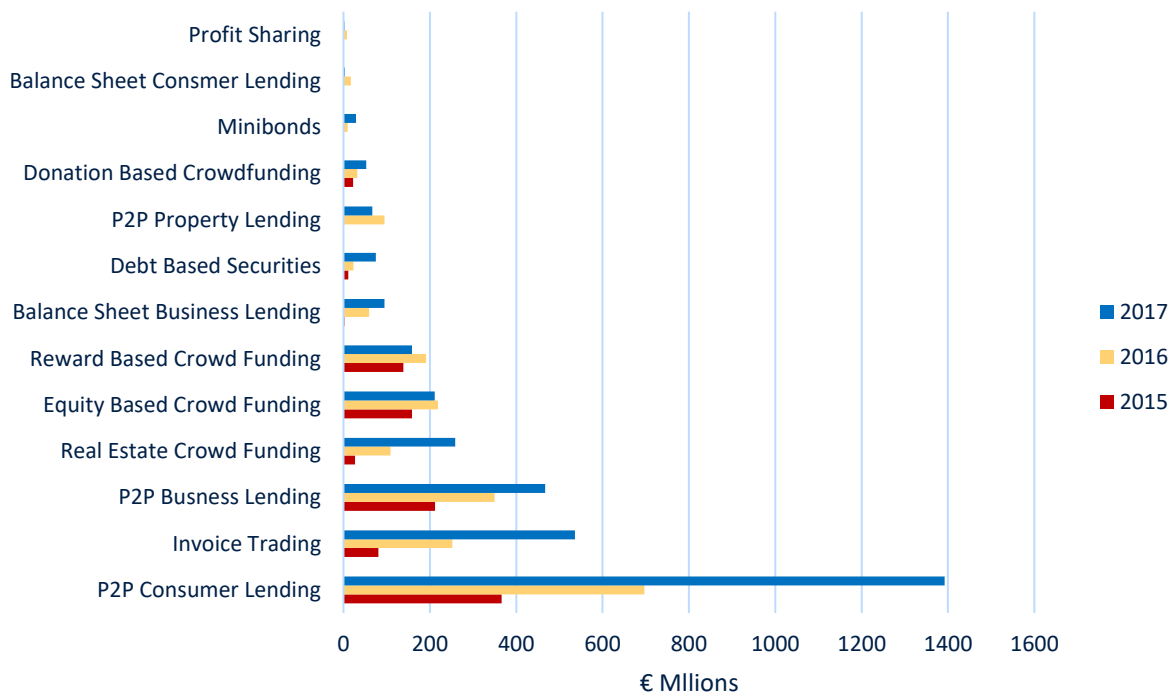
Crowdfunding has the potential to resolve the capital requirement problem for less financially capable buyers, but also to remove geographical barriers (see Factornerd, 2019 and P2P

Market Data, 2019). Reducing the minimum deal size for an investor should widen the potential buyer base and the pool of available capital.

Capital raisers – Brickvest, Property Partner, Capitalrise, Property Crowd, Property Moose, Piggyback and Mashvisor, in the somewhat patronising yet hopeful words of the latter, have claimed to “*let average people become savvy individual investors to make profitable real estate investments and rental strategy decisions through an online platform that instantly aggregates real estate data*”.

Increasingly, new GP platforms (for example, Cogress or Shojin) use their own crowdfunding solutions as a retail distribution channel to fund single property investments and developments. Single properties are unregulated, so the result of the collision of retail crowdfunding and regulated investment management business is yet to become clear. The mechanism used for more sophisticated investments involves retail investors being grouped into one LP, advised by the platform. Whether good advice is being proved by professionals in these platforms is at best unclear.

Figure 32: Annual volumes, 2015-2017, alternative finance, Europe



Source: Cambridge Alternative Finance

Debt crowdfunding and mortgage platforms including Trussle and pioneer peer to peer real estate lending platform LendInvest are also in place. Up to 2016, real estate crowdfunding had raised \$3.5 billion for 125 companies in the US, around 10% of global crowdfunding capital raised (Esbaitah, 2016). However, the crowdfunding and peer to peer lending markets have since seen several failures and lack any real scale.

Real estate (property) crowdfunding explained 8% of the total volume of European alternative finance, or €259m, in 2017. Given that the UK alone (say 10% of the global market) sees real estate transactions of around £50bn in a typical single year, crowdfunding’s share is estimated at somewhere between 0.1% and 0.25% of all capital raised, not yet a runaway

success, somewhat illustrated by the failure, pivot or downsizing of many pioneer companies such as Property Partner or Brickvest.

5.9 Real estate tokenisation

It would be great if properties could be split into smaller pieces so that anyone could get on the property ladder with £1,000. And after a year or two why not use your phone to trade that £1,000 for £1,100, instantly, for a tiny fee? This, and more, is the promise of tokenisation – defined by many insiders as the process of representing fractional ownership interest in an asset with a blockchain-based token.

Table 10: Benefits of real estate tokenisation

Potential benefits	Details
Fractionalization	<ul style="list-style-type: none"> • Assets such as real estate have high barrier to entry due to large upfront capital required • Fractionalizing such assets democratizes its access for smaller investors
Customizability	<ul style="list-style-type: none"> • Tokenization enables exposure to individual real estate assets. Thus, instead of investing in the whole sector, portfolios can be customized down to single buildings.
Liquidity	<ul style="list-style-type: none"> • Fractionalization increases the pool of potential investors and can unlock global investor base • Secondary markets also facilitate additional liquidity • Liquid assets command a premium and can increase asset value
Automation	<ul style="list-style-type: none"> • Smart contracts can automate steps such as compliance, document verification, trading, an escrow • Dividends and other cash flows can be programmatically paid when due
Cost Efficiency	<ul style="list-style-type: none"> • By removing certain intermediaries and increasing efficiency of processes, costs can be lowered
Settlement Time	<ul style="list-style-type: none"> • Tokens can settle in minutes or hours (depending on the underlying blockchain) • This unlocks the capital that is tied in the market which currently settles at T+3/T+2
Data Transparency	<ul style="list-style-type: none"> • Secure and visible recordkeeping on blockchain can increase transparency to the underlying data • Especially for complex derivative products, the ability to clearly link a security to its underlying value drivers
Structured Products	<ul style="list-style-type: none"> • Additional value can be realized once assets are tokenized and that enables the creation of additional layered financial products such as basket of assets and derivatives • Since the underlying is tokenized, creating complex products becomes simpler through coded smart contracts

Source: MIT (2019)

Is the promise of tokenisation realistic? How big could it become? Baum (2020) examines the mechanisms now available to fractionalise real asset ownership and to create active secondary markets in tokenised or fractionalised units. A subsidiary use of tokenisation is focussed on building use, not ownership – so-called utility tokens are very relevant for real estate. Hybrid ownership/utility tokens are also interesting. Why not own a part of your local coffee shop and get free or cheap coffee (Shrier, 2019)?

Real estate suffers from illiquidity and lumpiness. If real estate assets were to be easily unitised, or fractionalised, this would surely improve the risk-return characteristics of typical real estate portfolios, while at the same time the liquidity of a typical asset would increase. However, it is not clear that all market participants see improved liquidity as a positive benefit without a price.

There are several ways in which a real estate asset can be (or has been) split into component parts, or fractionalised. These include splitting the freehold ownership between several legal persons; sub-dividing the building physically (vertically, horizontally or both, including strata title); creating a time share structure; creating leasehold and sub-leasehold interests; tranching, which is a term used to mean splitting the entitlement to income receipts from an asset between different people; and syndication.

There are several examples in history of failed real estate fractionalisation schemes, including modern crowdfunding platforms. London's IPSX, which was launched in 2019, is the latest large scale attempt to innovate in this space, using shares in a single asset property company as the fractionalised investment being transacted. The first IPSX building was listed on the platform in January 2020.

The key issue influencing or limiting fractionalisation is control of the entire non-divided asset. If a property is divided into 1,000 parts, who pays for repairing the roof? Who pays for maintenance of the elevator – does that include those on lower floors? What happens when the value of the whole is bigger than the sum of the parts and one person refuses to sell?

Figure 33: Tokenising real estate through an intermediate structure



Source: Hoffman, 2019

Intermediate ownership (such as a single asset property company) can in principle cope with any of these problems. This solution is used in real estate syndications, debt and funds.

There are four structures which are used to standardise the manager/investor relationship within the framework of a well understood body of common law or statute. These are the company (including a simple joint venture and, in the U.S., the limited liability company or LLC); the partnership (including limited partnerships, limited liability partnerships); the trust; and (in Germany) the KVG, a regulated contract defined by the KAGB law.

It is claimed that digital tokenisation would be a better solution. It is hoped that by moving to the digital world promoters can avoid regulations; avoid tax; reduce fees; achieve disintermediation; speed up transactions; avoid public information being made available; exploit the efficiencies of blockchain; and enable crypto currency trades.

There is a difference between security or investment tokens and utility tokens (Marinova, 2019). Security tokens can be classified as equity tokens (comparable to traditional shares) and debt tokens (the blockchain-equivalent to bonds). A utility token, on the other hand, offers

the holder the rights to a specific service, for example building access, use of meeting rooms, cloud storage and so on.

Security tokens will be regulated. There is room for regulatory arbitrage as Singapore, Switzerland, Lichtenstein, Luxembourg and many other smaller regimes make it as easy as possible to attract new business.

Connecting blockchain and real estate is by no means fanciful. However, the work needed to justify the digitalisation of data requires velocity of transactions, so that the *use* of a building – security passes, use of power, meeting rooms and so on, which is already fractionalised - will be more relevant than simple tokenisation of ownership. The acid test lies, as ever, in economics. What capital investment is required to establish an efficient tokenisation platform? What will be the running and transaction costs compared to conventional fractionalisation? What demand will there be for the product, and will there be enough transactional velocity to amortise the development costs?

It is clear that unnecessary restrictions on the digital representation of ownership are being cleared away, but the major regulatory limitations will remain in place. There has been a small number of single asset tokenisations (for example, AspenCoin: see Alois 2019). But to spread ownership more widely requires an intermediate structure – a company, a partnership, or a trust. This is likely to put the investment (a security token) into the regulated world. There have been more examples of fund tokenisations.

The tokenisation of real estate funds is the most natural of all real estate tokenisation endeavours. The property fund is already in an appropriate legal form and the investor base is already fractionalised; and the legal entitlements of the fund investors have already been established through a corporate structure or REIT, a trust, or a limited partnership.

Successfully tokenising a single asset, on the other hand, requires the creation of an untested market for units in single assets; it requires confidence in the platform or promoter, which could be a start-up; it requires a belief in blockchain technology; and it will require the transfer of the asset into a corporate structure or REIT, or trust, or limited partnership, in order that shares or the trust or partnership units can be traded. Market experts expect these instruments to have a significant bid offer spread, greatly limiting their liquidity, and to trade below par value. Is there really enough effective demand to buy units in buildings to justify this expense and overcome the risk of an untried platform?

There is no 'official' record of successful – or unsuccessful – recent attempts at real estate tokenisation. In a November 2019 FIBREE/CBRE/Oxford survey, there were 54 respondents, of which 21 completed the full survey. In Table 11 we list 17 successful or ongoing tokenisations: nine were funds; seven were single assets, all involving intermediate legal structures such as a REIT; one was debt. More are in the pipeline (see, for example, Leaseum Partners, 2019), but there have been several failures (Allison, 2019).

Table 11: real estate tokenisations

Promoter	Domicile of Promoter	Label	Type	Size (€)
Aspen Digital	United States	Aspen Coin	Single Asset	16,330,200
Blockimmo	Switzerland	Hello World	Fund	2,705,600
Blocksquare	Slovenia	Techpark	Single Asset	15,000
Bolton	United Arab Emirates	Bolton Coin	Debt	61,537,800
Brickblock	Germany	Peaksid Fund	Fund	2,200,000
BrickMark	Switzerland	BrickMark	Single Asset	110,000,000
Equitybase	Hong Kong	BASE	Fund	5,290,300
Evarei Management	Cayman Islands	Evareium	Fund	1,814,500
Fraxtor	Singapore	Fraxtor	Single Assets	small
iCap Equity	Washington, US	iCap Equity	Fund	1,130,000
Max Property Group	Netherlands	Max Property Fund	Fund	6,090,000
Peaksid	Germany	Peaksid Fund IV	Fund	Up to 200m
Property Token SA	Luxembourg	Belval	Single Asset	small
QuantumRE	United States	Quantum REIT	Fund	20,000,000
Resolute	United States	Resolute Fund	Fund	up to 100m
Shojjin	United Kingdom	Smartlands PBSA	Single Asset	1,000,000
SocialRemit	United Kingdom	CSR	Single Asset	2,078,700

Source: FoRE/CBRE/FIBREE

Tokenisation opportunities for the future include structured finance; fund exchange platforms; and hybrid (utility/security) tokens.

Tokenisation combines two very different movements. The democratisation or fractionalisation of real estate assets is something of a utopian dream: the tokenisation of single property assets for the retail investor is (in our opinion) very unlikely to gather significant momentum. However, the use of blockchain technology to administer ownership registers is good economics and likely to be adopted in time. Economics supports one, but not the other.

It is better to invest in blockchain-supported solutions to economically advantageous innovations with a proven demand (such as funds) than to risk undermining the appeal of the technology by mis-applying it. There are many committed evangelists and several examples showing the potential of the technology. To grow faster, the market needs broader adoption and understanding of the benefits and challenges of these new products, and the continued monitoring and reporting of new developments. Tokenisation offers exciting possibilities for the real estate investment market. It is, however, at an early stage of its development, and real estate applications will take time to develop and become accepted.

6. Innovations: the sharing economy

In this chapter we discuss the sharing economy, which is a term used to describe the common use of assets supported by apps, websites and technology platforms

Poster children: Airbnb, WeWork, Clutter, AppearHere

6.1 Introduction

The sharing, or shared, economy – or collaborative consumption - is a way of distributing goods and services that differs from the traditional model of corporations (hiring employees, manufacturing and selling products to consumers). In the shared economy, distributed ownership of a resource enables individuals to split the use of things like cars, houses and other spaces, or to hire out personal and real property assets to other intending users. Collaborative consumption differs from standard commercial consumption in that the cost of purchasing the good or service is not borne by one individual, but instead is divided across a larger group or recouped by a single owner through renting or exchanging.

Baum (2017: 51) sets out the conditions that make a shared economy proposal attractive to tech investors and entrepreneurs. The conditions are (i) a diverse, widely distributed source of demand; (ii) a diverse, widely distributed and heterogeneous source of supply; (iii) no dominant, efficient mechanism for bringing demand and supply together; (iv) potential financial gains to the demand side, the supply side and an intermediary; and (v) scalability.

Figure 34: The app creates the shared real estate economy



Source: FoRE

Figure 34 illustrates the conditions that made a business like Airbnb a possibility in 2008. Billions of people in the world are looking for space to occupy. Billions of rooms owned and operated by or on behalf of real estate owners are looking for occupiers and the revenue they will contribute. Apple launches the App Store, and the connection can be made. With the appropriate software, a space offering which is fractionalised by time can be offered to a large

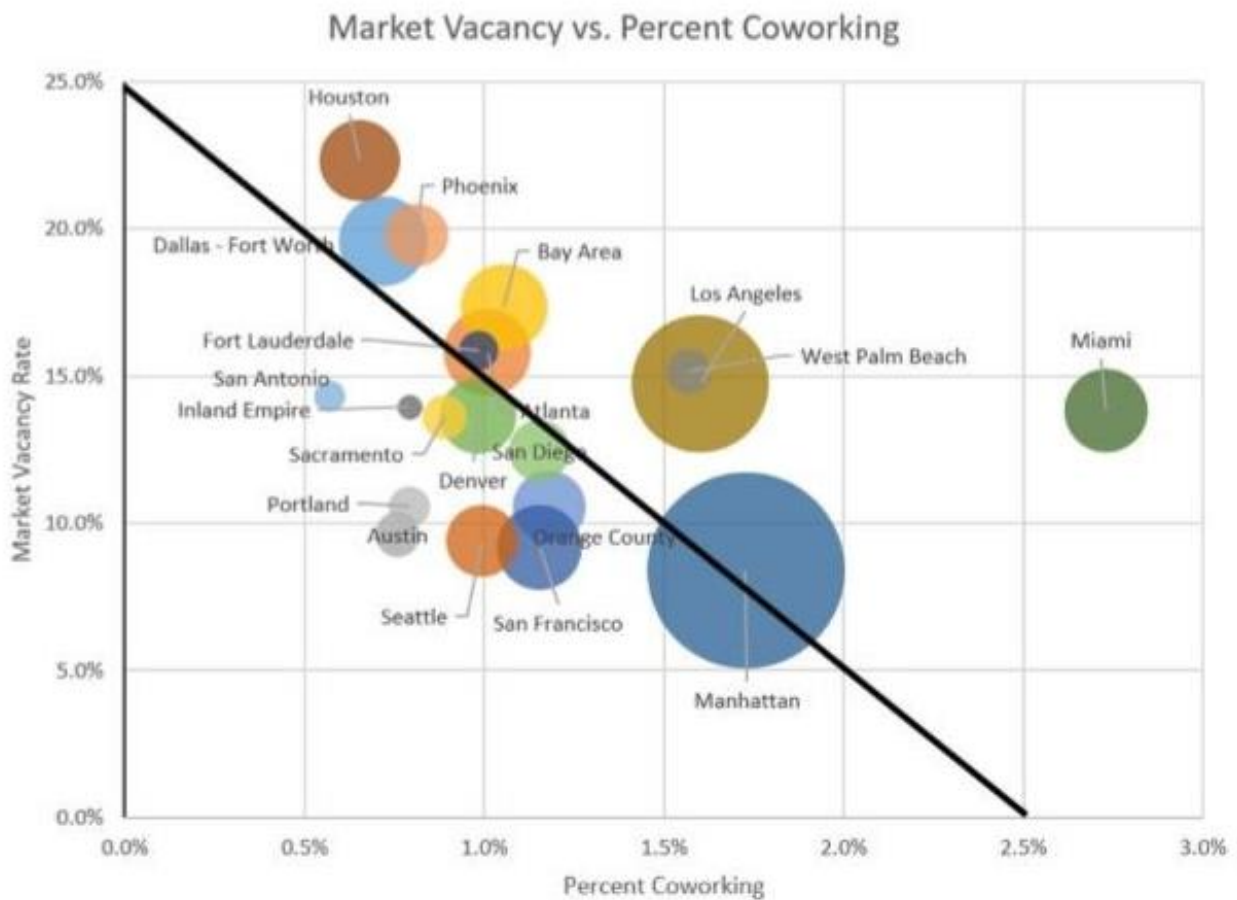
market place, with huge economies of scale justifying heavy investment in high quality UI/UX – a long way from traditional non-fractionalised space, contracted out on a long lease to a single tenant and justifying very little expense on innovation and customer service (see Chapter 4).

6.2 The office sector

Regus pioneered the workspace-as-a-service concept in the 1990s, first in Europe and later in the Americas. The original idea was to provide space for self-employed workers and for the small number of corporate employees that were traveling or working remotely. However, the proliferation of technology in today’s market has enabled a fresh approach to this concept termed ‘space as a service’, based around three key principles: efficiently employing spare capacity; minimising the cost of a transaction; and adding attractive benefits beyond space.

Spare capacity is an economic term which describes the potential for utilisation of an object, service or space that is not currently being used. It describes the unrealised potential of an unused resource through its inefficient allocation. As Figure 35 shows, co-working has been associated with reduced vacancy rates in the US; it is likely that this is driven by the efficient employment of spare capacity achieved by co-working operators.

Figure 35: US city vacancy rates vs co-working supply



Source: Fiorilla, 2018

The cost of a transaction determines how efficiently a resource can be allocated and re-allocated based on market demand and supply. These costs can be further divided into three separate categories (Dahlman, 1979):

- Search and information costs, expended to determine that the required good is available on the market, its lowest price, etc.
- Bargaining costs, required to come to an acceptable agreement with the other party to the transaction, drawing up an appropriate contract and so on.
- Policing and enforcement costs, to ensure the other party sticks to the terms of the contract, and if necessary, the cost of taking appropriate action.

The rise of space as a service has been enabled both through the emergence of smart building technologies, allowing for an accurate measurement of real estate spare capacity, and the development of financial technologies able to reduce the associated search, bargaining and enforcement costs of a transaction, facilitating a more efficient allocation of unused space.

Figure 36: Global flexible office market headlines



Source: Instant Group, 2019

The ability of a landlord or operator to shorten leases and subdivide real estate spare capacity has created a social shift within the commercial real estate occupier market, driving it closer towards a hospitality model, where a strong user experience is essential. With much shorter contractual obligations comes an increasing frequency of choice. The end user of the space is now able to leave without penalty if that space does not meet expectations or requirements. Accordingly, managers of flexible space have begun to include as many luxuries as possible as a part of their service offering. These include WeWork's famous 'free beer', and the classic Google ping pong table.

The demand for space as a service is driven by increasing choice and flexibility, required by SMEs and corporates alike, as they both scale and outsource, and also by the opportunities for collaboration that these shared spaces present. Collaboration is defined as the sharing or exchange through peer-to-peer based platforms of such intangible assets as skills, expertise, innovation and user experience. In a 2016 JLL poll, 74% of respondents indicated that *"thinking, talking, and brainstorming create the most value for an organisation. In response,*

companies are turning to alternative workplace solutions such as co-working to encourage collaboration” (JLL, 2016).

To retain existing customers while attracting new occupiers is increasingly being built around creating an experience within any space, and companies such as Convene are helping to drive this movement by taking and operating communal space within multi-tenant buildings such as 22 Bishopsgate in London. New job titles such as ‘head of workplace’ or ‘community officer’ are increasingly being designed to allocate accountability for these functions.

The rise of space as a service will not only enable vacancy rates of buildings to decrease, but should also allow the desk utilisation rates of individual offices to increase. As mentioned in Chapter 4, the average workstation in Central London costs £17.5k pa, yet the average desk utilization rate is only 45%. In an office containing 500 workstations, a system of enabling 100% desk utilization could generate close to £5m a year (Stanton, 2019). With low barriers to entry in the flexible office market, as most co-working space involves small areas (Fiorilla, 2018), competition among the plurality of small landlords is likely to grow, looking to capitalise on this £5m opportunity cost. Comparing the newer space-as-a-service office sector to the relatively mature hospitality sector, it is highly likely that a desk brokerage platform will emerge through which prospective tenants will be able to book the spare capacity in participating landlords’ offices on a short term daily basis. Such a system is currently offered by JLL-backed start-up Hubble, although currently their minimum lease term is one month.

JLL (2019) predicts that 30% of all US office space will be operated under a space-as-a-service model by 2030 (the currently proportion is 5%), and Deloitte (2018) suggests that over 50% of surveyed professionals are looking to increase property investments with a flexible lease. The shifts in real estate markets that this growth would facilitate would be game-changing, with the following implications.

1. Net promoter scores (customer satisfaction ratings) will be used to compare various commercial spaces and ultimately drive tenant demand. Building owners and occupiers will, like hospitality operators, begin to think about their business in terms of B2B, B2C and platform (Trip Advisor etc) channels.
2. The collection and analysis of space utilisation data will allow for the dynamic pricing of spaces, increasing in price at peak times and decreasing in price when demand is low, thus enabling a fuller occupancy at all times and maximising the value of the asset.
3. Building values will no longer be calculated universally based on the strength of the tenant’s covenant and the terms of the lease, but increasingly on the basis of EBITDA or revenue per available desk.

While leading space-as-a-service brand WeWork may not continue to grow at its previous rate, it is clear that this particular unicorn’s early success has created a chain reaction which will have a lasting impact on the market for commercial real estate. Since our 2017 report, the smart real estate and shared economy verticals have converged. The customer-first approach of space-as-a-service operators has led to changing expectations for a modern office and begun to make occupant wellbeing a financial imperative. Subsequently, major landlords are now producing their own flexible working spin-offs. Examples include CBRE’s Hana and Savills Pivot as well as service offerings for new generation flexible office operators such as CBRE Host.

The major risk facing all space-as-a-service providers is how they will maintain revenue during an economic downturn (Fiorilla, 2018). While tenants value short-term flexibility, long-term leases protect the landlord. Small businesses and start-ups, the most common occupiers of co-working spaces, are the first to fail during recessions, while successful entrepreneurial workers can opt to work from home. Large corporations would also likely opt to terminate co-working leases when belts need to be tightened. The industry has grown during the long economic recovery and certainly will be tested the next time the economy dips.

WeWork kicked off 2019 with over 400,000 members at 425 locations in 100 global cities (Fearn, 2019). In 2018 the supposed \$47bn company's losses and revenues both doubled, to \$1.9 billion and \$1.8 billion, respectively (Aydin 2019), signalling troubled times ahead. WeWork acquired shared economy platform Spacious in August 2019, shortly before a failed IPO in September 2019 dealt a severe blow to WeWork's growth plans.

Meanwhile, the We Company (WeWork's parent) has started to buy buildings that it intends to occupy through the creation of a new \$2.9bn fund (Byrne, 2019).

"Now, after more than a year of planning, WeWork is creating an investment fund that aims to raise billions of dollars to buy stakes in buildings where it will be a major tenant. If all goes according to plan, the fund, called ARK, will start with \$2.9 billion, including \$1 billion from Canadian real estate investor Ivanhoe-Cambridge. WeWork has long said it mostly stuck to leasing space because it believed in being "asset-light." Now it's wagering that buildings become more valuable with WeWorks in them, in which case ARK will put more of that added value back in the company's own pocket" (Bloomberg Business Week, 2019)

WeWork's original success came through managing offices under a space-as-a-service model. This process has been described by some as 'space arbitrage'. As WeWork become landlords, their opportunity for arbitrage is even greater. They will now be able to drive ROI through increasing the cash flow on underperforming assets, and increasing building value as a result. This convergence of the high risk start-up and the conservative property company has always been inevitable.

6.3 Residential real estate and hospitality

Co-living

In late 2019, co-living investor Six Peak Capital employed Cushman & Wakefield to raise \$1 billion in debt and equity to fund its US expansion. A clear expression of the asset-lite shared economy is now being expressed through co-living businesses such as Six Peak, OpenDoor Co-Living or The Collective, which create collaborative living spaces (a perfect example of collaborative consumption). These spaces (says OpenDoor) *"are targeted at urban creatives and millennials. Our homes are curated social environments that facilitate sharing, connections, and meaningful relationships. We are currently negotiating with developers on multiple new construction projects in the 20,000+ sqft size range"*.

Trulia and Zillow – both originally house sales intermediaries – have now expanded into shared economy propositions. They set out to make house purchase and renting more efficient, for example by finding a renter for a second bedroom to support house purchasers or rent to rent entrepreneurs. Splittable (later A Casa) facilitates the shared use of living space

by tracking expenses and facilitating the sharing of bills, spinning off so-called ‘big data’ which can be sold to traditional owners, offering another revenue stream. London-based Lyvly focusses on technology which enables apartments and houses to be shared efficiently.

Shared storage

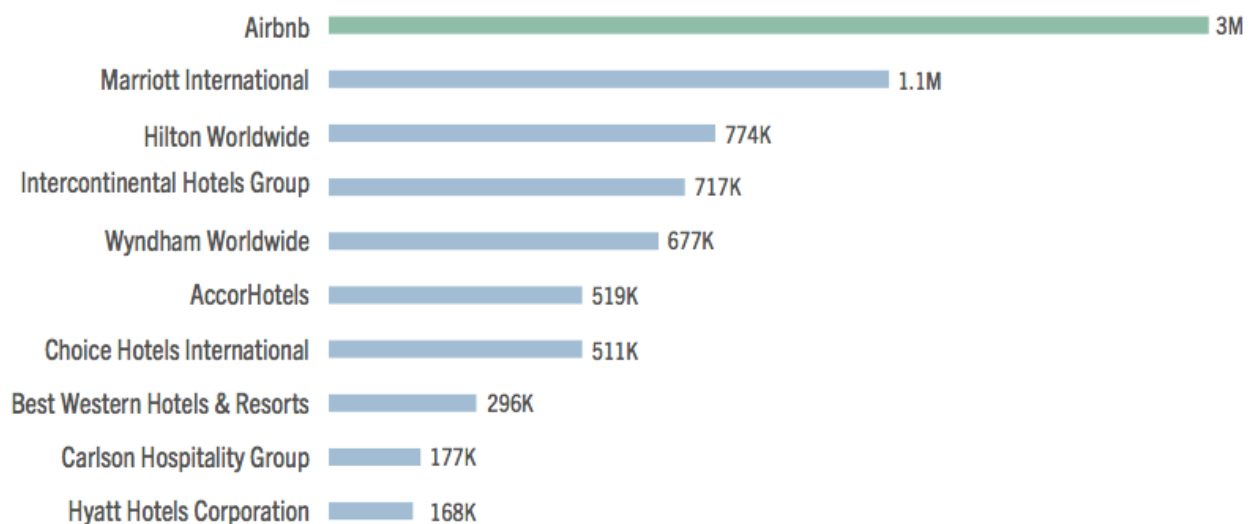
It is not just beds which people are now able to share within their homes. Start-up Clutter enables an individual’s disused garage space to be sold as short, medium and long term storage. Softbank recently injected \$200m into Clutter’s business, while competition in this space comes from MakeSpace, Omni, Trove, Livible and ClosetBox.

Hospitality

Airbnb is the standout shared economy platform in the real estate sector. Operational in over 57,000 cities in 192 countries, its key appeal is the classic PropTech proposition referred to earlier: offering a diverse, widely distributed source of demand (potential users of short stay hospitality); a diverse, widely distributed and heterogeneous source of supply (rooms); no dominant, efficient mechanism for bringing demand and supply together; potential financial gains to the demand side, the supply side and an intermediary; and scalability.

The dominant efficient mechanism appears to be a very simple combination of a website and a brand. Traditional marketing and sales is by no means unimportant, but the value of brand, often associated with first or early mover advantage, is a huge factor in the automatic and low cost generation of volume. Shared economy businesses need ‘liquidity’ - lots of traffic. Small slices of supply revenue can be taken by the intermediary because potential volume is so large.

Figure 37: Largest lodging companies by rooms/listings, 2016



Source: STR, 2017

As in the office space market, incumbents in the hospitality sector are beginning to follow in the footsteps of market leading PropTech companies. Marriot recently partnered with Hostmaker, a home-rental management company, and offered 340 properties for home-sharing stays in Paris, Rome, Lisbon and London as part of a pilot scheme which it now wants to roll out in the US.

Airbnb is also being blamed for rising local rents in many global cities, generating increasing opposition from city officials. For this and other reasons, diversification is inevitable. In 2019, Airbnb announced a partnership with New York City developer RXR Realty to launch its first hotel, which can be booked on Airbnb's platform (El-Bawab, 2019). In 2019, Airbnb also acquired Hotel Tonight, a company that collects bookings from hotels and offers them at a discounted price, and invested in Oyo Hotels & Homes, an Indian hotel-booking company,

6.4 Other sectors

In addition to the developments discussed in Chapter 4, support for the high street is coming from sharing economy operators such as AppearHere, whose proposition is to enable small boutiques and independent shops to either hire a single clothes rail within an existing store or to take control of a vacant shop on a short lease, commonly known as a pop-up store.

A new investible shared economy asset to have emerged on the back of the successes of home delivery services such as Uber Eats, Deliveroo and Just Eat is that of dark kitchens (also known as grey or ghost kitchens). As the demand for restaurant-prepared meals has increased in popularity, so have these combined search, payment and logistic operation platforms. As many restaurants do not have the extra capacity to deal with this extra demand while continuing to service their inhouse customers, many have begun to outsource their food delivery functions into converted warehouses, trailers and homes which now resemble industrial 'kitchens-as-a-service' facilities. Full capacity restaurants can rent a station at these dark kitchens in order to satisfy their excess demand. A single site may streamline the delivery functions of multiple restaurants, with delivery drivers/cyclists/bikers no longer tied to inconvenient restaurant locations.

Deliveroo opened its Deliveroo Editions kitchens in May 2017. There are fewer than 20 in the UK, predominantly in London. The 2.5k sq ft units are in locations chosen to meet the food choices of each locality (roughly a 2-mile radius from the kitchen). The sector is now attracting investment from tech investors such as SoftBank and Naspers in the expectation that dark kitchens can yield serious efficiencies in a fast-growing sector (Thame, 2019).

6.5 The sharing economy 3.0

The sharing economy relies on an ability to identify and exploit spare capacity and to reduce the associated search, bargaining and enforcement costs of a transaction, thus facilitating a more efficient allocation of unused space. With blockchain reportedly offering enhanced transaction speeds and auditability for micro payment solutions, in the near future we may see space-as-a-service offerings begin to extend into the realm of digital space, creating the shared economy 3.0. We know of one graphics company which rewards computer gamers for the spare capacity of their console's hard drive in order to crowdsource the computing power needed to develop the latest games. Such a system works through the ability of blockchain to enable the use of utility tokens and micropayments for the sharing of this digital asset. Perhaps the datacentres of the future are not warehouses in Scandinavia, but the combined spare capacity of all unused office hard drives.

The work needed to justify the digitalisation of data requires considerable velocity of transactions, so that the use of a building – security passes, use of power, meeting rooms, etc, which is already fractionalised - will be more relevant than simple tokenisation of

ownership. Blockchain and tokenisation can be used to control rights to occupy and use space; this may be the first step before ownership rights are connected to the same system.

The likely effective demand for an efficient token-based system recording and charging for the use of space, the use of energy and the use of consumables such as food and drink is guaranteed to be high. This is a natural extension of pre-paid credit cards that act as intelligent building passes, and of the WeWork model for flexible space use. The cost is unlikely to be high, and the development costs incurred will be spread over a very large number of transactions. In addition, hybrid tokens offering a combination of a utility (the use of space) and a return (income and/or capital) have a promising future. Examples include fractionalised private residential, where rent/buy structures are partially financed through hybrid tokens, and community facilities such as community centres, local co-working sites and coffee shops.

Blockchain may provide the transaction platform which allows for real estate and cyberspace to converge, allowing shopping centre owners to capture on-line expenditure, helping digital twins within larger virtual smart city platforms to generate revenue, or to facilitate the collection of 'rent' from the digital augmentation of an asset. While this may seem highly abstract, it is our lack of understanding about how the digital and physical realms co-exist and our inability to capture the uplift in online sales generated through a physical store presence which is contributing to the demise of many, once powerful, retail firms.

7. Futures

In this chapter, we examine the difficulties currently facing many PropTech start-ups and investors, consider how innovation is accommodated and speculate about what PropTech 2020 will mean for the future of real estate

7.1 Introduction

To borrow the saying attributed to the Greek philosopher Heraclitus, “*change is the only constant in life*”. Given the influx of emerging technologies resulting in many innovations within the real estate industry, it is clear that the near future will look very different from the recent past. Chapter 2 of this report detailed how flows of venture capital have poured into the PropTech market. However, attempting to explain what this means with regards to the future of the real estate industry inevitably involves a lot of blind speculation. This challenge was eloquently summarised by James Dearsley (in Kubiak, 2019): “*PropTech is similar to teenage sex; everyone is talking about it, everyone thinks that others are doing it, and everyone is telling others that they are doing it, yet nobody knows what on earth they are doing*”.

This chapter aims to highlight the relevant difficulties currently facing many PropTech start-ups and investors, and to speculate with at least one good eye about what PropTech 2020 will mean for the future of real estate.

7.2 Technology adoption-diffusion theories

“Adoption-diffusion theories refer to the process involving the spread of a new idea over time. The adoption process refers to the individual’s decision over whether to integrate an innovation into his or her life; diffusion describes a collective adoption process over time” (Straub, 2009: 629).

There are many different models that can be used to attempt to explain the technology adoption decision made by individuals, and no single model has been proven as having a greater or more consistent explanatory power than any other. However, Rogers’ (1995) Diffusion of Innovation (DOI) and Tornatzky and Fleischer’s (1990) Technology, Organisation and Environment (TOE) models are the most widely cited works regarding the rate of diffusion of innovations within organisations.

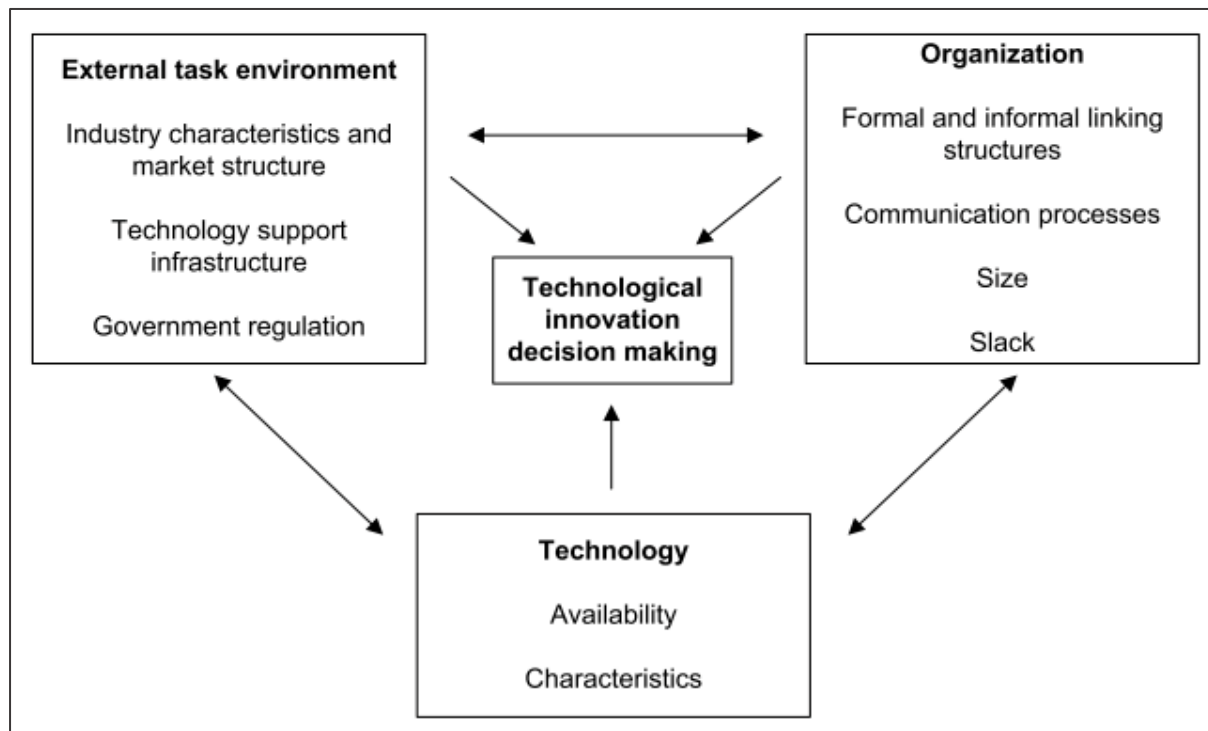
Rogers’ organisational DOI process is divided into two subprocesses, which are (i) initiation and (ii) implementation. The *initiation* of an innovation involves identifying an organizational problem that has created a perceived need for innovation, often triggered through a performance gap, where delivered performance has fallen short of expected performance.

Implementation of the innovation concerns the decisions, events and actions required to put the innovation into use. Firstly, both the organization and innovation must be capable of iterative redefinition and restructuring so as to best align the two and solve the required organisational problem. Next, clarity is needed through training and information disseminated to members of the organisation so as to increase understanding of the innovation. Finally, routinisation occurs when the innovation becomes embedded in organisational practice.

The Technology, Organisation and Environment Framework, illustrated in Figure 38, identifies three contextual aspects of organisations that influence the adoption-diffusion

process of any technological innovation. The first is the context of the new technology with reference to existing internal and available external technologies. The second is the organizational context, meaning the characteristics of the firm such as its scope, size, and managerial structure. The third key contextual characteristic which affects the rate of adoption of an innovation by any single organization is the industry and regulations in which the firm operates, or its environmental context.

Figure 38: The TOE Framework



Source: Oliveira and Martins, 2011

Saull (2019) suggests that the TOE framework is a best fit model for studies of Smart Building technology adoption, although different models may be preferable in attempting to explain Real Estate FinTech or Shared Economy technology use. However, many barriers remain.

7.3 Barriers to PropTech adoption

Saull and Baum (2019) identify a number of barriers to PropTech adoption. These operational, regulatory and social barriers are summarised below.

Operational barriers represent process changes required in the legacy systems of the real estate industry or the platforms developed by technology start-ups. They include:

- Software process integration: any new system must integrate with existing legacy practices and software.
- Standardised digital data: there is a need for up to date, accurate digitalised data before technology can bring efficiencies.
- Critical mass: efficiencies are only realised once a new system becomes widely used. One legacy actor in a network can reduce the whole process to analogue techniques.
- Transition costs: there is considerable financial expense in upskilling the existing software, hardware and labour force. Technologies should not simply focus on the

adoption of a new system but must also concern themselves with the difficulties in discharging the old.

- Data security: it is vital to ensure that new systems are resilient in the event of physical disaster or cyber-attack.

Regulatory barriers represent the legal issues which new technologies have overlooked, or issues which the industry must confront in order to deliver successful technological adoption. They include:

- Legal framework: any solution must not bypass existing legislation, while there is a need to ensure that current legislation is not stifling innovation.
- Technology transparency: technology solutions must be transparent as to their data sources and the reasoning behind any outputs.

Social barriers relate to behavioural and emotional resistance to the adoption of any new system. They include:

- Damaged revenue: new technologies attempting to bring process efficiencies must do so to the financial benefit of their target users. The long term financial benefits a technology can bring must be clearly understood.
- Risk of disintermediation: we need to develop a clear understanding of the winners and losers resulting from the adoption of any new technology, with aligned incentives for potential adopters.
- Trust in innovation: there is a lack of trust based on poor understanding of new technology solutions which are nevertheless capable of bringing increased efficiency to business processes. The misuse of data by multinational social media businesses, and healthy suspicion about the dangers of fuelling potential data monopolists, holds back many private sector data collaborations.
- Collaborative attitude: real estate organisations are unwilling or unable to allow open access to their data.

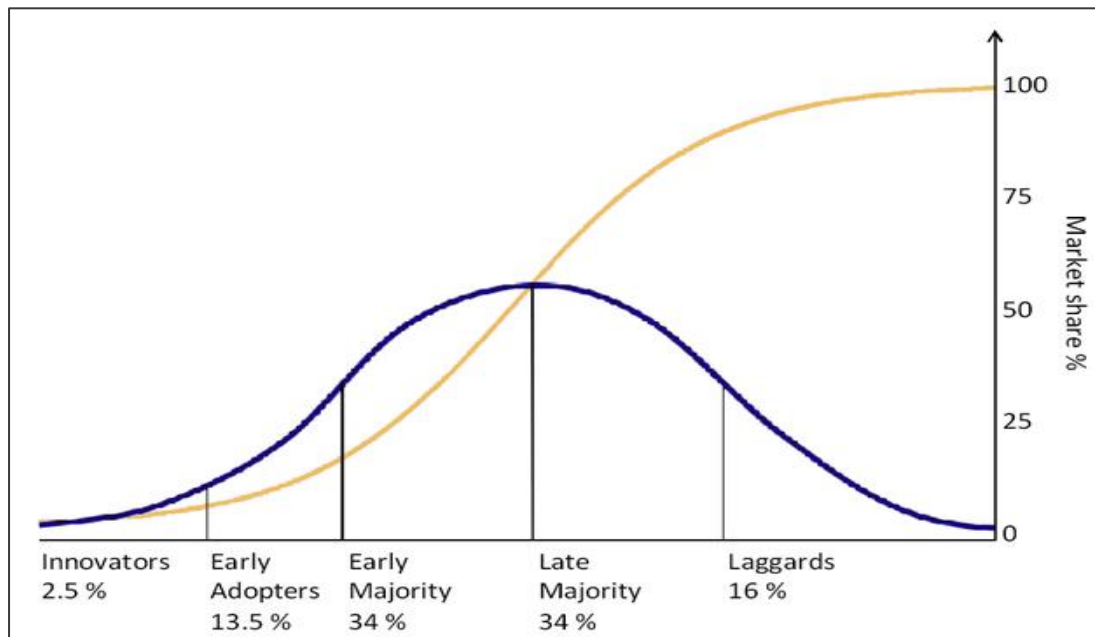
These barriers will play out in differing combinations and strengths depending on characteristics unique to each real estate organisation. Many evangelical PropTech start-ups looking to 'disrupt' the industry will only be able to do so following a series of transformations. Saull (2019) uses the landlord-tenant split-incentive problem created by legacy lease structures as an example of a barrier impeding change and requiring such a complementary transformation.

7.4 Predicting PropTech adoption

Diffusion of Innovation (DOI) theory

Rogers' (1995) Diffusion of Innovation (DOI) theory not only details the process of organisational adoption, but provides an interdisciplinary framework through which we can model the rate of technology adoption within any industry (Straub, 2009).

The DOI theory begins with data describing the share of a market using a new technology. The model uses adopter categories to classify the members of a social system according to their 'innovativeness', or the degree to which an individual or organisation is relatively quick to adopt new ideas, captured by the innovators, early adopters, early majority, late majority and laggards classifications shown in Figure 39.

Figure 39: Rogers' Diffusion of Innovation bell curve and adoption curve

Source: Thompson, 2016

To use an example, 60% of real estate firms are still using spreadsheets as their primary tool for reporting (Altus, 2019). It will be a long time before many PropTech offerings appeal to the laggards.

Gartner's Hype Cycle

Gartner's Hype Cycle provides a graphic representation of the maturity and adoption of technologies and applications. This methodology gives a view of how a technology or application evolves over time, providing insights which help to manage its deployment within the context of specific business goals. The five stages of the cycle detailed in Figure 40 are as follows.

Innovation Trigger: A potential technology breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist, and commercial viability is unproven.

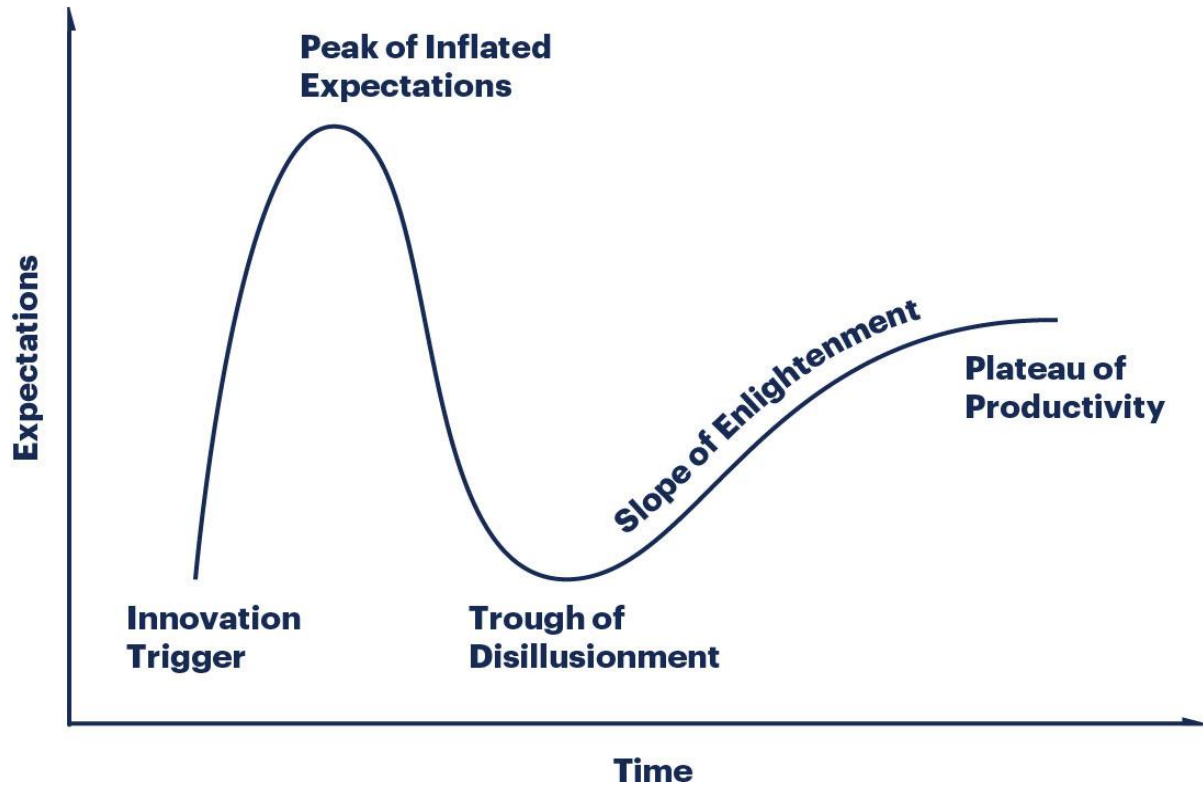
Peak of Inflated Expectations: Early publicity produces a number of success stories — often accompanied by scores of failures. Some companies take action; many do not.

Trough of Disillusionment: Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investments continue only if the surviving providers improve their products to the satisfaction of early adopters.

Slope of Enlightenment: More instances of how the technology can benefit the enterprise start to crystallize and become more widely understood. Second- and third-generation products appear from technology providers. More enterprises fund pilots; conservative companies remain cautious.

Plateau of Productivity: Mainstream adoption starts to take off. The criteria for assessing provider viability are more clearly defined. The technology's broad market applicability and relevance are clearly paying off.

Figure 40: The Gartner Hype Cycle



Source: Back, 2018

Each year, Gartner release their views concerning emerging technologies and the hype cycle. The position of those technologies relevant to PropTech in their 2018 review are summarised in Table 12.

Given the conservatism of real estate businesses, it will take longer for these technologies to combine with real estate industry practices to form PropTech innovations. For example, Blockchain was first developed in 2008, but it was not until 2018 that it reached the top of the hype cycle. Only then did novel real estate start-ups begin to experiment with real estate applications.

Gartner (2019b) offer their insight as the likely future development of blockchain:

Blockchain enabling technologies: 2009-2020

This early phase of blockchain-enabled experiments is built on top of existing systems to reduce cost and friction in private, proprietary activities. They have only limited distribution capabilities to a small number of nodes either within or between enterprises.

Blockchain-inspired solutions: 2016-2023

The current phase of blockchain-inspired solutions are usually designed to address a specific operational issue – most often in terms of inter-organizational process or record-keeping inefficiency. These solutions generally have distribution, encryption and immutability.

Blockchain complete solutions: 2020s

Blockchain complete offerings, starting in the 2020s, will have all five elements, delivering on the full value proposition of blockchain, additionally including decentralization and tokenization.

Blockchain enhanced solutions: Post 2025

Blockchain enhanced solutions offer all five elements and combine them with complementary technologies such as AI or IoT.

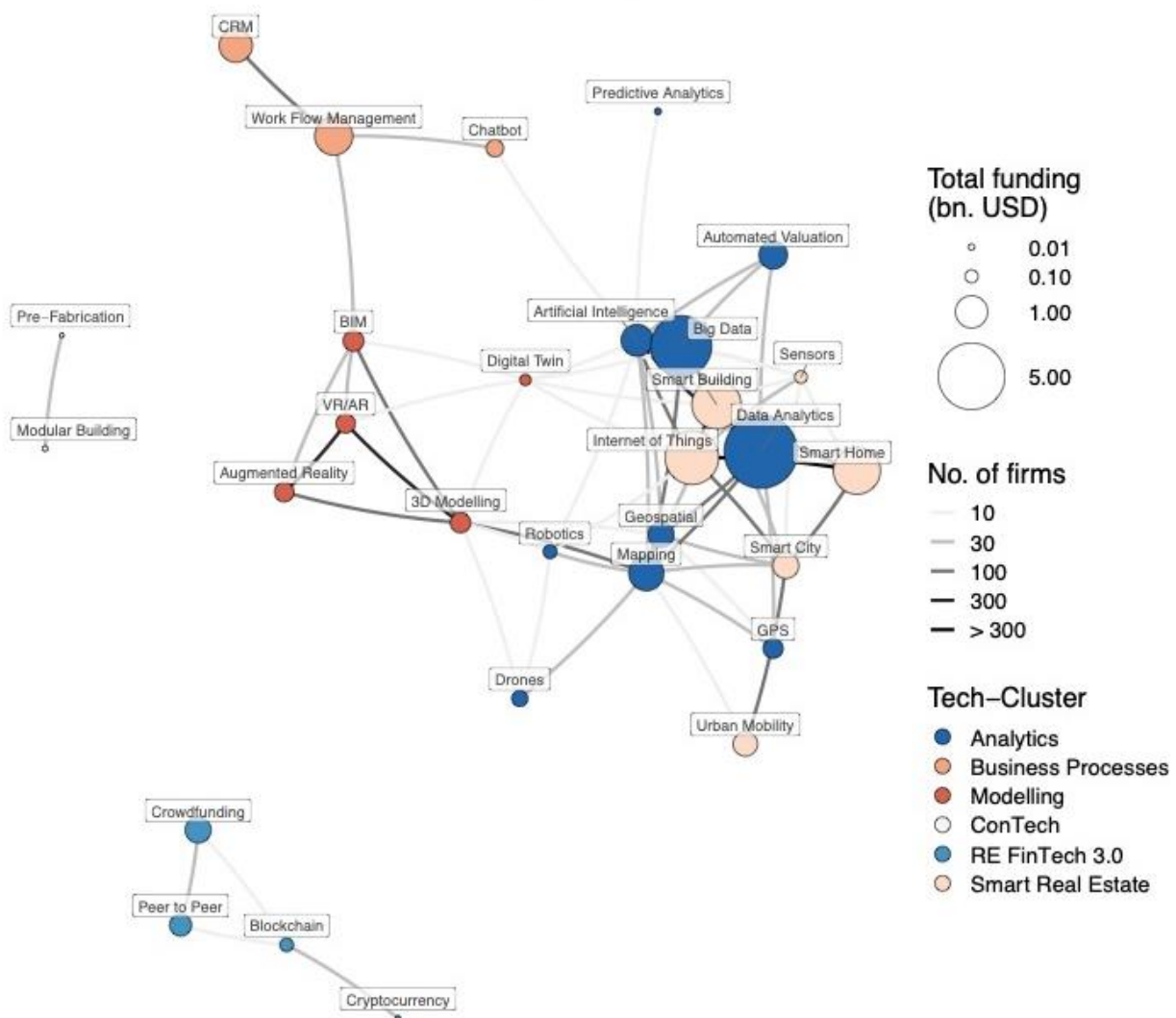
Table 12: Gartner Hype Cycle and PropTech applications

Hype cycle	PropTech application	Position	Time until plateau of productivity
2018	Augmented reality	Trough of disillusionment	5-10 years
2018	Autonomous driving (level 5)	Innovation trigger	More than 10 years
2018	Smart workspace	Peak of inflated expectations	5-10 years
2018	IoT platform	Peak of inflated expectations	5-10 years
2018	Digital twin	Peak of inflated expectations	5-10 years
2018	Blockchain	Peak of inflated expectations /trough of disillusionment cusp	5-10 years
2018	Flying autonomous vehicles	Innovation trigger	More than 10 years
2018	Virtual assistants	Peak of inflated expectations	2-5 years
2019	Immersive workspace	Innovation trigger	5-10 years
2019	Flying autonomous vehicles	Innovation trigger	More than 10 years
2019	Light cargo delivery drones	Peak of inflated expectations	5-10 years
2019	Autonomous driving (level 5)	Peak of inflated expectations	More than 10 years
2019	5G	Peak of inflated expectations	2-5 years
2019	3D sensing cameras	Trough of disillusionment	2-5 years
2019	Decentralised Web	Innovation trigger	More than 10 years

Source: Gartner, FoRE

Figure 41 shows the resulting network of the most important 30 technologies used in PropTech. In order to identify clusters of technologies in the resulting network, we analyse Unissu data (which excludes shared economy offerings such as WeWork and Airbnb) and apply the Louvain method for community detection. The technologies that are joined together in the resulting clusters represent those regions of the network that are more densely connected with each other than with other parts of the network.

Figure 41: The PropTech network



Source: FoRE

We identify six tech clusters, which to some extent confirm the theoretical classification presented in previous chapters. Data analytics forms a distinct cluster at the core of the network, which is highly connected with the Smart Real Estate cluster that contains technology tags such as ‘Smart Buildings’ or ‘Internet of Things’. Connected to this core component of the network are the technologies around 3D Modelling and Virtual Reality. The Business Processes tech cluster consisting of ‘Work Flow Management’, ‘Chatbot’, and ‘CRM’ tags is only loosely connected to the other three clusters. Completely detached is the ConTech cluster, including ‘Pre-Fabrication’ and ‘Modular Building’ technologies. Also detached is the Real Estate FinTech 3.0 cluster, which contains tags ‘Crowdfunding’, ‘Peer to Peer’, ‘Blockchain’, and ‘Cryptocurrency’.

The full list of technologies which gravitated towards each other to form our data-driven PropTech clusters are highlighted in Table 13. (The ‘Analytics’ cluster includes two sub-clusters of data analytics and spatial analytics. The latter technologies are presented in italics.)

Table 13: Data driven PropTech applications

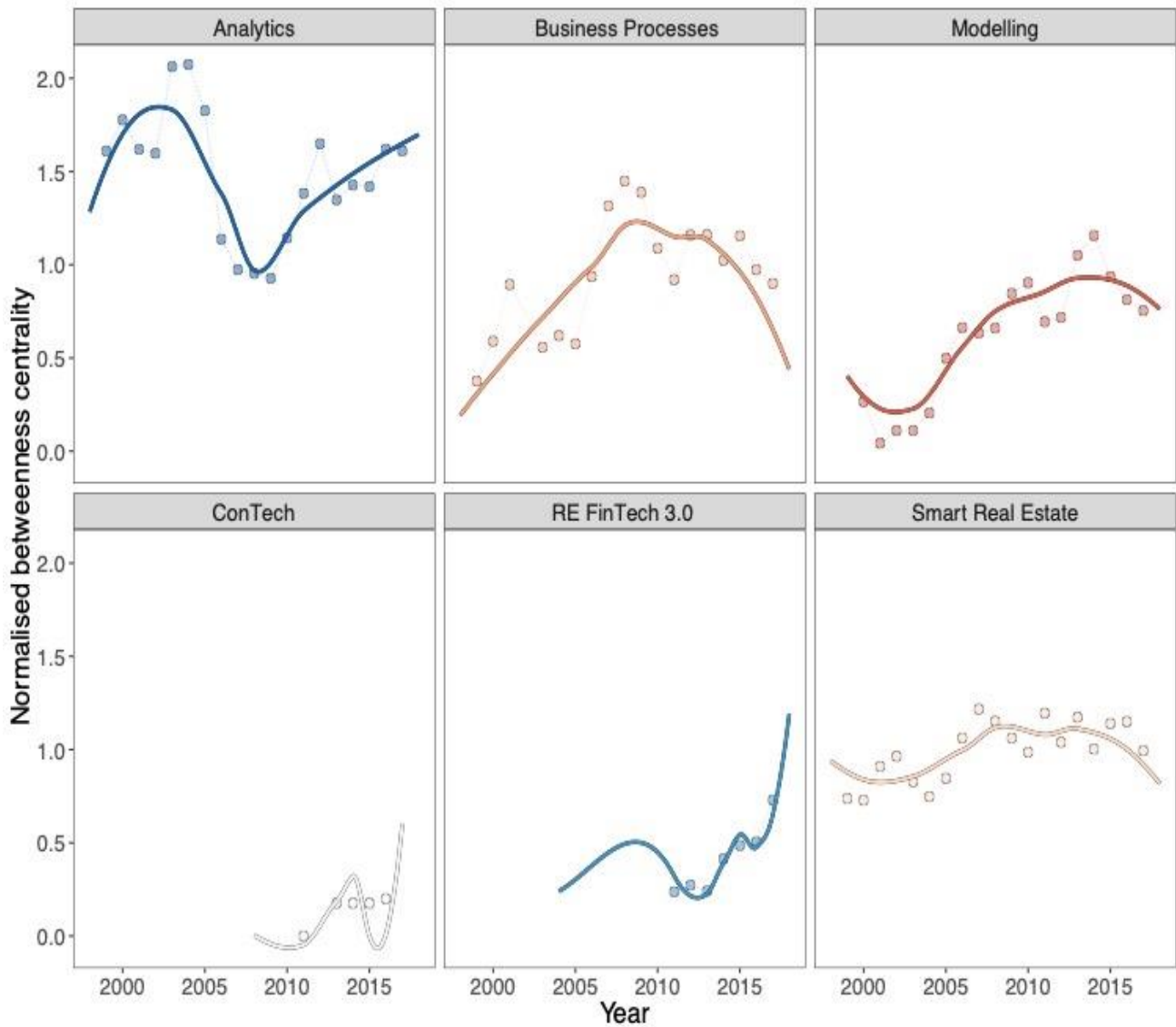
RE FinTech	ConTech	Business Processes	Modelling	Smart Real Estate	Analytics
Cryptocurrency	Pre-Fabrication	CRM	BIM	Smart Building	Predictive Analytics
Blockchain	Modular Building	Workflow Management	VR/AR	Internet of Things	Automated Valuation
Peer to Peer		Chatbots	Augmented Reality	Smart Home	Artificial Intelligence
Crowdfunding			Digital Twin	Urban Mobility	Big Data
			3D Modelling	Smart City	Data Analytics
				Sensors	<i>Geospatial</i>
					<i>Mapping</i>
					<i>GPS</i>
					<i>Drones</i>
					<i>Robotics</i>

Source: FoRE

Identifying these clusters allows us to develop a Hype Cycle for each (Figure 42). This shows distinct shifts in importance over the past two decades. The Analytics cluster, now the most important tech-group within PropTech, was already very central in the first stage of our observation period around 2000, before it steeply decreased in centrality between 2005 and 2008, and started to rise in importance from 2010 onwards. Business Processes, today a less central cluster, went through a different cycle, its centrality increasing steadily up until 2007 when its importance started to decrease.

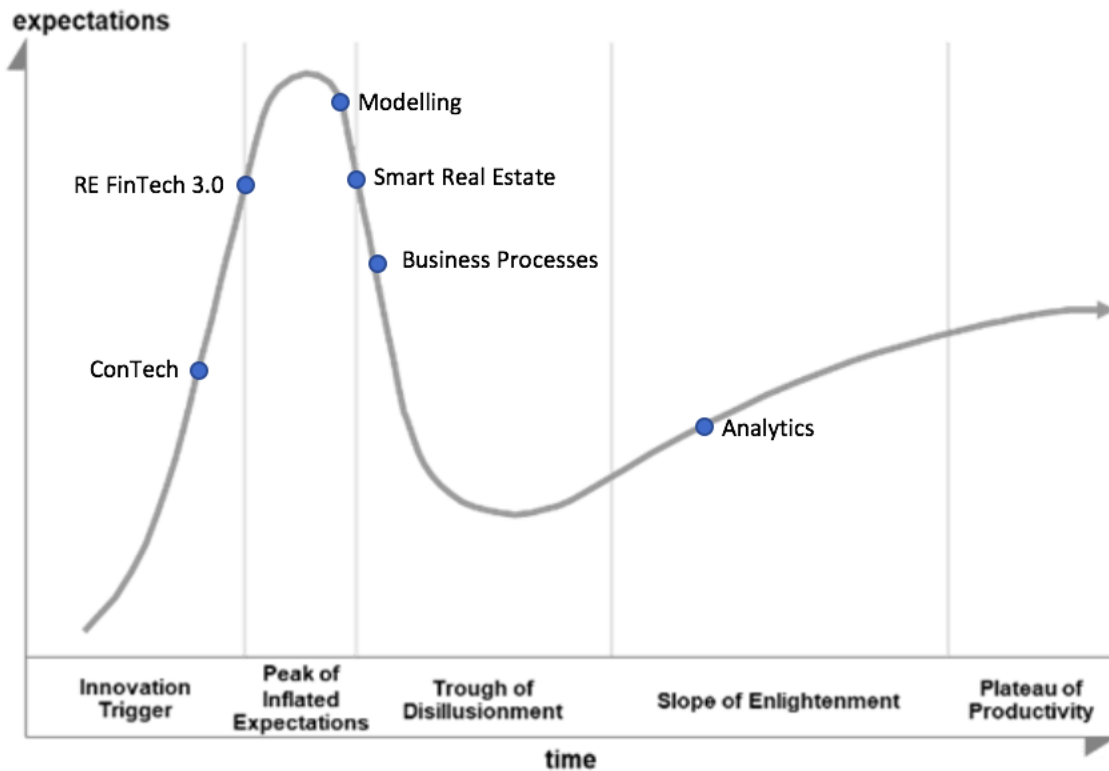
In contrast, Modelling and Smart Real Estate show less volatile dynamics, being relevant topics throughout the complete observation period. Real Estate FinTech 3.0 and ConTech on the other hand, were basically non-existent before 2010, but recently started to gain momentum; this is particularly the case for the Real Estate FinTech 3.0 cluster.

Figure 42: PropTech Hype Cycles, 2000-2020



Source: FoRE

This analysis also allows us to hypothesise the position and maturity of these different technologies and business sectors using the Gartner typologies explained previously, and to predict which current industry models of operation are most likely to be disrupted through technology in the near term (see Figure 43).

Figure 43: the PropTech Hype Cycle, 2020

Source: FoRE

We can see that, using levels of funding as a proxy for market hype, those technologies used in data analytics have transitioned through the full cycle and will likely be the first PropTech solutions to be widely adopted by the real estate industry. Many of the technologies being discussed today are located around the peak of inflated expectations, and may not deliver their disruptive potential in the near future. However, we can also see the scale of new technologies maturing within a 5-10 year time horizon, suggesting that by the end of the 2020-2030 decade things will begin to look a lot different.

We conclude that the most important property technologies in the current PropTech market are those which produce digital data and generate value from it. In comparison to these technologies, promising terms like 'Blockchain' or 'Cryptocurrency' remain peripheral. It is to be seen whether it will be possible to create sustainable business models that use these prominently-discussed technologies. Based on the small number of firms using these technologies in combination with more accepted approaches and the limited funding raised, many promising technologies are not yet ready for commercial application.

7.5 The entrance of the tech giants

The organisations best poised to experiment with new technologies and invest in innovative concepts are tech giants Google, Apple, Amazon and Facebook (plus the Chinese powerhouses Tencent, Baidu and Alibaba). Recently, each of the top US tech companies has made a foray into real estate.

In July 2019, Amazon announced a partnership with real estate firm Realty Holdings Corp., offering homebuyers up to \$5,000 in Amazon products with the purchase of a home. They have also launched numerous high profile smart home technologies, with new products in

the pipeline. New wireless technology Sidewalk will use the 900mHz wireless band to let users control their home devices at a longer range than Wi-Fi or Bluetooth currently allows. SmartRent is a smart home automation platform for property managers and renters using voice technology applications. Amazon also continues to build, own and operate massive data centres.

Apple's recent partnership with London-based property rental company LIFENEST, "*the world's first global renting and home life experience brand*", offers discounts on their products to those who use the rental platform. It is reported that Google, which is currently developing its own European headquarters building in Kings Cross, London, is also partnering with developers and property managers to incorporate their digital assistants into rental apartments. Their interest in PropTech lies in solutions for "*a cohesive unified user experience built into the walls of the apartment*". The Sidewalk Labs (an Alphabet company) development in Toronto is a more ambitious attempt to develop a smart city powered by technology.

In October 2019, Facebook announced the launch of its \$1bn affordable housing initiative to help those displaced by rising house prices close to their headquarters. This move into residential development is accompanied by similar gestures provided to local residents by Amazon, Microsoft and Google. Like Amazon, Facebook also builds and operates data centres.

Beckerman (2019) writes: "*Imagine for a moment that Google uses its vast search data to build a real estate recommendation engine. Amazon, with its increasing emphasis on the home, enters the office world by building products to connect people at work and enhance their efficiency, communication, and operations. They also licence their robotics investments and sell to third party logistic providers in a model similar to its cloud technology and AWS. Microsoft, which owns LinkedIn, uses its CRM and company employee data to build a recommendation engine to help companies optimize office space locations. The possibilities are endless.*"

This may be the way of the future for real estate: alliances between space providers and product brands. Amazon, Apple and Google all see the smart building sector as a battle ground on which their technologies can grab a large amount of market share through first mover advantage. What starts as a residential focus could easily evolve into commercial real estate partnerships and eventually dominance, with each company possessing adequate funding to squeeze the margins of any real estate sector they decide to enter.

7.6 Resisting monopoly

The new, tech-enabled world is creating a pointed and general challenge to modern society. Will we allow technology-owning monopolies to grow and control us (Susskind, 2018)? Or will we rely on mechanisms of social order, which govern the behaviour of a set of individuals within a given community, building regulatory institutions identified with a social purpose, mediating the rules that govern living behaviour?

According to Justin Wilson, Investment Director at Softbank, any combination of technology trends which could generate a single commercial real estate platform would represent the holy grail of PropTech: "*No one has yet come up with a full stack, end-to-end software solution that covers the full spectrum of everything that an investor or operator would need. Something that covers where to build, what to build, the leasing and asset management side, investment*

and lending. I've been surprised at how fragmented that world continues to be, and the fact that there is no software package that powers commercial real estate” (Phillips, 2019a).

Existing processes are clearly sub-optimal: there are underlying process changes which need to occur before technology can be successfully implemented. However, is the Softbank solution credible? If it were, do we really want a full stack, end-to-end software solution in the hands of a monopoly? Facebook has not exactly been a great role model for the digital data sharing age.

The biggest barrier to real estate technology adoption can be identified as a lack of technical literacy within the real estate industry, and the lack of focus on these skills during the recruitment process. This is often coupled with a lack of real estate knowledge within the technology start-ups. But the fear of a real estate data monopoly is also holding back innovation and change.

While real estate organisations believe that a simple solution is to increase technology education and training initiatives, many start-ups believe that the real drive for technology adoption will come from the public, with educated customers demanding more democratisation exemplified by the transition towards online banking applications. Real estate organisations are unwilling or unable to allow open access to their information and will likely only do so through an industry consortium or government mandate.

7.7 Tomorrow's technology

According to MetaProp, only 13% of PropTech companies are more than five years old. The risk of obsolescence of any individual technology is a critical factor affecting much of the potential technology adoption in such a rigid asset class as real estate. While this report has focused on those emerging technologies directly applicable to real estate, Baum (2017) highlights the unforeseen impact which exogenous technologies can have on the real estate industry. After all, who could have foreseen the impact which the internet or smart phone has had on how the industry operates?

While we do not have the foresight to suggest the likely application of all exogenous technologies, we need to be aware of the major direction of travel for tomorrow's technology. According to Gartner (2019c) the major developments are likely to be as follows.

Hyperautomation: the application of advanced technologies including artificial intelligence (AI) and machine learning (ML) to increasingly automate processes and augment humans.

Multi-experience: replacing technology-literate people with people-literate technology. In this trend, the traditional idea of a computer evolves from a single point of interaction to include multi-sensory and multi-touchpoint interfaces like wearables and advanced computer sensors.

Democratization of technology: providing people with easy access to technical or business expertise without extensive (and costly) training. It focuses on four key areas — application development, data and analytics, design and knowledge — and is often referred to as “citizen access,” which has led to the rise of citizen data scientists, citizen programmers and more.

Human augmentation: using technology to enhance both an individual's cognitive and physical experiences.

Transparency and traceability: the evolution of technology is creating a trust crisis. As consumers become more aware of how their data is being collected and used, organizations are also recognizing the increasing liability of storing and gathering the data, leading to technology which offers enhanced ethics, integrity, openness, accountability, competence and consistency.

Edge computing: a distributed computing approach which brings computation and data storage closer to the location where it is needed, to improve response times (reduce latency) and save bandwidth.

Distributed cloud: distribution of public cloud services to locations outside the cloud provider's physical data centres, but which are still controlled by the provider.

Autonomous things: these include drones, robots, ships and appliances which exploit AI to perform tasks usually done by humans.

Practical blockchain: a truly integrated distributed ledger shared by all participants in a network, extended to including autonomous machines and sensors.

AI security: protecting AI-powered systems; securing AI training data, training pipelines and machine learning (ML) models; leveraging AI to enhance security defence; using ML to understand patterns, uncover attacks and automate parts of the cybersecurity processes; anticipating the nefarious use of AI by attackers; identifying attacks and defending against them.

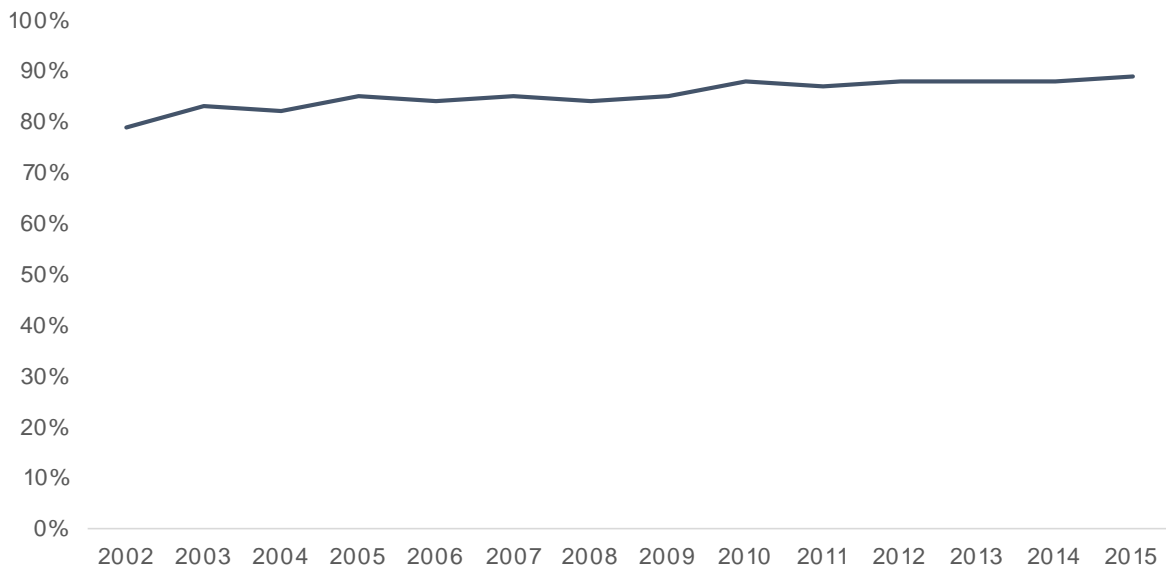
7.8 Employment

Previous industrial revolutions are credited with creating four jobs to every one lost. Will the fourth industrial revolution be very different? What is the future of real estate work?

Susskind's *The Future of the Professions* (Susskind and Susskind, 2015) predicts the decline of today's professions and describes the people and systems that will replace them. The authors argue that we will neither need nor want doctors, teachers, accountants, architects, the clergy, consultants, lawyers, and many others, to work as they did in the 20th century. *The Future of the Professions* explains how "increasingly capable systems" - from telepresence (the use of virtual reality technology for the remote control of machinery or for apparent participation in distant events) to artificial intelligence - will bring fundamental change in the way that the "practical expertise" of specialists is made available in society.

In an era when machines can out-perform human beings at most tasks, what are the prospects for employment, who should own and control online expertise, and what tasks should be reserved exclusively for people?

DelPrete (2018) uses as an example the residential real estate brokerage industry, and reveals that despite 90% of home sales being originated via online portals such as Rightmove, Zoopla, Trulia and Zillow when searching for a property, "*consumers want to work with an agent in order to reduce the chances of a potentially costly mistake when selling their house. Agents are insurance.*" Figure 44 shows that despite the dominance of house portals in generating sales, a continually increasing percentage of sales employ an agent (90% in 2016, up from 80% in 2001).

Figure 44: Homes sold using an agent in the US

Source: DelPrete, 2018: 177

“What we think we will see in the next ten to fifteen years in real estate is human judgment deepening and becoming less biased, thanks to algorithms and machine learning. Most of us in real estate still use manual, or at best semi-automated, processes in finance, property management and portfolio management. Spreadsheets abound, collating and analysing data for property valuations, cost analysis, lease management and forecasting. Vast swathes of time are spent reading, manipulating and extracting key data which are not only open to error and security breaches, but so dull!

Viewing humans and ‘robots’ as complementing each other, rather than competing with other, is the more astute view. In corporate real estate, for example, the area where we can see robotics and cognitive automation helping professionals is in analysing data with more speed and accuracy. We see it streamlining the management of lease recording, as well as compliance and risk monitoring. As productivity increases, so costs decrease; automation and machine learning technologies are generally more cost effective to implement than the historic practice of offshoring.

However, perhaps most important is the satisfaction that more creative and human-centric work can bring us. Technologies that relieve our staff of repetitive and mundane work mean that time can be spent doing meaningful work, like evaluating business models or developing new service lines. Never before has the built environment needed us to transform our outlook and develop our skillsets as today; and never before have there been so many commercial opportunities that need us to show our humanity” (Moss, 2018).

7.9 Global mega forces and sustainability

Each year the World Economic Forum publishes its Global Risks Report. The results of this report for 2019 are detailed below. Figure 45 shows those risks most likely to occur and those which would have the most devastating impact.

Figure 45: The top 10 global risks for 2019

Likelihood	Impact	Categories
1 Extreme weather events	1 Weapons of mass destruction	<ul style="list-style-type: none"> ◆ Economic ◆ Environmental ◆ Geopolitical ◆ Societal ◆ Technological
2 Failure of climate-change mitigation and adaptation	2 Failure of climate-change mitigation and adaptation	
3 Natural disasters	3 Extreme weather events	
4 Data fraud or theft	4 Water crises	
5 Cyber-attacks	5 Natural disasters	
6 Man-made environmental disasters	6 Biodiversity loss and ecosystem collapse	
7 Large-scale involuntary migration	7 Cyber-attacks	
8 Biodiversity loss and ecosystem collapse	8 Critical information infrastructure breakdown	
9 Water crises	9 Man-made environmental disasters	
10 Asset bubbles in a major economy	10 Spread of infectious diseases	

Source: World Economic Forum, 2019

Below, we hand pick three of these we perceive to require direct action from the real estate industry:

Climate change. the International Panel on Climate Change warns of a need to reduce global greenhouse gas emissions by 45% before 2030 in order to best mitigate the adverse effects of global warming and limit the global temperature increase to 1.5c. Given that the real estate and construction industries are currently responsible for 40% of total GHG emissions, this will require a significant effort, and PropTech is expected and needed to play a full part in this response.

Cyber attack: the rise of smart buildings containing thousands of IoT connected devices offers a gateway for malicious actors using ever more powerful computers and advanced machine learning techniques. If not properly secured, smart buildings could pose a real threat to the function of any integrated smart city platform, and in extreme cases, national security.

Data theft: The speed with which AI has been developed has outpaced our ability to regulate the use of personal data, a void that has long been exploited by major technology providers: “Many of the practices associated with capitalizing on these newly perceived opportunities (have) challenged social norms associated with privacy and are contested as violations of rights and laws” (Zuboff, 2015: 85). Dubbed ‘surveillance capitalism’, at its extreme urban big data monopolisation and exploitation has the potential to create a panoptic city, where all aspects of smart city life may be monitored, and which will “threaten to stifle rights to privacy, confidentiality, and freedom of expression” (Kitchin, 2014: 12).

8. Summary and conclusions

In this chapter we summarise our findings and identify five key areas of future activity: smart real estate, real estate FinTech, the real estate shared economy, data digitalisation and smart cities

The internet and mobile telephony have enabled a boom in technology platforms to be applied to nearly all areas of our lives. The global shift towards the use of digital technology or the ‘fourth industrial revolution’ has facilitated innovation in real estate, specifically in the three horizontals of information provision, supporting transactions, and enabling management and control.

PropTech describes the digital transformation that is currently taking place within the real estate industry. The roots of PropTech lie in construction technology, legal technology, the shared economy movement and FinTech, and in our 2017 report we identified three semi-independent real estate impacts or verticals. These were smart real estate; real estate FinTech and the real estate shared economy.

Smart Real Estate describes technology-based platforms which facilitate the *operation and management* of real estate assets. The assets can be single property units or entire cities. The platforms may simply provide information about building or urban centre performance, or they may directly facilitate or control building services. This sector supports real estate asset, property and facilities management.

Real Estate FinTech describes technology-based platforms which facilitate the trading of real estate asset *ownership*. The assets can be buildings, shares or funds, debt or equity; ownership can be freehold or leasehold. The platforms may simply provide information for prospective buyers and sellers, or they may more directly facilitate or effect transactions of asset ownership or leases with a (negative or positive) capital value. This sector supports the real estate capital markets.

The Shared Economy describes technology-based platforms which facilitate the *use* of real estate assets. The assets can be land or buildings, including offices, shops, storage, housing and other property types. The platforms may simply provide information for prospective users and sellers of space, or they may more directly facilitate, or effect, rent or fee-based transactions. This sector supports the real estate occupier markets.

In this report, we continue to focus on these three sectors, which we discuss in Chapters 4, 5 and 6. We also (in Chapter 7) use AI applied to Unissu data to identify six tech clusters without any prior category identification.

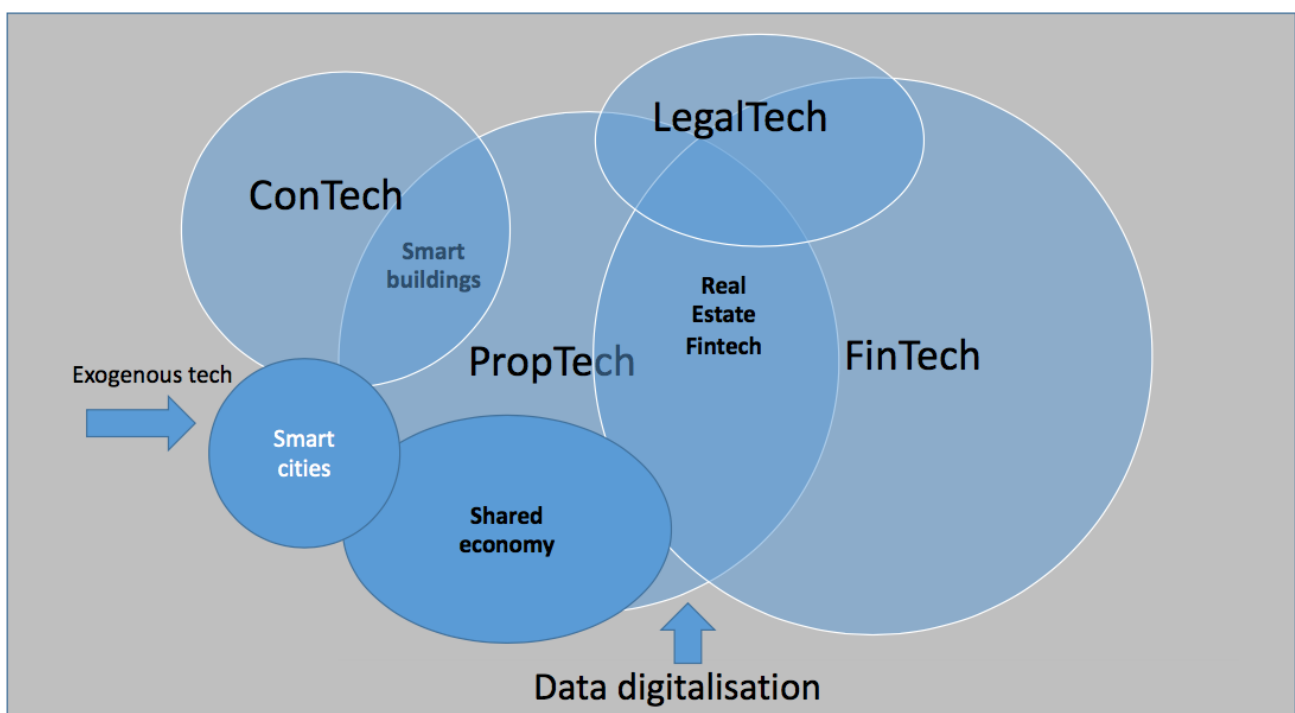
Given that the Unissu data excludes the major Shared Economy platforms, we put this one side as an important standalone PropTech category. We find that Data Analytics forms a distinct cluster at the core of the network; this is strongly connected with the Smart Real Estate cluster that contains technology tags such as ‘Smart Buildings’ or ‘Internet of Things’. There is a Business Process cluster; a detached Contech cluster, which includes Pre-Fabrication and Modular Building technologies; and a detached Real Estate FinTech 3.0 cluster, which contains tags ‘Crowdfunding’, ‘Peer to Peer’, ‘Blockchain’, and ‘Cryptocurrency’.

Business Processes and Construction Technology or *Contech* are largely outside the scope of this document, although Contech is strongly related to (and a driver of) Smart Real Estate.

Therefore, in addition to our three major verticals, two of which are identified in our data analysis and one of which is excluded from the data, we can add another major area of activity, which is *Data Analytics and Digitalisation*: data management, data analysis and data visualisation, what some call the 'nuts and bolts' of PropTech, driven relentlessly on by the digitalisation movement. Much of the desired progress in innovation and technology adoption depends on unsung data mechanics fixing the basic engineering of the sector.

Figure 46 attempts to represent these five drivers and the major PropTech activity areas.

Figure 46: The FoRE Proptech 2020 schematic



Source: FoRE

The five drivers are:

- construction technology
- legal technology
- the shared economy movement
- FinTech
- exogenous technology

The four key areas of PropTech activity are:

- Smart real estate
- Real estate FinTech
- The real estate shared economy
- Data digitalisation/analytics (nuts and bolts)

We should also add the important impact of large scale exogenous technology, usually transport-related, on the way increasingly *smart cities* will work, as an extension of the smart real estate sector.

At least \$20bn has been invested in these sectors in the last 4-5 years, giving oxygen to 7,000 PropTech start-ups employing a variety of technologies, including:

- Websites and smartphone apps
- APIs
- Data analysis and visualisation
- The Internet of Things (IoT)
- Artificial intelligence and machine learning
- Blockchain and distributed ledger technology
- Sensors
- Virtual and augmented reality
- Geospatial and 5G technologies
- Cloud computing
- Transportation tech: drones, autonomous vehicles and hyperloop
- Other technologies, including 3D printing, wearables and environmentally-friendly building materials.

From our analysis, we conclude that the most important property technologies in the current PropTech market are those which produce digital data and generate value from it. This is where funding should be focussed in 2020.

There are several barriers slowing down tech adoption and innovation in the real estate industry. These include operational barriers, regulatory barriers and social barriers. Many PropTech start-ups looking to ‘disrupt’ the industry will only do so following complementary transformations in the non-tech operations of the real estate industry, such as modifying the way leases work to protect the interests of landlords while delivering customer satisfaction and incentivising energy saving.

The PropTech 1.0 wave had its roots in the 1980s personal computer, and the internet and e-mail taking off in the mid- to late-1990s. It ended with the dotcom crash of 2001. The PropTech 2.0 wave was stimulated by the GFC and tech developments culminating in the App Store, and there are signs that it is now maturing. PropTech 3.0 will be driven by the global pressures of climate change and rapid urbanisation and enabled through the maturing of exogenous technologies including the Internet of Things, Machine Learning and Artificial Intelligence, and Blockchain.

Baum (2017) concluded that there is an oversupply of activity in Real Estate FinTech based on a misjudgement of the velocity of real estate transactions, an excess of optimism in shared economy real estate, and a real need for smart buildings. Our data analysis and the resulting hype cycle shows that has been played out to a large extent. What else has happened since?

We have progressed through the hype cycle to the beginning of the disillusionment phase for some applications with the result that we now see fewer start-ups, but more money invested in the sector, implying maturation and consolidation.

We have seen increasing attention paid to the nexus of smart buildings and shared economy applications, with some convergence of these verticals, exemplified by space-as-a-service.

More consolidation is certainly on the way, and we can expect to see traditional broking and advisory businesses cherry-picking the best ideas and moving into the space currently occupied by the more thoughtful start-ups. Property owners will Hoover up tech firms and combine high return service operations with low risk ownership. As they mature, tech firms – even Amazon, Google and Facebook - will increasingly focus on accessing the benefits of real estate ownership.

In order to be sustainable and to continue to attract talent and capital, the PropTech sector needs to focus on three areas:

- the nuts and bolts of data engineering and digitalisation;
- solving real problems of inefficiency in real estate businesses and the real estate market, including understanding the relationship of real estate and cyberspace in order to capture the value created by control of both; and
- the big world issues of climate change, demographic change and urbanisation.

PropTech activity is centralised and focussed on a small number of cities, including San Francisco, New York, London, Berlin and Shanghai. The size of the domestic markets and the unfractured nature of their political geographies make the US and China extremely powerful engines of growth. There is, however, great potential for many developments in data analysis and the future will see the growth of smart city technology which is able to aid in the planning, ownership, and operation of both developing settlements and increasingly dense urban conurbations. This issue is not confined to the homes of Amazon and Alibaba.

We also need to avoid making large mistakes, specifically:

- over-investing in exciting but ultimately utopian and unprofitable areas; and
- fuelling a real estate data monopoly

By 2050 the world's population is expected to double, with 90% of that growth predicted in Africa and Asia. For the first time in our history over 50% of the world's population is living in urban areas, and this figure is predicted to increase to 68% by 2050. This poses many questions of shelter, needs provision, resource consumption, and equality. The PropTech industry has a part to play as a benign contributor to human welfare.

References

- ABI Research (2019): *Digital Twins, Smart Cities, and Urban Modeling*. Retrieved from https://www.abiresearch.com/market-research/product/1033835-digital-twins-smart-cities-and-urban-model/?utm_source=media&utm_medium=email, accessed on 10 October 2019.
- Adobe (2019): *Augmented reality marketing and smart AR glasses technology concept*. Retrieved from https://stock.adobe.com/sk/images/augmented-reality-smart-ar-glasses-technology-smart-city-internet-of-things-concept-customer-using-ar-application-see-digital-3d-rendering-building-with-blur-city-background/167750809?asset_id=167705082, accessed on 10 October 2019.
- Agarwal, Y., Balaji, B., Gupta, R., Lyles, J., Wei, M. and Weng, T. (2010): *Occupancy-driven energy management for smart building automation*, Association for Computing Machinery (ACM), 1-6. <https://doi.org/10.1145/1878431.1878433>
- Ahmad, J., Larijani, H., Emmanuel, R., Mannion, M. and Javed, A. (2018): *Occupancy detection in non-residential buildings – A survey and novel privacy preserved occupancy monitoring solution*, Applied Computing and Informatics, Elsevier B.V. <https://doi.org/10.1016/j.aci.2018.12.001>.
- Akerlof, G. (1970): *The market for “lemons”: Quality uncertainty and the market mechanism*, Quarterly Journal of Economics, 84:488–500.
- Allen, J.G., MacNaughton, P., Satish, U., Santanam, S., Vallarino, J. and Spengler, J.D. (2016): *Associations of cognitive function scores with carbon dioxide, ventilation, and volatile organic compound exposures in office workers: a controlled exposure study of green and conventional office environments*, Environ Health Perspect, 124:805–812. <http://dx.doi.org/10.1289/ehp.1510037>.
- Allison, I. (2019): *Tokenized Real Estate Falters as Another Hyped Deal Falls Apart*, Yahoo Finance Online, 26 November. Retrieved from <https://finance.yahoo.com/news/tokenized-real-estate-falters-another-090000644.html?guccounter=1>, accessed on 8 December 2019.
- Alois, J.D. (2019): <https://www.crowdfundinsider.com/2019/01/143318-aspencoin-migrates-over-to-securitize-with-18-million-security-token/>, accessed on 22 December 2019.
- Alsadi, S. (2015): *Zillow’s Reliance on Multiple Network Effects*, Digit Online. Retrieved from <https://digit.hbs.org/submission/zillows-reliance-on-multiple-network-effects/>, accessed on 16 March 2019.
- Altus Group (2019): *The Innovation Opportunity in Commercial Real Estate: A Shift in PropTech Adoption and Investment*, Altus CRE Innovation Report.
- Altus Group (2019b): *Real estate development trends report*. Retrieved from https://go.altusgroup.com/EMEA-Development-Trends-Report-2019?utm_source=Future%20Proptech&utm_campaign=Development-trends-report-EN-future-proptech, accessed on 27 October 2019.
- Archambault, L.L. (2018): *Real Estate and Innovative Tech: A Love Story*, Commercial Property Executive Online, 26 September. Retrieved from <https://www.cpexecutive.com/post/real-estate-and-innovative-tech-a-love-story/>, accessed on 17 May 2019.
- Attema, J.E., Fowell, S.J., Macko, M.J. and Neilson, W.C. (2018): *The Financial Case For High Performance Buildings*, San Francisco: Stok, LLC.
- Augment. (2017): *3 Innovative Real Estate Technologies You Can’t Miss*, Augment Online, 22 June. Retrieved from <https://www.augment.com/blog/author/augment/>, accessed on 8 January 2020.
- Aydin, R. (2019): *WeWork isn’t even close to being profitable — it loses \$219,000 every hour of every day*, New Haven Register Online, 3 July. Retrieved from <https://www.nhregister.com/technology/businessinsider/article/WeWork-isn-t-even-close-to-being-profitable-14070188.php>, accessed on 23 August 2019.

- Baatar, T. (2018): *PropTech Insights from Korea*, Infabode Online, 7 November. Retrieved from https://www.infabode.com/hubs/general-global-property-technology/hub_posts/82412, accessed on 17 May 2019.
- Back, A. (2018): *Blockchain & Crypto Hype Cycle: Where We're at and What's Coming Next*, Medium Online, 5 November. Retrieved from <https://medium.com/blockchain-review/blockchain-crypto-hype-cycle-where-were-at-and-what-s-coming-next-c71cd3f60688>, accessed on 27 October 2019.
- Baker, J. (2011): *The Technology–Organization–Environment Framework*, September. DOI: 10.1007/978-1-4419-6108-2_12.
- Barter, S. (1989): *Real Estate Finance*, Butterworths Law.
- Baum, A. (2017): *PropTech 3.0: The future of Real Estate*, Saïd Business School, University of Oxford Research.
- Baum, A. (2020): *Real Estate Tokenisation – The Future of Real Estate?* SBS, University of Oxford Research.
- Baum, A. and Dearsley, J. (2017, in Derbyshire, 2019): *What is PropTech*, Unissu Online, 5 March. Retrieved from <https://www.unissu.com/proptech-resources/what-is-proptech>, accessed on 16 April 2019.
- Baum, A. and Hartzell, D (2012): *Global Property Investment – Strategies, Structures, Decisions*, Wiley Blackwell.
- Beckerman, M. (2019): *Reimagining the Retail User Experience*, CRETech Online, 22 August. Retrieved from <https://www.cretech.com/michael-beckerman/reimagining-the-retail-user-experience/>, accessed on 13 October 2019.
- Beckerman, M. (2019): *Who will drive the ultimate tech revolution in CRE?*, CRETech Online, 14 March. Retrieved from <https://www.cretech.com/michael-beckerman/who-will-drive-the-ultimate-tech-revolution-in-cre/>, accessed on 27 October 2019.
- BidX1 (2019): *Buying Property with BidX1 UK*, BidX Online, 13 March. Retrieved from <https://bidx1.com/en/news/buying-property-bidx1-uk>, accessed on 15 October 2019.
- Block, A. and Aarons, Z. (2019): *PropTech 101: Turning chaos into cash through real estate innovation*, Advantage, ISBN: 979-1-64225-060-2.
- Blocksquare (2019): *Proptoken Generation Event (Pilot): Underground Garage Parking Space In Technology Park Ljubljana*. Retrieved from <https://blocksquare.io/pilot>, accessed on 6 January 2020.
- Blomquist, D. (2018): *Top Real Estate Disrupters: Offerpad Disrupting the Disrupter*, Attom Data Solutions Online, 1 August. Retrieved from www.attomdata.com/news/attom-insights/client-case-studies/top-real-estate-disrupters-offerpad/, accessed on 27 September 2018.
- British Council for Offices (2017): *Defining and Measuring Productivity in Offices*. Retrieved from http://www.bco.org.uk/Research/Publications/Defining_and_Measuring_Productivity_in_Offices.aspx, accessed on 6 November 2019.
- British Council for Offices (2018): *Fast and Slow Buildings: Responsiveness through Technology and Design*, Retrieved from http://www.bco.org.uk/Research/Publications/Fast_and_Slow_Buildings_Responsiveness_through_Technology_and_Design.aspx, accessed on 8 January 2020.
- British Property Federation and Future Cities Catapult (2018): *Lost in translation: How can real estate make the most of the Proptech revolution?*
- Business Wire (2018): *VTS Announces VTS MarketView: First-Ever Real-time Benchmarking and Market Analytics for Commercial Real Estate*, Business Wire Online, 18 June. Retrieved from <https://www.businesswire.com/news/home/20180618005302/en/VTS-Announces-VTS-MarketView™-First-Ever-Real-time-Benchmarking>, accessed on 14 October 2019.

Byrne, N. (2019): *WeWork Launches \$2.9bn to Become Landlord*, PlaceTech Online, 17 May. Retrieved from <https://placetechnet.com/news/wework-launches-2-9bn-fund-to-become-landlord/>, accessed on 22 August 2019.

Cambridge Centre for Alternative Finance (2018): *5th UK Alternative Finance Industry Report*, Judge Business School, University of Cambridge.

CBRE (2019): *#TechCBRE*, CBRE Online. Retrieved from <https://tech.cbre.com>, accessed on 23 April 2019.

Célérier, L. (2018): *The Proptech Unicorn Club*, Stonup Online, 18 June. Retrieved from <https://stonup.com/blog-article/the-proptech-unicorn-club/>, accessed on 2 May 2019.

Chimwa, G. (2019): *UK Storms Ahead in 3100-strong European PropTech Landscape*, FUTURE PropTech Insight Report, Unissu Online. Retrieved from https://s3-eu-west1.amazonaws.com/unissu.branding/FUTURE_PropTech_Report_Unissu.pdf?inf_contact_key=f74ba45a2dd72b85bca93758286e14d0, accessed on 20 May 2019.

Concrete Ventures (2019): *PropTech Central Confidential Investor Prospectus*, Unpublished.

Corluka, D. and Lindh, U. (2017): *Blockchain: A New Technology That Will Transform The Real Estate Market*, Degree Project, Real Estate And Construction Management, Building And Real Estate Economics, Stockholm. Retrieved from <https://kth.diva-portal.org/smash/get/diva2:1124675/FULLTEXT01.pdf>, accessed on 31 July 2018.

CRETech (2019): *2018 End of Year Report*, CRETech Online. Retrieved from <https://www.crettech.com/product/crettech-2018-end-year-report/>, accessed on 25 April 2019.

Crouse, A. (2018): *How drones, data and AI are changing the property sector*, World Economic Forum Online, 24 January. Retrieved from <https://www.weforum.org/agenda/2018/01/proptech-drones-data-ai-property-sector/>, accessed on 17 May 2019.

CrowdFundInsider. (2019): *Aspencoin Migrates Over to Securitize with \$18 Million Security Token*, Crowd Fund Insider Online, 16 January. Retrieved from

Crunchbase (2019): *Softbank Vision Fund*, Online database. Retrieved from <https://www.crunchbase.com/fund/softbank-raised-softbank-vision-fund--abf5a098#section-overview>, accessed on 25 April 2019.

Dahlman, C. J. (1979): *The Problem of Externality*, *Journal of Law and Economics*, 22 (1): 141–162. doi:10.1086/466936. ISSN 0022-2186.

De Groote, M., Volt, J. and Bean, F. (2017): *Smart buildings decoded*, Building Performance Institute Europe. Retrieved from http://bpie.eu/wp-content/uploads/2017/06/PAPER-Smart-buildings-decoded_05.pdf, accessed on 4 May 2019.

Deloitte (2017): *Blockchain and real estate: Mining unexplored terrain*. Retrieved from www2.deloitte.com/content/dam/Deloitte/nl/Documents/real-estate/deloitte-nl-fsi-re-blockchain-in-re.pdf, accessed on 3 January 2019.

Deloitte (2018): *Blockchain in commercial real estate: The future is here*, Perspectives, Deloitte Online. Retrieved from <https://www2.deloitte.com/us/en/pages/financial-services/articles/blockchain-in-commercial-real-estate.html>, accessed on 8 January 2019.

DelPrete, M (2018): *Global Real Estate Portal Report*. Retrieved from <https://www.mikedp.com/articles/2018/10/23/2018-global-real-estate-portal-report>, accessed on 3 May 2019.

DelPrete, M. (2020): *The 2019 iBuyer Scorecard*, Infabode Online, 5 February. Retrieved from www.infabode.com/hubs/general-global-property-technology/hub_posts/157367, accessed on 6 February 2020.

Derbyshire, W. (2019a): *What is PropTech*, Unissu Online, 5 March. Retrieved from <https://www.unissu.com/proptech-resources/what-is-proptech>, accessed on 16 April 2019.

- Derbyshire, W. (2019b): *Global PropTech Funding in 2018*, Unissu Online, 25 February. Retrieved from <https://www.unissu.com/proptech-resources/global-proptech-funding-in-2018>, accessed on 23 April 2019.
- Dijkstra, M. (2017): *Blockchain: Towards Disruption in the Real Estate Sector*, Masters Thesis, Delft University of Technology, 1 November.
- Dong, J., Winstead, C., Nutaro, J., & Kuruganti, T. (2018): *Occupancy-Based HVAC Control with Short-Term Occupancy Prediction Algorithms for Energy-Efficient Buildings*, *Energies*, 11(9), 2427. <https://doi.org/10.3390/en11092427>.
- Drone Dispatch (2017): *Commercial Real Estate Drone Video*, Youtube, 6 November. Retrieved from www.youtube.com/watch?v=in2Sk6hRi0, accessed on 8 January 2020.
- Ekwevugbe, T., Brown, N., Pakka, V. and Fan, D. (2017): *Improved Occupancy Monitoring in Non-Domestic Buildings*, *Sustainable Cities and Society*, Elsevier. Retrieved from https://dora.dmu.ac.uk/bitstream/handle/2086/13316/Improved%20Occupancy%20Monitoring%20in%20%20Non%20Domestic%20Buildings%20_TE4.docx?sequence=5&isAllowed=y, accessed on 16 May 2019.
- El-Bawab, N. (2019): *Marriott plans to launch home-rental market platform that would compete with Airbnb, report says*, CNBC Online, 29 April
- Erickson, V. L. and Cerpa, A. E. (2010): *Occupancy based demand response HVAC control strategy*, In Proceedings of the 2nd ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Building - BuildSys 10, p7, New York, New York, USA: ACM Press. <https://doi.org/10.1145/1878431.1878434>.
- Erickson, V.L., Carreira-Perpiñán, M.Á. and Cerpa, A.E. (2014): *Occupancy Modeling and Prediction for Building Energy Management*, *ACM Transactions on Sensor Networks*, 10(3), 1–28. <https://doi.org/10.1145/2594771>.
- Ericsson (2017): *Internet of Things forecast*, Ericsson Online Resource. Retrieved from <https://www.ericsson.com/en/mobility-report/internet-of-things-forecast>, accessed on 17 May 2019.
- Esbaitah, W, (2016): *Growth of real estate Crowdfunding in 2016*. Retrieved from <http://crowdfundbeat.com/2016/04/05/growth-of-real-estate-crowdfunding-in-2016/>
- EY (2018): *Accounting For Crypto Assets*, Online Resource. Retrieved from [https://www.ey.com/Publication/vwLUAssets/EY-IFRS-Accounting-for-crypto-assets/\\$File/EY-IFRS-Accounting-for-crypto-assets.pdf](https://www.ey.com/Publication/vwLUAssets/EY-IFRS-Accounting-for-crypto-assets/$File/EY-IFRS-Accounting-for-crypto-assets.pdf), accessed on 8 January 2019.
- Factornerd (2019): *20 proven real estate crowdfunding platforms from Europe that I like*. Retrieved from <https://factornerd.com/top-european-real-estate-crowdfunding-platforms/>, accessed on 12 December 2019.
- Farauo, F. (2018): *Individual Investors Are Starting Seeing the Benefit of Cutting Edge Technology*, Propmodo Online, 30 October. Retrieved from <https://propmodo.com/individual-investors-are-starting-seeing-the-benefit-of-cutting-edge-technology/>, accessed on 14 October 2019.
- Farauo, F. (2019a): *The Truth About PropTech Funding*, Propmodo Online, 26 February, <https://www.propmodo.com/the-truth-about-proptech-funding/>, accessed on 15 March 2019.
- Farauo, F. (2019b): *Stop calling your building smart, prove it*, Propmodo Online, 30 June. Retrieved from <https://www.propmodo.com/stop-calling-your-building-smart-prove-it/>, accessed on 13 October 2019.
- Farauo, F. (2019c): *CoStar CEO on Company's Push Into Hospitality, Its Product Roadmap and, of Course, WeWork*, Propmodo Online, 3 October. Retrieved from <https://www.propmodo.com/costar-ceo-on-companys-push-into-hospitality-its-product-roadmap-and-of-course-wework/>, accessed on 16 October 2019.
- Fearn, N. (2019): *WeWork Files Confidentiality for IPO*, PlaceTech Online, 30 April. Retrieved from <https://placetech.net/news/wework-files-confidentially-for-ipo/>, accessed on 23 August 2019.
- FIBREE. (2019): *FIBREE Industry Report: Blockchain Real Estate 2019*.
- Financial Stability Board (2019): *Decentralised financial technologies: Report on financial stability, regulatory and governance implications*, 6 June. Retrieved from <https://www.fsb.org/2019/06/decentralised-financial->

technologies-report-on-financial-stability-regulatory-and-governance-implications/, accessed on 29 December 2019

Financial Times (2019): *FSB Warns Tokenised Liquidity Could be Illusory*, FT Online. Retrieved from <https://ftalphaville.ft.com/2019/06/06/1559824318000/FSB-warns-tokenised-liquidity-could-be-illusory/>, accessed on 29 December 2019.

Fiorilla, P. (2018): *Shared Space: Coworking's Rising Star*, Commercial Property Executive Online, 8 February. Retrieved from <https://www.cpexecutive.com/post/shared-space-coworkings-rising-star/>, accessed on 22 August 2019.

Frick, W. (2019): *How to Survive a Recession and Thrive Afterward*, Harvard Business Review Online, May–June 2019 Issue. Retrieved from <https://hbr.org/2019/05/how-to-survive-a-recession-and-thrive-afterwards>, accessed on 17 May 2019.

Fuerst, F and McAllister, P (2018): The impact of Energy Performance Certificates on the rental and capital values of commercial property assets, *Energy Policy*, 2011, vol. 39, issue 10, 6608-6614

Gartner (2018): *5 Trends Emerge in the Gartner Hype Cycle for Emerging Technologies, 2018*, Gartner Online. Retrieved from <https://www.gartner.com/smarterwithgartner/5-trends-emerge-in-gartner-hype-cycle-for-emerging-technologies-2018/>, accessed on 27 October 2019.

Gartner (2019): *5 Trends Appear on the Gartner Hype Cycle for Emerging Technologies, 2019*, Gartner online. Retrieved from <https://www.gartner.com/smarterwithgartner/5-trends-appear-on-the-gartner-hype-cycle-for-emerging-technologies-2019/>, accessed on 27 October 2019.

Gartner (2019b): *The reality of blockchain*, Gartner Online, 22 October. Retrieved from <https://www.gartner.com/smarterwithgartner/the-reality-of-blockchain>, accessed on 27 October 2019.

Gartner (2019c): *Gartner Top 10 Strategic Technology Trends for 2020*, Gartner Online, 21 October. Retrieved from <https://www.gartner.com/smarterwithgartner/gartner-top-10-strategic-technology-trends-for-2020/>, accessed on 30 October 2019.

GeoPhy (2018): *Using supervised machine learning to create fast, reliable valuations for commercial real estate*, GeoPhy Online. <https://geophy.com>.

Griffith, E. (2018): *Softbank's Futuristic Vision Fund Takes On The Real (Estate) World*, Wired Online, 16 April. Retrieved from <https://www.wired.com/story/softbanks-futuristic-vision-fund-takes-on-the-real-estate-world/>, accessed on 25 April 2019.

GVA (2019): *Real Estate Technology Sector Report Q1 2019*, Sector Reports and Market Updates, Online Resource. Retrieved from https://gcaglobal.com/sector-reports-market-updates/real-estate-technology-q1-2019/?utm_source=linkedin&utm_medium=social&utm_campaign=RETech-0419-CG, accessed on 1 May 2019.

Harriss, J. and Harris, T. (2019): *Could Tech Stimulate the Next Housing Bubble?*, Online resource. Retrieved from <https://timandjulieharris.com/2019/07/12/could-tech-stimulate-the-next-housing-bubble.html>, accessed on 16 October 2019.

Hay, Z. (2019): *Home Is Where The Hotend Is: 3D Printed Homes – 4 Most Fascinating Projects in 2019*, All3DP Online, 20 February. Retrieved from <https://all3dp.com/2/3d-printed-homes-most-fascinating-projects>, accessed on 8 July 2019.

Hodgson, L. (2018): *The top 10 VC investors in European proptech*, Pitchbook Online, 26 November. Retrieved from <https://pitchbook.com/news/articles/the-top-10-vc-investors-in-european-proptech>, accessed on 25 April 2019.

Hoffman, D. (2019): *Introducing RealT: Tokenizing Real Estate on Ethereum*, Medium Online, 9 May. Retrieved from <https://medium.com/realtplatform/introducing-realt-tokenizing-real-estate-on-ethereum-9b8a995dc3fe>, accessed on 9 December 2019.

Hoffmann, V. (2011): *Knowledge and Innovation Management*, Module Reader, Hohenheim University.

- Holmes, E. (2019): *PropTech Data Providers: It's Time to Tell Everyone Where Your Information Comes From*, Propmodo Online, 14 March. Retrieved from <https://www.propmodo.com/proptech-data-providers-its-time-to-tell-everyone-where-your-information-comes-from/>, accessed on 1 May 2019.
- Hometrack. (2018): *Automated Valuation Model*, Hometrack Online. Retrieved from www.hometrack.com/uk/products/valuations/automated-valuation-model/, accessed on 15 October 2019.
- Hughes, D. (2019): *The LIQUID Report: Leading the digital transformation of global Real Estate*, Commissioned by the British Property Federation.
- Instant Group (2019): *The Global Flex Market: The top 18 markets for Flexible Workspace in 2019*. Retrieved from https://www.theinstantgroup.com/media/2016/global_cities_flexible_workspace_review2019.pdf, accessed on 3 March 2019.
- International Energy Agency (2017): *Digitalization and Energy 2017*. Retrieved from <http://www.iea.org/digital>, accessed on 27 April 2019.
- Investment Property Forum (2004): *Liquidity in Commercial Property Markets*, Working Paper Five: Liquidity – Findings and Recommendations, April.
- Jacobs, J. (1961): *The Death and Life of Great American Cities*.
- JLL (2016): *A New Era of Co-working*. Retrieved from <http://www.jll.co.uk/united-kingdom/en-gb/research/339>, accessed on 22 August 2019.
- JLL (2019): *Flexible space evolves: Markets that are flexing their muscles in 2019*, Research Online. Retrieved from <https://www.us.jll.com/en/trends-and-insights/research/flex-space>, accessed on 22 August 2019.
- Juneja, P. (2019): *Information Asymmetry in Real Estate Markets*, Management Study Guide Online, ISO 2001:2015. Retrieved from <https://www.managementstudyguide.com/true-cost-of-owning-a-property.htm>, accessed on 8 October 2019.
- Kang, M. (2019): *Smart and sustainable, but are these green buildings secure?*, Eco-business Online, 20 June. Retrieved from <https://www.eco-business.com/news/smart-and-sustainable-but-are-these-green-buildings-secure>, accessed on 14 October 2019.
- Kejriwal, S. and Mahajan, S. (2018): *2019 Commercial Real Estate Outlook: Agility is key to winning in the digital era*, Deloitte Centre for Financial Services.
- Klein, L., Kwak, J., Kavulya, G., Jazizadeh, F., Becerik-Gerber, B., Varakantham, P. and Tambe, M. (2012): *Coordinating occupant behavior for building energy and comfort management using multi-agent systems*, Automation in Construction, 22, 525–536.
- Koones, S. (2019): *Modular Construction 101*, Forbes Online, Real Estate, 3 June. Retrieved from https://www.forbes.com/sites/sherikoones/2019/06/03/modular-construction-101/?utm_source=MetaProp+NYC+Community&utm_campaign=fff7996cab-Newsletter_10_17_2018_Launched+and+Accelerate_COPY&utm_medium=email&utm_term=0_f0e4674aaf-fff7996cab-178500765#4431f6482ceb, accessed on 8 July 2019.
- KPMG (2018): *The road to opportunity: An annual review of the real estate industry's journey into the digital age*, Global PropTech Survey, September 2018. Retrieved from <https://home.kpmg/content/dam/kpmg/uk/pdf/2018/09/kpmg-global-proptech-survey.pdf>, accessed on 31 October 2019.
- Krekel, C., Ward, G. and De Neve, J.E. (2019): *Employee Wellbeing, Productivity, and Firm Performance*, Said Business School Research Papers, March.
- Kubiak, R. (2019): *PropTech, a 50-Year Overnight Success*, Propmodo Online, 14 March. Retrieved from <https://www.propmodo.com/proptech-a-50-year-overnight-success>, accessed on 25 April 2019.

Kurlat, P. and Stroebel, J. (2015): *Testing for Information Asymmetries in Real Estate Markets*, The Review of Financial Studies, v28 n8. Oxford University Press. doi:10.1093/rfs/hhv028.

Labeodan, T., Zeiler, W., Boxem, G. and Zhao, Y. (2015): *Occupancy measurement in commercial office buildings for demand-driven control applications - A survey and detection system evaluation*, Energy and Buildings, April 15, Elsevier Ltd. <https://doi.org/10.1016/j.enbuild.2015.02.028>.

Leaseum Partners (2019): <https://www.leaseumpartners.com> and <https://medium.com/leaseum-partners/introducing-leaseum-13008e6818fd>

Levison, T. and Levison, D. (2019): *How to Adopt Technology in Commercial Real Estate*. CommissionTrac Whitepaper. Retrieved from <https://commissiontrac.com/white-papers-e-books/how-to-adopt-technology-in-commercial-real-estate/>, accessed on 6 November 2019.

Liggio, B. And Kim, L. (2019): *The PropTech Industry is Set for a Wave of Consolidation*, PropTech Pulse, Goodwin Law Online, 4 March. Retrieved from https://www.goodwinlaw.com/publications/2019/03/03_04-proptech-pulse, accessed on 1 May 2019.

Macaulay, T. (2018): *How Propportunity is helping homebuyers by predicting future prices*, Techworld Online, 4 October. Retrieved from <https://www.techworld.com/startups/how-propportunity-is-helping-home-buyers-by-predicting-future-prices-3684736/>, accessed on 7 May 2019.

Madison Gas and Electric (2019): *Building Automation Systems*, Online Resource. Retrieved from https://www.mge.com/saving-energy/business/bea/article_detail.htm?nid=1829, accessed on 4 May 2019.

Mandelbaum, R.F. (2019): *Google Confirms Achieving Quantum Supremacy*, Gizmodo Online, 24 October. Retrieved from https://www.gizmodo.com.au/2019/10/google-confirms-achieving-quantum-supremacy/?inf_contact_key=83dc7bb05bad39bf3206d08e8314ac42, accessed on 29 October 2019.

Marinova, P. (2019): *What Is a Security Token? Harbor's CEO Explains*, Fortune Online, 18 May. Retrieved from <https://fortune.com/2018/05/18/security-token-harbor-ceo/>, accessed on 7 December 2019.

Market Research Engine (2018): *IoT Sensor Market By Product Type, By Application Type and by Regional Analysis - Global Forecast 2016 – 2022*. Retrieved from <https://www.marketresearchengine.com/iot-sensor-market>, accessed on 8 July 2019.

Marr, B. (2016): *What Is The Difference Between Artificial Intelligence And Machine Learning?*, Forbes, 6 December. Retrieved from www.forbes.com/sites/bernardmarr/2016/12/06/what-is-the-difference-between-artificial-intelligence-and-machine-learning/#47ec9b32742b, accessed on 8 January 2020.

Melki, M.M. (2018): *Real Estate and Innovative Tech: A Love Story*, Commercial Property Executive Online, 26 September. Retrieved from <https://www.cpexecutive.com/post/real-estate-and-innovative-tech-a-love-story/>, accessed on 17 May 2019.

MIT Digital Currency Initiative (2019): *Tokenised Securities and Commercial Real Estate*, MIT
Morley, A., (2017): *Epic Realty: Bringing VR To Real Estate*. Idaho Virtual Reality Council, 25 September. Retrieved from <https://idahovirtualreality.com/epic-realty-bringing-vr-real-estate/>, accessed on 8 January 2020.

Morris, C. (2019): *Your Next Home Could Be 3D-Printed*, Tech. 3d Printed Houses, Fortune Online, 22 April. Retrieved from <https://fortune.com/2018/04/22/3d-printed-homes/>, accessed on 8 July 2019.

Moss, R. (2018): *The Transformation Game – Leading Innovation In Real Estate*, Holtby Turner <https://www.holtbyturner.co.uk/category/insights/proptech/>

Myinvestment.blog, visited December 12th 2019

National BIM Standard (2014): *Facts and Questions: What is BIM?*, National BIM Standard Online. Retrieved from <https://web.archive.org/web/20141016190503/http://www.nationalbimstandard.org/faq.php#faq1>, accessed on 17 May 2019.

NBS (2013): *BIM for All – Dummies or not*, NBS Online, 1 August. Retrieved from <https://www.thenbs.com/knowledge/bim-for-all-dummies-or-not>, accessed on 17 May 2019.

New Statesman (2018): *The future of home-buying: How technology is set to transform conveyancing*, 6 April. Retrieved from www.newstatesman.com/sites/default/files/future_of_home_buying_supp_clc_6th_april_2018.pdf, accessed on 27 June 2019.

Nguyen, T.A. and Aiello, M. (2013): *Energy intelligent buildings based on user activity: a survey*, *Energy Build.* 56, 244–257.

Nickelsburg, M. (2019): *Facebook launches \$1B affordable housing initiative, joining tech peers trying to close the gap*, *GeekWire Online*, 22 October. Retrieved from <https://www.geekwire.com/2019/facebook-launches-1b-affordable-housing-initiative-joining-tech-peers-trying-close-gap/>, accessed on 29 October 2019.

Novak, N. (2017): *Initial Coin Offerings: When Are Tokens Securities in the EU and US? A comparative analysis on the application of US and EU securities laws to initial coin offerings*, *Academia Online Resource*. Retrieved from https://www.academia.edu/38386804/Initial_Coin_Offerings_When_Are_Tokens_Securities_under_EU_and_US_Law, accessed on 9 December 2019.

Obando, S. (2019): *Global Proptech Investment Hits Record High in First Half of 2019*, *National Real Estate Investor Online*, 2 October. Retrieved from <https://www.nreionline.com/technology/global-proptech-investment-hits-record-high-first-half-2019>, accessed on 4 October 2019.

Oberoi, A. (2018): *How Zillow Works: Business Model and Revenue Streams*, *Daffodil Online*, 1 August. Retrieved from <https://insights.daffodilsw.com/blog/how-zillow-works-business-model-and-revenue-streams>, accessed on 18 March 2019.

Ohnsman, A. (2019): *Self-Driving Startup Embark Raises \$70 Million, Opens Freight Transfer Hubs For Robot Big Rigs*, *Forbes Online*, 25 September. Retrieved from <https://www.forbes.com/sites/alanohnsman/2019/09/25/self-driving-startup-embark-raises-70-million-opens-freight-hubs-for-robot-big-rigs/#4248b9b3653a>, accessed on 10 October 2019.

Oliveira, T. and Martins, M.F. (2011): *Literature Review of Information Technology Adoption Models at Firm Level*, *The Electronic Journal Information Systems Evaluation*, Volume 14 Issue 1, pp110- 121. Available online at www.ejise.com.

Olsen, D. (2018): *The 14 most active VC investors in US real estate tech*, *Pitchbook Online*, 28 August. Retrieved from <https://pitchbook.com/news/articles/the-top-14-vc-investors-in-real-estate-tech>, accessed on 25 April 2019.

Paulos, E., RJ Honicky, R.J., Hooker, B. (2008): *Citizen Science: Enabling Participatory Urbanism*, Book Chapter for *Urban Informatics: Community Integration and Implementation*.

Pérez-Lombard, L., Ortiz, J. and Pout, C. (2008): *A review on buildings energy consumption information*, *Energy and Buildings*, 40(3), 394–398. <https://doi.org/10.1016/j.enbuild.2007.03.007>.

Perez, A. (2019): *iBuying or iLosing*, *Oxford MBA Strategy Assignment*. Unpublished.

Phillips, M. (2019a): *WeWork Backer SoftBank On Its Disruptive Real Estate Push*, *Bisnow Online*, 20 February. Retrieved from https://www.bisnow.com/london/news/technology/exclusive-wework-backer-softbank-on-its-massive-real-estate-push-97606?utm_source=CopyShare&utm_medium=Browser, accessed on 25 April 2019.

Phillips, M. (2019b): *Can PropTech Dream Big Enough For VC Investors?*, *Bisnow Online*, 28 April. Retrieved from https://www.bisnow.com/london/news/technology/as-fifth-wall-raises-468m-can-proptech-dream-big-enough-for-vc-investors-98638?utm_source=CopyShare&utm_medium=Browser, accessed on 25 April 2019.

P2P Market Data (2019): *Crowdfunding in Europe: Market Size by Country & Finance Model (2019)*, *P2P Market Data Online*, 5 June. Retrieved from <https://p2pmarketdata.com/crowdfunding-europe/>, accessed on 12 December 2019.

Pi Labs (2019): *The Future of Construction Tech*, London, United Kingdom. License: Creative Commons Attribution CC BY 3.0 IGO

Putzier, K. (2017): *Data Wars*, The Real Deal Online. Retrieved from https://therealdeal.com/issues_articles/data-wars/, accessed on 15 October 2019.

PwC (2017): *Worldwide REIT regimes*, Compare and Contrast, PwC Online, July. Retrieved from <https://www.pwc.com/gx/en/asset-management/assets/pdf/worldwide-reit-regimes-2017.pdf>, accessed on 29 December 2019

PWC (2018): *Cloud Computing in Real Estate*, Online Resource, 31 July. Retrieved from <https://www.pwc.de/en/real-estate/digital-real-estate/cloud-computing-in-real-estate.html>, accessed on 29 July 2019.

RICS (2019): *The big data 20*, RICS Online, 2 September. Retrieved from <https://www.rics.org/uk/news-insight/future-of-surveying/surveying-technology/the-big-data-20>, accessed on 8 January 2020.

Roche, J. (1995): *Property futures and securitisation: the way ahead*, Woodhead Publishing.

Rogers, E.M. (1995): *Diffusion of innovations*, Fourth Edition ed., New York, Free Press.

Roper, J. (2019): *BIM vs Smart Building vs Digital Twin – what is the difference?*, PropTech Zone Online, 8 September. Retrieved from <https://proptech.zone/bim-vs-smart-building-vs-digital-twin-what-is-the-difference/>, accessed on 10 October 2019.

Saull, A. (2019): *The Key to a Green Building*, Masters Dissertation, Sustainable Urban Development, Department of Continuing Education, Kellogg College. University of Oxford.
Saull, A. and Baum, A. (2019): *The Future of Real Estate Transactions*. Oxford Research. Saïd Business School.

Savian, C. (2019): *Digital Twin: The cutting-edge technology for the built environment*, BIM Today Online, 20 June. Retrieved from <https://www.pbctoday.co.uk/news/bim-news/digital-twin-built-environment/58778/>, accessed on 8 July 2019.

Savills (2018): Retrieved from <https://www.savills.com/impacts/market-trends/8-things-you-need-to-know-about-the-value-of-global-real-estate.html>, accessed on 05 June 2019.

Savills (2019): *Impacts: The future of Global real estate*, Issue 2. Retrieved from https://www.savills.com/impacts/Savills_Impacts_2019_download.pdf, accessed on 13 October 2019.

Schulte, K-W., Rottke, N. and Pitchke, C. (2005): *Transparency in the German Real Estate Market*, Journal of Property Investment & Finance, 23 (1). 90-108.

Schwab, K. (2017): *The Fourth Industrial Revolution*, Crown Publishing Group, New York, NY, USA.

SEC (2019): *Regulation Crowdfunding*, US SEC Online. Retrieved from <https://www.sec.gov/smallbusiness/exemptofferings/regcrowdfunding>, accessed on 29 December 2019.

Shrier, D. (2019): *The Face of Financial Innovation*, Get Smarter Online, 6 August. Retrieved from <https://www.getsmarter.com/blog/career-advice/david-shrier-the-face-of-financial-innovation/>, accessed on 27 December 2019.

Slumbers, A. (2019a): *Space as a service: the trillion dollar hashtag*, Megatrends, Propmodo Online, January 14. Retrieved from <https://www.propmodo.com/space-as-a-service-the-trillion-dollar-hashtag/>, accessed on 1 April 2019.

Slumbers, A. (2019b): *AI and retail real estate - the impact on valuation*, Unissu Online, 25 February. Retrieved from https://www.unissu.com/proptech-resources/ai-and-retail-real-estate-the-impact-on-valuation?inf_contact_key=3142ae5c9cd937a121fb91e6881d4b0e, accessed on 13 October 2019.

Smart Cities World (2019): *Finnish university sets out the drivers for 6G*, Online resource, 11 September. Retrieved from <https://www.smartcitiesworld.net/news/finnish-university-sets-out-the-drivers-for-6g->

- 4568?utm_source=newsletter&utm_medium=email&utm_campaign=Weekly%20Newsletter, accessed on 10 October 2019.
- Snyers, A and Pauwels, K. (2018): *ICOs in Belgium: down the rabbit hole into legal no man's land? Part 1*, International Commercial Law Review afl. 8, (483)484.
- Squint Opera (2019): *Hyperform*. Retrieved from <https://www.squintopera.com/projects/hyperform/>, accessed on 10 October 2019.
- Stanton, Y. (2019): *Using sensors to measure workplace occupancy*, MIPIM PropTech Online, Contributor Series, 6th Edition, 16 May. Retrieved from <https://www.mipim-proptech.com/en/our-community.html>, accessed on 16th May 2019.
- Stern, S. (2005): *Temporal Dynamics of Disclosure: The Example of Residential Real Estate Conveyancing*, Utah, Rev. 57.
- Stevens, B. (2019): *Retail set to spend more on AI than any industry this year*, Charged Retail Online, 14 March. Retrieved from <https://www.chargedretail.co.uk/2019/03/14/retail-set-to-spend-more-on-ai-of-any-industry-this-year/>, accessed on 13 October 2019.
- Stevens, B. (2019b): *How technology is blurring the lines between the digital world and reality*, Charged Retail Online, 27 August. Retrieved from <https://www.chargedretail.co.uk/2019/08/27/how-technology-is-blurring-the-lines-between-the-digital-world-and-reality/>, accessed on 13 October 2019.
- Stevens, B. (2019c): *Baidu overtakes Google in smart home market with 3700% growth*, Charged Retail Online, 28 August. Retrieved from <https://www.chargedretail.co.uk/2019/08/28/baidu-overtakes-google-in-smart-home-market-with-3700-growth/>, accessed on 13 October 2019.
- STR (2017): *Airbnb & Hotel Performance: An analysis of proprietary data in 13 global markets*. Retrieved from <https://str.com/sites/default/files/2019-07/Airbnb-and-Hotel-Performance.pdf>, accessed on 8 January 2019
- Straub, E.T. (2009): *Understanding Technology Adoption: Theory and Future Directions for Informal Learning*, Review of Educational Research, 79(2), 625–649. <https://doi.org/10.3102/0034654308325896>.
- Szabo, N. (1996): *Smart Contracts: Building Blocks for Digital Markets*. Retrieved from http://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart_contracts_2.html, accessed on 10 January 2019.
- Taherdoost, H. (2018): *A review of technology acceptance and adoption models and theories*. In *Procedia Manufacturing*: Vol. 22, pp. 960–967, Elsevier B.V. <https://doi.org/10.1016/j.promfg.2018.03.137>.
- Tekla (2018): *What is BIM*, Tekla Online. Retrieved from <https://www.tekla.com/about/what-is-bim>, accessed on 8 October 2018.
- Ten Fold Engineering. (2019): *K-Case and Cabin Box concept videos*. Ten Fold Engineering online. Retrieved from <https://www.tenfoldengineering.com>, accessed on 25 October 2019
- Thame, D. (2019): *How Amazon's Deliveroo Takeaway Depends On Dark Kitchens (And Not Breaching Competition Rules)*, Bisnow Online. 17 October.
- Tombs, L. (2018): *Discovering what's possible with Digital Street*, HM Land Registry Blog, 1 May. Retrieved from hmlandregistry.blog.gov.uk/2018/05/01/discovering-whats-possible-with-digital-street/, accessed on 6 June 2018.
- UK Department for Business, Energy and Industrial Strategy (2016): *Building Energy Efficiency Survey. Executive Summary*, November.
- Unissu (2019a): *PropTech in the USA*, UNissu Online, 31 May. Retrieved from https://www.unissu.com/proptech-resources/proptech-in-the-usa?inf_contact_key=c5de8f77042bb78640d99568bb3fad4b, accessed on 12 June 2019.

- Unissu (2019b): *PropTech in the UK*, Unissu Online, 28 May. Retrieved from https://www.unissu.com/proptech-resources/proptech-in-the-uk?inf_contact_key=642c2ab72f343b120834d5a565d88ef3, accessed on 12 June 2019.
- Unissu (2019c): *Global PropTech Analysis: Europe*, Unissu Online, 21 August. Retrieved from <https://www.unissu.com/proptech-resources/proptech-europe>, accessed on 3 October 2019.
- Unissu (2019d): *Global PropTech Analysis: Asia*, Unissu Online, 23 August. Retrieved from <https://www.unissu.com/proptech-resources/global-proptech-analysis-asia>, accessed on 10 January 2020
- Untitled Inc. (2019): *Main Token Types by Dimension*. Retrieved from <http://www.untitled-inc.com/wp-content/uploads/2018/01/TCF-Types-Table-only.png>, accessed on 30 December 2019.
- Vagnani, G. and Volpe, L. (2017): *Innovation attributes and managers' decisions about the adoption of innovations in organizations: A meta-analytical review*, International Journal of Innovation Studies, 1(2), 107–133. <https://doi.org/10.1016/j.ijis.2017.10.001>
- Van Alstyne, M., Parker, G. and Choudary, S. (2016): *Pipelines, Platforms, and the New Rules of Strategy*, Harvard Business Review, Online Resource. Retrieved from <https://hbr.org/2016/04/pipelines-platforms-and-the-new-rules-of-strategy>, accessed on 18 March 2019.
- Vander Capital Partners (2019): *A practical guide to understanding PropTech in 2019*, Unpublished. Available on request via: roberto.charvel@vandercp.com.
- Vaughn, C. (2019): *What does 5G roll-out mean for property?*, PlaceTech Online, 14 August. Retrieved from <https://placetech.net/news/what-does-5g-roll-out-mean-for-property/>, accessed on 10 October 2019.
- Venkatesh, V., Morris, M.G., Davis, F.D. and Davis, G.B. (2003): *User Acceptance of Information Technology: Toward a Unified View*, MIS Quarterly, 27, 425-478.
- Venture Scanner (2019a): *Real Estate technology Investors With the Most Activity*. Online resource, 19 March. Retrieved from <https://www.venturescanner.com/blog/tags/proptech>, accessed on 2 May 2019.
- Venture Scanner (2019b): *Real Estate Technology Startup Highlights – Q3 2018*, Online resource, 27 December. Retrieved from <https://www.venturescanner.com/blog/tags/proptech>, accessed on 2 May 2019.
- Venture Scanner (2019c): *Real Estate Technology Experiences Highest Funding Ever in 2018*, Online resource, 26 March. Retrieved from <https://www.venturescanner.com/blog/tags/proptech>, accessed on 2 May 2019.
- Veuger, J. (2018): *Trust in a viable real estate economy with disruption and blockchain*, Facilities 36(1/2), 103-120.
- Welles, H. (2018): *Here's How Drones Will Transform Your Commercial Real Estate Business*, Propmodo Online, 24 September. Retrieved from propmodo.com/heres-how-drones-will-transform-your-commercial-real-estate-business/, accessed on 8 January 2020.
- Wiggers, K. (2019): *Microsoft furthers \$5 billion IoT plan with new Azure features*, Venture Beat Online, 28 October. Retrieved from <https://venturebeat.com/2019/10/28/microsoft-furthers-5-billion-iot-plan-with-new-azure-features/>, accessed on 8 January 2019.
- Wilson, M. (2019): *Alphabet and other giants are betting that the future of real estate is robotic*, Fast Company Online, 5 September. Retrieved from <https://www.fastcompany.com/90399075/alphabet-is-betting-that-the-future-of-real-estate-is-robotic>, accessed on 13 October 2019.
- World Green Building Council (2014): *Health, Well-being & Productivity in Offices: The Next Chapter for Green Building*, September.
- Zancanella, P., Bertoldi, P., Boza-Kiss, B. (2018): *Energy efficiency, the value of buildings and the payment default risk*, Joint Research Centre, European Commission

- Zamani Gharaghooshi, F., McMeel, D. and Manfredini, M. (2014): *Digital Technologies and the Production of Spaces of Resistance*, International Contemporary Urban Issues.
- Zillow Group, Inc. (2019): *Form 10-K, Annual Report for the Fiscal Year Ended December 2018*, Zillow Online. Retrieved from <http://d18rn0p25nwr6d.cloudfront.net/CIK-0001617640/7a4d596b-799d-4f16-b144-8dc96c1e127f.pdf>, accessed on 8 January 2019.
- Zillow Group, Inc. (2019b): *Zillow Group Reports Fourth Quarter and Full Year 2018 Results*, Zillow Online. Retrieved from <http://investors.zillowgroup.com/news-releases/news-release-details/zillow-group-reports-fourth-quarter-and-full-year-2018-results>, accessed on 9 March 2019.
- Zillow Group, Inc. (2019c): *Zillow Unveils Smarter, More Accurate Zestimate That 'Sees' Unique Home Features, Incorporates Greater Real-Time Data*. Press Release, 27 June. Retrieved from <http://zillow.mediaroom.com/2019-06-27-Zillow-Unveils-Smarter-More-Accurate-Zestimate-That-Sees-Unique-Home-Features-Incorporates-Greater-Real-Time-Data>, accessed on 15 October 2019.
- Zuboff, S. (2015): *Big Other: surveillance capitalism and the prospects of an information civilization*, Journal of Information Technology (30) 75-89.
- Zvi, N. B. (2019): *How Location Analytics Can Pull Commercial Real Estate out of the Darkness*, Propmodo Online, 22 June. Retrieved from <https://www.propmodo.com/how-location-analytics-can-pull-commercial-real-estate-out-of-the-darkness/>, accessed on 8 July 2019.



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