Chapter 3 Artificial intelligence robot safety: a conceptual framework and research agenda based on new institutional economics and social media

Rita Yi Man Li, Department of Economics and Finance, Hong Kong Shue Yan University, email ritarec1@yahoo.com.hk / ymli@hksyu.edu
M. James C. Crabbe, Wolfson College, Oxford University, U.K.; Institute of Biomedical and Environmental Science & Technology, School of Life Sciences, University of Bedfordshire, Park Square, Luton, U.K.; School of Life Sciences, Shanxi University, Taiyuan, China. Email james.crabbe@wolfson.ox.ac.uk / james.crabbe@beds.ac.uk

Abstract
According to "Huang's law", Artificial intelligence (AI)-related hardware increases in power 4 to 10 times per year. AI can benefit various stages of real estate development, from planning and construction to occupation and demolition. However, Hong Kong's legal system is currently behind when it comes to technological abilities, while the field of AI safety in built environments is still in its infancy. Negligent design and production processes, irresponsible data management, questionable deployment, algorithm training, sensor design and/or manufacture, unforeseen consequences from multiple data inputs, and erroneous AI operation based on sensor or remote data can all lead to accidents. Yet, determining how legal rules should apply to liability for losses caused by AI systems takes time. Traditional product liability laws can apply for some systems, meaning that the manufacturer will bear responsibility for a malfunctioning part.

That said, more complex cases will undoubtedly have to come before the courts to determine whether something unsafe should be the manufacturer's fault or the individual's fault, as well as who should receive the subsequent financial and/or non-financial compensation, etc. Since AI adoption has an inevitable relationship with safety concerns, this project intends to shed light on responsible AI development and usage, with a specific focus on AI safety laws, policies, and people's perceptions. We will conduct a systematic literature review via the PRISMA approach to study the academic perspectives of AI safety policies and laws and data-mining publicly available content on social media platforms such as Twitter, YouTube, and Reddit to study societal concerns about AI safety in built environments. We will then research court cases and laws related to AI safety in 61 jurisdictions, in addition to policies that have been implemented globally. Two case studies on AI suppliers that sell AI hardware and software to users of built environment will also be included. Another two case studies will be conducted on built environment companies (a contractor and Hong Kong International Airport) that use AI safety tools. The results obtained from social media, court cases, legislation, and policies will be discussed with local and international experts via a workshop, then released to the public to provide the international community and Hong Kong with unique policy and legal orientations.

Keywords: artificial intelligence, robot, new institutional economics, PRISMA, law, case studies, Hong Kong

1. Introduction

Based on expert predictions, the world's population will grow by 4 billion over the next 60 years. With an additional 1,200,000 to 1,500,000 residential units being needed annually, traditional construction methods will not support such demand. Coupled with high labour costs and a labour shortage, there is a growing trend towards adopting more innovative approaches. In light of this, new methods such as prefabricated buildings and construction being carried out

by AI robots with object detection will become more commonplace (Baghdadi *et al.* 2020). In Hong Kong, we are already using AI to identify people not wearing masks in housing estates and shopping malls during the Covid-19 pandemic. Building surveying and property management professionals have begun to use drones to detect cracks in concrete and water leaks via object detection.

Even though AI provides considerable levels of convenience and is generally prone to making fewer errors than humans, the danger of AI errors remains significant. Although computer program designs and algorithms are generally accurate, training a program requires sufficiently large, accurate, and non-biased data, which is usually challenging to acquire in the real world. Once applied to real-world instances, an AI design exposed to biased, false, or otherwise corrupted data can modify its 'understanding' to simply accept the biased or inaccurate information as accurate, thereby functioning according to erroneous data (Giuffrida 2019). Moreover, strong AI, such as neuromorphic artificial general intelligence, appears to be the most dangerous.

Given that most people's time is spent within built environments and safety is an essential aspect of responsible AI (as well as corporate social responsibility) and there is a general lack of related studies in this field, we plan on studying academia's perspectives on AI safety across the four stages of real estate development: planning, construction, occupation, and demolition.

Although Plato was famous for advocating the need to leave policy decisions to the experts, others have argued for the importance of public comments (Awad, Anderson, Anderson, Liao, 2020 forthcoming). We can gauge global views on AI safety in built environments by studying publicly available social media comments. This data can then be compared with 61 jurisdictions with AI safety-related laws, policies, and court cases to understand the deviation between public needs and presently available statutes and policies. The results will provide local and international communities with unique policy orientations and offer insights into responsible AI development in the future. Revealing the differences in legal and policy design worldwide will also allow us to understand the impact of socio-cultural factors on AI safety laws and policy development.

Since successful law and policy implementation requires satisfying local needs, two case studies of AI suppliers and another two case studies of AI users who engage in the planning, construction, and occupation stages, will help us better understand their expectations regarding AI policies and laws. Finally, experts will discuss our results before a final policy and law recommendation for Hong Kong.

The objectives of this research are fivefold:

1. To study academia's and the public's concerns on AI safety in built environments globally;
2. To review existing AI safety policies and regulations in built environments;
3. To reveal the impact of six dimensions of culture and socio-economic development on global AI safety regulations and policies;
4. To study the safety concerns and experiences of AI users and suppliers in Hong Kong's built environment;
5. To provide the international community and Hong Kong with unique policy and law orientations based on the results mentioned above.

2. Literature review

2.1 Applications of AI in built environments

Traditional real estate development includes planning, construction, occupation, and demolition stages. AI can be applied in all these stages.

In the planning stage, AI is a potential saviour with much potential for engaging computer companies (Yigitcanlar et al. 2021). Semantic enrichment of building information models (BIM)—using AI methods to supplement such models with explicit information derived using algorithms trained to recognise and infer predefined sets of target concepts within patterns of building data—can remove the need for normalisation (Sacks *et al.* 2020). Similarly, a combination of an artificial bee colony and a neural network has been used for approximating the safety factor of retaining walls (Ghaleini *et al.* 2019).

During the construction stage, AI techniques such as latent class clustering analysis, hybrid models of case-based reasoning and the analytic hierarchy process, and the artificial neural network backpropagation approach have all been used to implement safety assessments in megaprojects (Ayhan & Tokdemir 2019).

The application of metaheuristic optimisation algorithms has been developed in planar (2D) structure designs. Improved black hole and multiverse algorithms for the optimal design of steel trusses and enhanced fireworks algorithms for the discrete sizing of steel skeletal structures have been used to reduce computational complexity. Moreover, 'topology optimisation'—a type of AI application—has been used in precast structures to find the optimal location of the elements, reducing the cost of trussed structures (Baghdadi *et al.* 2020).

During the occupation stage, the Internet of Things (IoT) and AI have been used to deliver improved energy efficiency and lower operational costs in smart cities (Boje *et al.* 2020). For example, the Internet of Robotic Things (IoRT) uses deep learning for smart cities. Care-0-Bot 4 provides a cost-effective approach to operating in different environments and supports a wide range of applications. It can be deployed in museums, airports, homes, and offices for security purposes to help with daily chores, monitor the elderly, and provide healthcare services to patients. AndyVision—an inventory assistant—helps shops by calculating various customer needs; while Packbot is a self-organising robot used to identify the location of bombs and other hazardous materials (Liu *et al.* 2020).

AI algorithms and robots have been used throughout the built environment. Yet, research on AI safety precedents, legislation, policy, and public opinions regarding built environments is scarce. As there are substantially more people who use and are affected by AI-related products in the occupation stage (e.g., AI robots for Covid-19 disinfection and heavy-duty transportation in warehouses and factories), we speculate that there are more AI safety issues in the occupation stage. Thus, we hypothesise that:

H1: Regulations, policies, and the public's (including academia) perception/opinion concerning AI safety in various stages of real estate development are different. There is vastly more concern with AI safety issues in the occupation stage.

2.2 Ethical and responsible AI: Safety liability

"AI gives rise to errors of inference, of decision, and of action, which arise from the more or less independent operation of artefacts, for which no rational explanations are available, and which may be incapable of investigation, correction, and reparation (Clarke 2019)."

Technologies, including AI, are intrinsically neutral, and humans (both developers and users) determine the purposes for which AI is applied (Feijóo & Kwon 2020). The starting point for examining 'computer-generated torts' is that AI is much safer than people in terms of the risk of injury (Perc *et al.* 2019). That said, accidents will always happen, and regulating AI in several ways already exists in terms of common law, statutory and regulatory obligations for organisations, and tort (Cuéllar 2019). However, determining how legal rules should apply to liability for losses caused by AI systems takes time. Rather than adapting or creating a full compensatory system for AI harm, we should focus on identifying, minimising, and perhaps compensating for the predicted harm with regular compulsory re-evaluation.

As systems become more autonomous, determining liability when humans are harmed becomes complicated (Jamjoom *et al.* 2020). For example, where a self-driving car appears to be doing something unsafe and the driver overrides it—was it the individual's or the manufacturer's fault is the crux of the issue (Perc *et al.* 2019). An accident may also be caused by defective AI design, training, sensor design, unforeseen consequences from multiple data inputs, erroneous AI operation based on sensor or remote data, or external interference that could have been accidental or intentional by either one or more private actors, or on behalf of a foreign organisation or nation. Notably, sensors from multiple companies may have never been used together. In such instances, causation and responsibility may be impossible to determine. *Res ipsa loquitur* (the thing that speaks for itself) which could allow a court to conclude that a defendant must have been negligent since it is the only reasonable explanation for such a harmful act, cannot be applicable (Giuffrida 2019).

The coexistence and interaction of humans and AI contributes to issues related to people's safety (Dodig Crnkovic & Çürüklü 2012), with a vital concern being hacking. What makes an AI robot useful—its strength, ability to access and operate in challenging environments, expendability, etc.—could also be turned against people, either by criminals or people causing mischief. This issue will become more important as robots become more networked and increasingly indispensable to everyday life, just as computers and smart phones are today (Lin *et al.* 2011). One might suggest that injuries caused by hacking could be avoided through better safety by design, encouraging product designers to consider safety concerns during development (Dodig Crnkovic & Çürüklü 2012).

In short, broader liability can be observed, particularly in the entities involved— the producer, distributor, seller, and the telecommunications provider—when, for example, the accident was caused due to a lack of an Internet connection (Perc *et al.* 2019). While researchers raise the concern of different stakeholders' liability for AI safety, none have studied the relative liability of these parties. We hypothesise that:
H2: *Res ipsa loquitur* is not applicable in AI safety in all built-up environments. Manufacturers, algorithm designers, and other stakeholders bear different levels of legal liability, including but not limited to financial consequences.

2.3 AI safety legal issue

2.3.1 AI safety legal issue 1: Compensation for injuries and encourage innovation

The idea of injury compensation provided by the wrongdoers can reduce negligence but often discourages putting innovative ideas into practice. A clear example comes from the National Childhood Vaccine Injury Act (Public Law 99-660) in the US, which bears the societal obligation to compensate those who suffer injuries associated with vaccination. The act created the Vaccine Injury Compensation Program (VICP) to collect taxes on each dose of vaccine to pay for compensation (Thompson *et al.* 2020). Similarly, New Zealand has a long-established

no-fault compensation scheme to cover almost all injury costs, including medical procedure damages, regardless of who was at fault (Fosch-Villaronga & Millard 2019). The experiences with autonomous cars suggest that we should encourage technological innovation while compensating those hurt by the new technology (Giuffrida 2019). While most of the no-fault compensation research sheds light on the medical industry, research into AI in this regard is scarce. As such, we hypothesise that:

H3: Most countries apply no-fault compensation related to injuries caused by AI applications in built environments. AI safety policies and laws that compensate those hurt by AI also include policies that encourage AI innovation.

2.3.2 AI safety issue 2: Does AI incur product or personal liability?

Given that currently product liability is strict (that is, independent of fault), and human activity is measured according to the standard of a reasonable person, several legal scholars claim that it is necessary to treat a computer tortfeasor as a person rather than as a product, thus incentivising automation and further improving safety. This means that intelligent objects should be evaluated under a negligence standard rather than a strict liability standard and that liability for damage would be comparable to that of a reasonable person (Abbott 2018). Additionally, suppose it is proven that computers are safer than people. In that case, this could set the basis for a new standard of care for humans, so that human acts would be assessed from the perspective of what a computer would have done; and how if they had used a computer, the human could have avoided the accident and the consequent harm (Perc *et al.* 2019).

In the European Union, the Product Liability Directive (85/374/EEC) states that when a defective product causes damage, it is recoverable under the Product Liability Directive which regulates strict liability tests. This means that where AI causes an accident due to malfunctioning software, the consumer can bring a claim under the Product Liability Directive against the producer of the software. However, when software is supplied over the Internet, potential defects do not fall within this directive. Thus, a specific order on the liability of suppliers of digital content is required. Article 2(1) of Directive 2001/95 on general product safety includes any product intended for consumer use or likely to be used by consumers "including in the context of providing a service" (Perc *et al.* 2019).

Although there is a discussion regarding damage caused by a defective product, it is unknown whether AI operating at any stage of real estate development—evaluated under either strict liability or negligence standards—is treated as a person or a product. We hypothesise that:

H4: Courts and policies treat AI that causes injury in built environments as a person rather than a product and evaluate intelligent object injury cases under negligence standards rather than strict liability standards.

2.4 Deviations between the implemented policies and regulations, and the needs of the public

A main line of research has always been whether existing policies meet the public's needs. Equally important are determining ways to improve them. For example, Lopez-Behar *et al.* (2019) present demand-focused policy interventions which need to be addressed, such as regulatory awareness/information and fiscal/financial measures. Financial/fiscal policy measures/aid are required to incentivise electric vehicle owners and building owners (e.g., encouraging retrofitting). Regulatory policy measures should address the rights and obligations of the stakeholders and mandatorily require the installation of charging stations in new multi-unit residential buildings. Im and Park (2020) revealed that ten crane safety Acts suffer from duplication, inadequacy, and conflict problems. They propose avoiding using ambiguous

expressions, strengthening relaxed specification requirements, and harmonising safety standards across related government authorities to ensure consistency of standards.

Despite safety being identified as one of the main challenges in AI (Dwivedi *et al.* 2019), there is no research into whether existing safety policies address the needs of AI users, suppliers, and sellers in built environments. Based on the literature as mentioned earlier, we hypothesise that:
H5: AI safety policies fail to address the needs/concerns of AI users, suppliers, and sellers in built environments.

2.5 New institutional economics, formal and informal institutions

Under the lens of new institutional economics, formal (law and policies) and informal (culture and norms) institutions affect people's behaviours. Regarding formal institutions, Tu *et al.* (2020) examined the market reaction to firms in heavy-polluting industries and the effects of external legal, institutional quality and internal environmental disclosure on firm value around the passing of the Environmental Protection Tax Law in China. Dr He has led more than ten legal research projects, including three for the National Social Science Fund. Li and Poon (2013) reviewed construction accident compensation in the United Kingdom and Hong Kong, while Li and Chau (2016) studied the impact of superstition (culture) on residential prices in Hong Kong.

Gu *et al.* (2020) suggested that G7 countries develop their high-tech industry and propose policies that encourage innovation through research and development—an increasingly important engine for technological progress. It is well known that government regulations promote improvements that incorporate environmental standards (Sun *et al.* 2020).

2.5.1 Global law and policy analysis and review

Comparative laws promote international harmonisation and unification. They reveal the common core of all law, increase understanding of foreign rules, concepts, and approaches, and facilitate communication among foreign lawyers (Junker 2014). (Lavelanet *et al.* 2020) reviewed 158 countries' laws, policies, standards and guidelines, and legal judgments related to barriers to abortion. Of the countries studied, 107 provided information about health care providers who can conduct induced abortion services. (Michalek *et al.* 2019) found that 69 countries out of 193 in the United Nations have regulations concerning the permissible level of heavy metals in cosmetics. While legal rules cover most high-income countries, none of the low-income countries has related laws. Using panel data of the legislative activity in 133 countries from 1999 to 2016, Eskander and Fankhauser (2020) found that parliamentary acts are driven by countries with a strong rule of law.

Kanter *et al.* (2020) assembled a global nitrogen policies database by reviewing 2,726 policies across 186 countries' legislatures and government agencies. They found that sink-centred policies predominantly focused on water. Most of the literature has not investigated the global landscape of AI safety-related policies and regulations. Thus, this research project aims to fill this gap and hypothesises that:
H6: AI safety laws and policies predominately cover most high-income countries' built environments, with predominant coverage on one (or more) area(s).
H7: Countries with a stronger rule of law are more likely to have laws and policies related to AI safety.

2.5.2 Cultural impact on AI safety policies and regulations

According to the Turing Institute, AI ethics is a set of values, principles, and techniques that

utilise widely accepted standards of right and wrong to guide AI's moral development and use. For example, a recent study by MIT, in which an autonomous vehicle was out of control and needed to choose between crashing into an old or young man and a dog or a human being, looked into moral machine research related to ethical concerns of AI safety. The results, which took into account 40 million participants' decisions across 233 countries, showed that people from collectivistic cultures, which emphasise respect for the elderly, have a weaker preference to save younger people (Awad et al., 2018). At the same time, most respondents exhibited a moral choice for autonomous vehicles sacrificing their passengers to save more pedestrians (Bonnefon, Shariff, & Rahwan, 2016).

Apart from the collectivism mentioned above, societies mainly differ in five core cultural values: masculinity, power distance, long-term orientation, uncertainty avoidance, and indulgence (Zotzmann *et al.* 2019). All of these may have an impact on the laws and policies that are implemented.

Likewise, legal-economic theorists argue that common law and civil law develop differently. For example, a study of the rigidity of 86 countries' labour regulations from 1950 to 2004 evidenced the negative impact of individualism on labour regulations, with rigidity being enhanced by the legal system. Individualism has no effect on the rigidity of labour market regulations in civil law countries. While individualists see the government as a possible barrier to achievement, collectivists feel that a benevolent government creates stability through active intervention. Consequently, collectivists will have a more favourable view of government labour market regulations (Ang & Fredriksson 2018).

One of the most attractive features of interpretive policy analysis is to provide a detailed and nuanced account of how policy-makers' actions shape and are shaped by broader cultural forces (Rogan, 2018). Although culture does affect labour regulations, there is a lack of research into whether cultural factors influence AI regulation and policy implementation. As such, we hypothesise that:
H8: Six dimensions of national culture and legal systems impact the likelihood of regulating AI safety via laws and policies.

2.6 Social media and policy making

As of January 2018, roughly 4.021 billion people worldwide use the Internet. Of these, 3.196 billion people used social media. Such activities generate massive amounts of text data. Despite most data being unstructured (Curiskis *et al.* 2020), with people increasingly using various social media tools (e.g., YouTube, Reddit, Twitter, etc.) to express themselves about different issues (e.g., delivery of government services), their positive or negative comments (Belkahla Driss *et al.* 2019; Yao *et al.* 2021) can complement, enrich, or even replace conventional data. Hence, these comments may hold great value and incur lower costs (Gal-Tzur *et al.* 2014).

Thus, extracting people's comments comprehensively from social media has become important for policy makers, and they may consider taking into account this information when making decisions (Belkahla Driss *et al.* 2019). Social media opinion mining is also better than surveys and interviews because the latter often have meagre response rates.

While previous research has found that social media provides valuable information when formulating transport policy—the outcomes were highly relevant to a wide range of stakeholders in the transport industry (Gal-Tzur *et al.* 2014)—its usefulness in studying people's perceptions of AI safety in terms of built environment policies and regulations are

unknown. Thus, we hypothesise that:
H9: Social media content provides valuable information regarding AI safety issues in the built environment for policy makers and legal drafters.

3. Research method

The data will be collected from four primary sources: (1) academia's perspectives on AI safety in built environments will be collected by a systematic literature review; (2) the public's viewpoints, demands, and expectations regarding AI safety in built environments will be collected by studying the comments expressed by the public on social media; (3) global AI safety policies and regulations will provide a picture of the current institutional framework, and (4) case studies will provide insights regarding the needs and concerns of Hong Kong's AI users and suppliers in terms of built environments. The four sources will then be integrated to show the supply and demand of AI safety policies and regulations, thereby informing policy makers on which current policies do not meet public expectations. The results will also provide the international community and Hong Kong with unique policy orientations, which can be developed globally as well as locally.

An expert panel consisting of legal experts, AI users in built environments, and AI suppliers will be formed to offer advice to the team.

3.1 Systematic literature review

Journal articles indexed in Web of Science, Science Direct, ASCE, Hein Online, West Law, and IEEE between 2001 and 2021 will be analysed utilising the systemic review approach. Systematic literature review offers a more accurate and broader level of understanding than a conventional literature review (Pati and Lorusso, 2018).

We will follow the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)—an evidence-based approach for conducting systematic reviews that involves identification, screening, eligibility, and included stages, and which has been used for articles in many leading journals such as The Lancet and JAMA. It involves the following steps (Figure 1):

1. Identification: We will use 'AI safety' and 'artificial intelligence safety' for the keyword search in the aforementioned electronic databases.
2. Screening: We will only include articles' titles and abstracts that are relevant to real estate development (planning, construction, occupation, and demolition stages) and smart cities and will remove duplicate and irrelevant ones.
3. Eligibility: Based on no. 2, we will review the articles which look relevant and identify suggestions regarding the concerns, legislation (statutes), court cases, and policies related to AI safety.
4. Included: Only relevant articles will be used for content analysis (Figure 1).
5. Content analysis: We will group the results of AI safety concerns according to (1) stages of real estate development, namely, planning, construction, occupation, demolition, and urban renewal; and (2) locations.

We can then compare people's main concerns over AI safety across the different stages of real estate development. Similar categories of concerns will be grouped in the form of content analysis. The content will also be studied through tokenisation, a natural language processing approach, as per Li, Tang, and Chau (2019). Phrases that occur most frequently will be ranked and reviewed. This will fulfil:

H1: Regulations, policies, and the public's (including academia) perception/opinion concerning AI safety in various stages of real estate development are different. There is vastly more concern with AI safety issues in the occupation stage.

The data collected will be used to write the first journal paper. The first draft is expected to be completed at month eight and submitted by month 12.

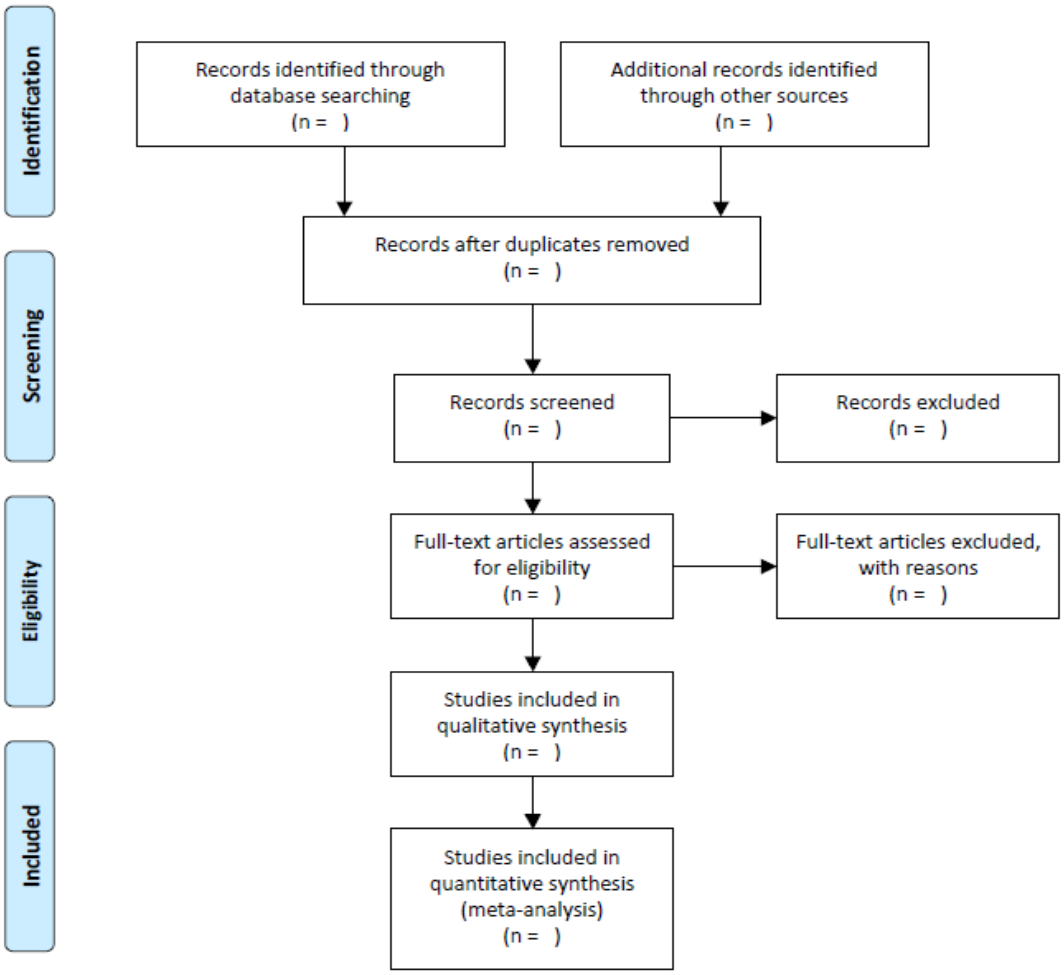

Figure 1: PRISMA systematic literature review (Moher *et al.* 2009)

3.2 Social media text and data mining (month 9–13)

To study the AI safety concerns of ordinary individuals who may be users of AI (e.g., smart home products or construction sector tools), we will explore public opinions by collecting people's comments on social media (e.g., Reddit, Twitter, and YouTube). Following Park *et al.* (2018), we will use PRAW (Python Reddit API Wrapper) to obtain discussion content on 'AI safety' and 'artificial intelligence safety' from the Reddit community r/safety. This public community allows anyone with Internet access to view the content. The two keywords, as mentioned earlier with hashtags, will be used to collect Tweets via NodeXL. We will subsequently review all scrapped content and only retain that related to any stage of built environment AI safety.

Regarding YouTube content, we will follow Devendorf *et al.* (2020) and clear our Internet

browser history and cache, log off all accounts, and use Google Chrome's Incognito mode to reduce bias from our computer. We will search for relevant videos using the "relevance" filter, which will be viewed manually to screen content pertinent to any stage of the built environment. Relevant content will be downloaded using youtube-transcript-API.

Only publicly available social media sites will be mined during the whole process, with the results presented in an aggregated format. The name, individual members' identity, and unique resource locator of each comment on the social media platform will not be disclosed. Social media sites with automated web crawlers restricted access, or blocked access by a robots.txt file will be excluded (Monkman *et al.* 2018). The exact wording of the people's opinions will be rewritten to protect individual identities from being disclosed.

As in stage 1, we will group the results of public opinions according to stages of real estate development and locations for those which can identify locations. Content analysis will be used to discover group content concerns over AI safety in built environments. In contrast, tokenisation will be used to determine the most frequently raised concerns. This will fulfil:
H1: Regulations, policies, and the public's (including academia) perception/opinion concerning AI safety in various stages of real estate development are different. There is vastly more concern with AI safety issues in the occupation stage.
H9: Social media content provides valuable information regarding AI safety issues for policy makers and legal drafters in the built environment.

3.3 Court cases, legislation, and policy study

Regulations and precedents can provide information regarding the legislators' concerns and disputes over AI safety issues. The proposed research will cover countries with publicly available court cases and regulation databases. Our preliminary research indicated the number of documents in these databases (Table 1). As of 15 July 2020, 61 out of 123 countries (a complete country list can be found at http://www.worldlii.org/countries.html) in the World Legal Information Institute have AI safety-related court cases, policies, and legislation. As suggested by Michaelek et al. (2019), we will first review the title and abstract/introduction (if applicable). We will then remove those which are unrelated to built environments and analyse the relevant ones via content analysis. Special precedent will be given to case studies.

AI-related policy data will also be collected using the main search engines (i.e., Google and Yahoo) with 'AI safety policy' and the corresponding country name and 'artificial intelligence and the country name. We will go through the results manually to determine which ones are related to built environments.

After collecting policy and legislation data, we will then analyse them using the content analysis method. As most leading journals request open data, we will modify (Kanter *et al.* 2020) Table 1 of global environmental policies to create our database of AI safety international policies and regulations in each of the four stages of real estate development. Each stage will then be subcategorised into: (1) name of the policy; (2) financial incentives for AI safety development; (3) compensation for AI-related accidents; (4) board objectives related to AI safety; (5) data and methods, including reporting protocols; and (6) research and development, e.g., funding according to different stages of real estate development. A similar process will be repeated for the regulations. Based on the six categories mentioned above, we will be able to provide suggestions for AI safety policy criteria and give the international community a unique policy orientation. This will fulfil:

H3: Most countries apply no-fault compensation related to injuries caused by AI applications in built environments. AI safety policies and laws that compensate those hurt by AI also include policies that encourage AI innovation.
H4: Courts and policies treat AI that causes injury in built environments as a person rather than a product and evaluate intelligent object injury cases under negligence standards rather than strict liability standards.
H8: Six dimensions of national culture and legal systems impact the likelihood of regulating AI safety via laws and policies.

Zhao *et al.* (2019) analysed data based on cluster and content analysis. While we will analyse court cases via thematic analysis; we will include analysis on judges' views regarding (1) level of financial and non-financial liability borne by different stakeholders for injuries caused by AI, (2) whether the court adopts negligence/liability standards for AI-related injury cases, (3) whether the court perceives AI that causes injury in built environments as a person rather than a product, and (4) judges' interpretation of objectives of AI safety laws. This will fulfil:
H2: *Res ipsa loquitur* is not applicable in AI safety in all built environments. Manufacturers, algorithm designers, and other stakeholders bear different levels of legal liability, including but not limited to financial consequences.
H4: Courts and policies treat AI that causes injury in built environments as a person rather than a product and that intelligent object injury cases are evaluated under negligence standards rather than strict liability standards.

Table 1: Legal databases that will be used and the number of 'artificial intelligence' cases available as of 15 July 2020 (searching for phrases such as 'artificial intelligence and injury' in the databases will filter out many relevant cases in these databases).

Legal Databases	Locations Covered	Search results included	No. of documents
WorldLII World Legal Information Institute	89 databases from 61 jurisdictions via 14 legal information institutes	International decisions, law journals, law reform treaties, international law	5438
CommonLII Commonwealth Legal Information Institute	61 common law databases from 42 Commonwealth and common law jurisdictions via eight legal information institutes	Case law, legislation, legal materials	4490
AustLIISearch Australasian Legal Information Institute	24 databases from 18 jurisdictions	Case law, law review, law report	3214
BAILII (2000–2020) British and Irish Legal Information Institute	United Kingdom, England and Wales, Scotland, Northern Ireland, Jersey, Ireland, Europe	Case law, legislation	1876
HKLII	Hong Kong	Cases from Court of First Instance	5

Legal Databases	Locations Covered	Search results included	No. of documents
NZLII New Zealand Legal Information Institute	New Zealand	Case law, legislation, law reform, treaties	305
SAFLII Southern African Legal Information Institute	Southern Africa	National gazettes, provincial gazettes, South Africa: municipal by-laws, South African national legislation, South African courts, tribunals, Labour courts, Court rolls	64
ULII Uganda Legal Information Institute	Uganda	Uganda statutory instruments (2), legislation as promulgated (1), judgment (4), government gazettes (3), consolidated legislation (1)	11
Asia AsianLII	63/23 databases from 17 Asian jurisdictions via 8 legal information institutes		276
CanLII	Canada (Federal) British Columbia Alberta, Saskatchewan, Manitoba, Ontario Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador, Yukon Northwest Territories, Nunavut	Cases (1,533), legislation (82)	1615
CY LAW	Cyprus		4
IRLII Irish Legal Information Initiative	Ireland	Statutory instruments	2
Ittig Institute of Legal Information Theory and Technique			8
Jersey Legal Information Board	Jersey	Unreported judgments (5), JGLR article (3), contents pages (1), law as enacted (1)	10

Legal Databases	Locations Covered	Search results included	No. of documents
LAWPHIL Philippine Laws and Jurisprudence Databank	Philippines	Search results enhanced by Google	27
LIIofIndia Legal Information Institute of India	India	Free, independent, and non-profit access to 159 databases of Indian law	111
MalawiLII Malawi Legal Information Institute		Judgment (5), Acts of Parliament (1)	6

A world map will be generated using Tableau to show the geographic coverage of countries with AI safety regulations related to built environments. A scatter plot for countries with and without regulations will be generated, as per income, the rule of law, and adult literacy profiles, according to Michalek *et al.* (2019).

3.4 Piecewise Structural Equation Modelling

Structural Equation Modelling (SEM) has often been used to study the interrelationship between various factors. Zeng and Li (2021) utilised SEM to analyse the relationship between satisfaction, willingness to revisit, and experiential value of mountain health tourism sites. Li, Tang, and Chau (2019) utilised SEM to study factors that affect people's willingness to share construction safety knowledge via the IoT and web 2.0 (including all social media channels that allow people to read and write (Li & Pak 2010; Li & Poon 2011) .

PiecewiseSEM, a type of structural equation modelling, is designed to analyse multivariate hypotheses and applies to categorical responses controlled by multiple factors. PiecewiseSEM paths represent causal relationships and account for correlations between various response variables (Robinson *et al.* (2020). Given the fact that policies/laws are implemented in one jurisdiction is categorical, some variables may have inter-relations. As such, we will follow Bowen et al.'s (2017) piecewiseSEM package to study the impact of six dimensions of culture and other socio-economic factors on the likelihood of implementing AI safety laws and policies. We will then report on the estimated path coefficient.

Table 2: Sources of data and hypothesis tests to be covered in the machine learning models.

Data	**Source of data (number of countries covered in the database)**	**Hypotheses to test for:**
Binary dependent variable: **Model 1:** AI safety regulation (with regulation =1, without =0) **Model 2:** AI safety policy (with regulation =1, without =0)	World Legal Information Institute (61 out of 123 jurisdictions contain court cases, policies, and legislation related to AI safety as of 15 July 2020). Some policies may be found in Google.	H6-H8
Independent variables		

Data	Source of data (number of countries covered in the database)	Hypotheses to test for:
Indices in Hofstede's model of six dimensions of culture: power distance (P), collectivism (C), masculinity (M), uncertainty avoidance (U), long-term orientation (L), and indulgence (I)	Hofstede Insights (117 countries) https://hi.hofstede-insights.com/national-culture	H8
Common law, civil law and mixed /other legal systems (the first variable common law =1, mixed /other legal systems =0, the second variable civil law =1, mixed /other legal systems =0) The interaction term between legal systems and the aforementioned cultural dimensions: common law*P, common law*C,…, common law*I; civil law*P,…, civil law*I etc.	Central Intelligence Agency (256 countries) https://www.cia.gov/library/publications/the-world-factbook/fields/308.html	H8
Income ranking based on PPP adult literacy rate of the country	World Bank (2020) (217 countries for income and 264 countries for adult literacy) https://datacatalog.worldbank.org	H6
The rule of law index	World Justice Project (128 countries) https://worldjusticeproject.org/rule-of-law-index/global/2020	H7

The Tableau world map and structural equation modelling will fulfil the hypotheses:
H6: AI safety laws and policies predominately cover most high-income countries' built environments, with predominant coverage on one (or more) area(s).
H7: Countries with a stronger rule of law are more likely to have laws and policies related to AI safety.
H8: Six dimensions of national culture and legal systems impact the likelihood of regulating AI safety via laws and policies.

3.5 Case studies

A case study refers to the research of an individual or an event. It involves an in-depth record of an individual or a group. A case study enables a researcher to obtain detailed information from observed behaviours and events. Although a case study lacks a breadth of study, it can be so unique that it affects the findings' validity (Li & Poon 2013). Much previous research has also adopted single or multiple case studies. For example, Sousa Cristóvão et al. (2016) conducted case studies with 25 participants from 15 countries to develop a procedural framework, information standards, and guidelines for forest management. The 15 case studies in Australia that study the possibility of co-development in social, economic and environmental

aspects in construction projects and materials production companies aim to reduce construction waste.

Two case studies on AI suppliers that sell AI hardware and software to built environment users will be included to study their perceptions regarding AI safety policies in the industry. Similarly, we will also conduct two case studies, one focusing on the main contractor that pioneers AI technology adoption during the planning and construction stages. The other may look at Hong Kong International Airport to study AI technology adoption during the occupation stage. Interviews with AI programmers, project managers, sales staff, and designers, as well as reviews of technical reports, websites, and on-site observations, will provide insights into future AI safety policy orientation on the local level.

4. Academic, practical and policy contributions

AI tools and applications have become more prevalent in all stages of real estate development. Yet, research into policies and regulations in built environments is scarce. Our analysis provides a global review of the latest law and policy developments in the field and looks at their sociocultural impact. The research will also contribute practically, with industry practitioners, both users and suppliers, becoming more aware of AI safety policies and laws in built environments. It will also provide the international community and Hong Kong with unique policy and law orientation.

Policy relevancy to Hong Kong AI has been applied in various real estate development cycles (e.g., planning, construction, occupation, and demolition). It is expected that there will be even greater use in the coming decade. In addition to innovations such as object detection by unmanned vehicles to detect cracks in walls and autonomous trains (10 three-car trains in Hong Kong's Southern District have carried 170,000 passengers daily since 2016), AI robots are also being used in the homes of the elderly, schools, and shopping malls. Furthermore, for a couple of years now, smart home tools have started to be included in many new residential real estate projects in Hong Kong. Ultimately, smart home robots and similar technologies are being developed rapidly, and safety issues surrounding these innovations have become more pertinent.

Unfortunately, the legal framework has lagged behind, potentially giving rise to problems regarding responsible AI usage. In this project, we propose exploring 61 jurisdictions' overseas policy approaches to AI safety in the four stages mentioned above of real estate development. Relevant implemented policies may provide the international community and Hong Kong with unique policy orientations. Given that corresponding regulations often accompany policies to ensure compliance, we will also review the legislation and regulatory precedents in different jurisdictions. In general, a complete separation of law and policy from people's expectations, concerns, and morals may lead to non-compliance, leading to the tools becoming meaningless. Thus, modern policy makers often draw knowledge from outside the public domain, with academic experts often being involved in the process. Hence, academics' views on AI safety regulations, court cases, and policy will be solicited via the PRISMA 2009 approach, while the general public's views on AI safety policies and regulations will be explored via social media data and content analysis.

Acknowledgement

An earlier version of this chapter was submitted for a research grant proposal.

References

Abbott R. (2018) The Reasonable Computer: Disrupting the Paradigm of Tort Liability. *George Washington Law Review* **86**, 1-45.
Ang J.B. & Fredriksson P.G. (2018) Culture, legal heritage and the regulation of labor. *Journal of Comparative Economics* **46**, 616-33.
Ayhan BU. & Tokdemir O.B. (2019) Safety assessment in megaprojects using artificial intelligence. *Safety Science* **118**, 273-87.
Baghdadi A., Heristchian M. & Kloft H. (2020) Design of prefabricated wall-floor building systems using meta-heuristic optimization algorithms. *Automation in Construction* **114**, 103156.
Belkahla Driss O., Mellouli S. & Trabelsi Z. (2019) From citizens to government policy-makers: Social media data analysis. *Government Information Quarterly* **36**, 560-70.
Boje C., Guerriero A., Kubicki S. & Rezgui Y. (2020) Towards a semantic Construction Digital Twin: Directions for future research. *Automation in Construction* **114**, 103179.
Clarke R. (2019) Regulatory alternatives for AI. *Computer Law & Security Review* **35**, 398-409.
Cuéllar M.-F. (2019) A Common Law For The Age Of Artificial Intelligence

Incremental Adjudication, Institutions, And Relational Non-Arbitrariness. *Columbia Law Review* **119**, 1773-92.
Curiskis S.A., Drake B., Osborn T.R. & Kennedy P.J. (2020) An evaluation of document clustering and topic modelling in two online social networks: Twitter and Reddit. *Information Processing & Management* **57**, 102034.
Devendorf A., Bender A. & Rottenberg J. (2020) Depression presentations, stigma, and mental health literacy: A critical review and YouTube content analysis. *Clinical Psychology Review* **78**, 101843.
Dodig Crnkovic G. & Çürüklü B. (2012) Robots: ethical by design. *Ethics and Information Technology* **14**, 61-71.
Dwivedi Y.K., Hughes L., Ismagilova E., Aarts G., Coombs C., Crick T., Duan Y., Dwivedi R., Edwards J., Eirug A., Galanos V., Ilavarasan P.V., Janssen M., Jones P., Kar A.K., Kizgin H., Kronemann B., Lal B., Lucini B., Medaglia R., Le Meunier-FitzHugh K., Le Meunier-FitzHugh L.C., Misra S., Mogaji E., Sharma S.K., Singh J.B., Raghavan V., Raman R., Rana N.P., Samothrakis S., Spencer J., Tamilmani K., Tubadji A., Walton P. & Williams M.D. (2019) Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management*, 101994.
Eskander SMSU. & Fankhauser S. (2020) Reduction in greenhouse gas emissions from national climate legislation. *Nature Climate Change* **10**, 750-6.
Feijóo C. & Kwon Y. (2020) AI impacts on economy and society: Latest developments, open issues and new policy measures. *Telecommunications Policy* **44**, 101987.
Fosch-Villaronga E. & Millard C. (2019) Cloud robotics law and regulation: Challenges in the governance of complex and dynamic cyber–physical ecosystems. *Robotics and Autonomous Systems* **119**, 77-91.
Gal-Tzur A., Grant-Muller S.M., Kuflik T., Minkov E., Nocera S. & Shoor I. (2014) The potential of social media in delivering transport policy goals. *Transport Policy* **32**, 115-23.
Ghaleini E.N., Koopialipoor M., Momenzadeh M., Sarafraz M.E., Mohamad E.T. & Gordan B. (2019) A combination of artificial bee colony and neural network for approximating the safety factor of retaining walls. *Engineering with Computers* **35**, 647-58.

Giuffrida I. (2019) Liability for AI Decision-Making: Some Legal and Ethical Considerations. *Fordham Law Review* **88**, 439-56.
Gu J., Umar M., Soran S. & Yue X.-G. (2020) Exacerbating effect of energy prices on resource curse: Can research and development be a mitigating factor? *Resources Policy* **67**, 101689.
Jamjoom A.A.B., Jamjoom A.M.A. & Marcus H.J. (2020) Exploring public opinion about liability and responsibility in surgical robotics. *Nature Machine Intelligence* **2**, 194-6.
Junker K.W. (2014) A Focus on Comparison in Comparative Law. *Duquesne Law Review* **52**, 69-99.
Kanter D.R., Chodos O., Nordland O., Rutigliano M. & Winiwarter W. (2020) Gaps and opportunities in nitrogen pollution policies around the world. *Nature Sustainability*.
Lavelanet A.F., Johnson B.R. & Ganatra B. (2020) Global Abortion Policies Database: A descriptive analysis of the regulatory and policy environment related to abortion. *Best Practice & Research Clinical Obstetrics & Gynaecology* **62**, 25-35.
Li RYM & Pak D.H.A. (2010) Resistance and motivation to share sustainable development knowledge by web 2.0. *Journal of Information and Knowledge Management* **9**, 251-62.
Li RYM & Poon S.W. (2011) Using Web 2.0 to share knowledge of construction safety: the fable of economic animals. *Economic Affairs* **31**, 73-9.
Li RYM & Poon S.W. (2013) *Construction Safety*. Springer, Germany.
Lin P., Abney K. & Bekey G. (2011) Robot ethics: Mapping the issues for a mechanized world. *Artificial Intelligence* **175**, 942-9.
Liu Y., Zhang W., Pan S., Li Y. & Chen Y. (2020) Analyzing the robotic behavior in a smart city with deep enforcement and imitation learning using IoRT. *Computer Communications* **150**, 346-56.
Lopez-Behar D., Tran M., Froese T., Mayaud J.R., Herrera O.E. & Merida W. (2019) Charging infrastructure for electric vehicles in Multi-Unit Residential Buildings: Mapping feedbacks and policy recommendations. *Energy Policy* **126**, 444-51.
Michalek I.M., Benn E.K.T., dos Santos F.L.C., Gordon S., Wen C. & Liu B. (2019) A systematic review of global legal regulations on the permissible level of heavy metals in cosmetics with particular emphasis on skin lightening products. *Environmental Research* **170**, 187-93.
Moher D., Liberati A., Tetzlaff J., Altman D.G. & The PG (2009) Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLOS Medicine* **6**, e1000097.
Monkman G.G., Kaiser M.J. & Hyder K. (2018) Text and data mining of social media to map wildlife recreation activity. *Biological Conservation* **228**, 89-99.
Park A., Conway M. & Chen A.T. (2018) Examining thematic similarity, difference, and membership in three online mental health communities from reddit: A text mining and visualization approach. *Computers in Human Behavior* **78**, 98-112.
Perc M., Ozer M. & Hojnik J. (2019) Social and juristic challenges of artificial intelligence. *Palgrave Communications* **5**, 61.
Robinson B.J.O., Barnes D.K.A. & Morley S.A. (2020) Disturbance, dispersal and marine assemblage structure: A case study from the nearshore Southern Ocean. *Marine Environmental Research* **160**, 105025.
Sacks R., Girolami M. & Brilakis I. (2020) Building Information Modelling, Artificial Intelligence and Construction Tech. *Developments in the Built Environment*, 100011.
Sousa Cristóvão D., Soares António L. & Pereira Carla S. (2016) Collaborative conceptualisation processes in the development of lightweight ontologies. *VINE Journal of Information and Knowledge Management Systems* **46**, 175-93.

Sun S., Li T., Ma H., Li R.Y.M., Gouliamos K., Zheng J., Han Y., Manta O., Comite U., Barros T., Duarte N. & Yue X.-G. (2020) Does Employee Quality Affect Corporate Social Responsibility? Evidence from China. *Sustainability* **12**, 2692.

Thompson K.M., Orenstein W.A. & Hinman A.R. (2020) Performance of the United States Vaccine Injury Compensation Program (VICP): 1988–2019. *Vaccine* **38**, 2136-43.

Tu W.-J., Yue X.-G., Liu W. & Crabbe M.J.C. (2020) Valuation Impacts of Environmental Protection Taxes and Regulatory Costs in Heavy-Polluting Industries. *International Journal of Environmental Research and Public Health* **17**, 2070.

World Bank (2020) GDP Ranking, PPP Based. URL https://datacatalog.worldbank.org/dataset/gdp-ranking-ppp-based.

Yao Q., Li RYM, Song L. & Crabbe M.J.C. (2021) Construction safety knowledge sharing on Twitter: A social network analysis. *Safety Science* **143**, 105411.

Yigitcanlar T., Corchado J.M., Mehmood R., Li R.Y.M., Mossberger K. & Desouza K. (2021) Responsible Urban Innovation with Local Government Artificial Intelligence (AI): A Conceptual Framework and Research Agenda. *Journal of Open Innovation: Technology, Market, and Complexity* **7**, 71.

Zeng L. & Li YMR (2021) Tourist Satisfaction, Willingness to Revisit and Recommend, and Mountain Kangyang Tourism Spots Sustainability: A Structural Equation Modelling Approach. *Sustainability* **13**, 10620.

Zhao X., Zuo J., Wu G. & Huang C. (2019) A bibliometric review of green building research 2000–2016. *Architectural Science Review* **62**, 74-88.

Zotzmann Y., van der Linden D. & Wyrwa K. (2019) The relation between country differences, cultural values, personality dimensions, and error orientation: An approach across three continents – Asia, Europe, and North America. *Safety Science* **120**, 185-93.