Review

Critical Infrastructures: Reliability, Resilience and Wastage

William Hurst 1,*, Kwabena Ebo Bennin 1, Ben Kotze 2 and Tonderayi Mangara 2

1 Information Technology Group, Wageningen University and Research, Leeuwenborch, Hollandseweg 1, 6706 KN Wageningen, The Netherlands; kwabena.bennin@wur.nl
2 Faculty of Engineering, Built Environment and Information Technology, Central University of Technology, Free State, 20 Pres. Brand Street, Bloemfontein 9300, South Africa; bkotze@cut.ac.za (B.K.); bmangara@cut.ac.za (T.M.)
* Correspondence: will.hurst@wur.nl

Abstract: By 2050, according to the UN medium forecast, 68.6% of the world’s population will live in cities. This growth will place a strain on critical infrastructure distribution networks, which already operate in a state that is complex and intertwined within society. In order to create a sustainable society, there needs to be a change in both societal behaviours (for example, reducing water, energy or food waste activities) and future use of smart technologies. The main challenges are that there is a limited aggregated understanding of current waste behaviours within critical infrastructure ecosystems, and a lack of technological solutions to address this. Therefore, this article reflects on theoretical and applied works concerning waste behaviours, the reliability/availability and resilience of critical infrastructures, and the use of advanced technologies for reducing waste. Articles in the Scopus digital library are considered in the investigation, with 51 papers selected by means of a systematic literature review, from which 38 strains, 86 barriers and 87 needs are identified, along with 60 methods of analysis. The focus of the work is primarily on behaviours, barriers and needs that create an excess or wastage.

Keywords: critical infrastructure; strain; waste behaviour

1. Introduction

The notion of the critical infrastructure is well-documented (with a full classification provided by the United States Department of Homeland Security in [1]). Society relies on the critical infrastructure service provision, and their interconnectivity is immensely complex providing an ever-growing research trend within domains such as cyber [2], resilience [3,4], physical protection [5] and cascading failure modelling [6]. Alongside these mainstay research areas, as this article demonstrates, critical infrastructure strain is receiving growing attention. This is because over half of the human population is predicted to live in an urban environment in the near future [7,8], exacting considerable demand on existing critical infrastructure distribution channels and their interdependence that could result in severe shortcomings during periods of high demand. For instance, Sänger et al. [9] discuss the effect COVID-19 had on existing healthcare infrastructures and Chan et al. [10] outline the transport strains of moving huge amounts of passengers and freight on railway under extreme environmental conditions. A further example is discussed by Mlambo [11], who documented a crisis looming over South Africa for future water distribution networks, where the water deficiencies are multifaceted, with climate change, water theft and a lack of infrastructure investment (for example, new dams, old pipe networks) to match the urbanisation growth as two core contributors [12,13]. The climate change issue of course adds further complications to the strain caused by urbanisation and extends beyond South Africa, as Páez-Curtidor et al. [14] discuss in their work on climate-resilient water safety plans for India.

Going forwards, a synergy should be established between (i) upgraded infrastructure and (ii) a reduction in waste behaviours (i.e, excess) to cater for strain and the future...
demands placed by urbanisation. Relating to point (i), suitable technologies discussed in the literature include integrating AI/machine learning techniques [15], IoT sensors [16], digital twinning technologies [17,18], smart grid [19] and solar and wind [20]. Regarding point (ii), as discussed later in the findings, a suitable approach for eliminating waste-generating behaviour is through education and developing an awareness of the impact waste behaviour has on the availability of critical services. However, the aim of this article is to further the discussion on point (ii). To achieve this, a systematic literature review (SLR) methodology is adopted focusing on articles over a 5-year period from November 2017 to November 2021.

To date, other SLR investigations have been conducted in critical infrastructure-related domains. For example, Couto et al. [21] conducted a review on the water, waste, energy and food nexus, focusing on Brazil. Their article emphasised critical interlinkages neglected in the literature, factoring in the synergies between natural resources. Sänger et al. [9] investigated critical health infrastructure resilience, focusing primarily on water supply. Guo et al. [4] focus on resilience under disasters and disruptive events, and Chowdhury [22] focuses on cyber-security specifically for nuclear power plants. However, the research in this article stands apart from other works by focusing on human-based waste behaviours within the critical infrastructure domain, where limited work has been conducted. To form the investigation, the following four research questions (RQ) are considered: (RQ1) which critical infrastructure domains are focused on primarily for waste reduction? (RQ2) Do articles tend to involve participants in the investigation? (RQ3) What are the main barriers or needs and the resulting strains on critical infrastructures? (RQ4) What methodologies are typically employed for the investigations? The SLR approach adopted in this article is an adaptation of the work by Tummers et al. [23], originally modelled on the work by Kitchenham [24]. Within existing SLR reviews, the duration of the paper search period varies. For example, Chowdhury [22] considers works from the last 10 years, whereas Sänger et al. [9] include articles from the last 30. In [25,26], the authors consider articles from the last 5 years, and this is a process we have also adopted in this investigation. Prominent in the search is the term waste, which refers to ‘excess’ in this article rather than sewage/trash.

The rest of the paper is as follows. Section 2 outlines the methodology for the SLR. Results are discussed in Section 3 along with a discourse on the findings. The conclusion is provided in Section 4.

2. Materials and Methods

The SLR methodology adopted focuses on a query-based search in the Scopus digital library using a compilation of the keywords outlined in Table 1.

| Keywords | Query String |
|----------|--------------|
| Waste/Wastage | Title-ABS-Key ((“waste” OR “wastage”) AND (“behaviour” OR “behavior”) AND (“critical infrastructure” OR “Infrastructure”)) AND (Limit-To (DOC-TYPE,”ar”)) AND (Limit-To (PubYear,2022:2017)) |

2.1. Search Strategy

In this investigation, a 5-year timeframe is considered to be appropriate due to the fast-moving pace of information technology, and this also aligns to other SLR works such as [27]. Table 1 details the list of keywords and a conceptual search query used for the Scopus-based article output. The selection of keywords is based on adopting a novel approach for the investigation. As defined in the Introduction, other SLR works tend to focus on synergies between natural resources [21], disaster management [4] or cyber-security [22]. However, at the time of writing this article, SLRs on waste behaviours within the critical infrastructure domain are lacking. In addition to the query-based search, 11 further articles
were found after snowballing (for example, the article by de Bruyn et al. [28], which is linked to this Special Issue paper), of which, 4 were later removed following examination of the article contents and quality analysis process. Four selection criteria (presented in Table 2), involving questions considered in [23], were employed to reduce the initial article count from 375 to a final amount of 55 prior to the Quality Analysis (QA). SQ1 to SQ3 were automated during the filtering process on the Scopus digital library. SQ4 and SQ5 were performed by hand by reading the full title, abstract and keywords.

Table 2. Keywords and Search Query Prior to QA.

| Label | Selection Criteria | Count |
|-------|--------------------|-------|
| SQ1   | Full Search String | 364   |
| SQ2   | Written in English and from the last 5 years | 314 |
| SQ3   | Full Journal Article | 209 |
| SQ4   | Relates to critical infrastructures, thus validating the current study | 63 |
| SQ5   | Article Availability | 55 |

For SQ4, some articles aligned well (in principle) to the search query, but the focus was on waste management, i.e., sewage logistics, rather than waste behaviours, or activities/patterns resulting in waste, excessive production or unsustainable practice in critical infrastructures. This is logical, and a result of the duel meaning of the word ‘waste’, which is used in literature to cover both studies on sewage and litter (trash), as well as the term excess that is related to this study. Therefore, removal of waste management papers required manual filtering, such as the work discussed by Thiel et al., that discussed personal protective equipment (PPE) waste build up [29], demolition waste as in [30] or discussion of waste reduction through second life cycle as in [31]. Filtered works also included discussion of COVID-19 in waste samples as in [32].

However, in the work by Sandhu et al., the focus is on throw-away coffee cups, yet the article is included as it is related to consumer behaviour with regard to eco-friendly choices [33] and relates to waste management as a critical infrastructure. Crucial in the selected papers is that human behaviour is involved in the application and that the work relates to one (or multiple) critical infrastructure types. For example, Wang et al. discuss environmental waste, but the focus is on incentivising humans to act [34]. Regarding SQ5, in some cases, articles required an institutional licence or subscription fee. Where possible, the authors requested articles through ResearchGate that were unavailable due to payment restrictions on the digital source (if no response was provided after 10 working days, the article was removed from the SLR).

2.2. Quality Assessment

The QA is a manual procedure involving reading each article and scoring by the quality criteria (either 1, 0.5 or 0, with 1 referring to the highest and 0 the lowest) as detailed in Table 3.

Table 3. Quality Assessment.

| Label | Selection Criteria |
|-------|--------------------|
| QA1   | The aims are clearly stated |
| QA2   | Scope, context, experimental design clearly stated |
| QA3   | Research process documented adequately |
| QA4   | Journal Ranking |
| QA5   | Coupled with real-life application (i.e., applied) |
| QA6   | Direct link to the research focus of the study (i.e., clear reference to strain) |

Points are assigned to the article for a clear outline of the aims (QA1); clear definition of the scope, context and experimental design (QA2); thorough documentation of the research process (QA3); the journal ranking, where Q1-Q2 journals are given a score of 1, Q3-Q4
journals are graded as 0.5 and unranked journals are graded as 0 (QA4); if the work is coupled to a real-life application (rather than the purely theoretical) (QA5); and if there is a direct link to the research focus of the study (i.e., clear reference to strain) (QA6). The final scores should not be considered a full reflection of the article quality (as many are published in Q1 journals), but rather the suitability to align with this study. The highest score an article could receive is 6, with the lowest possible score being 0. An overview of the article filtering process is presented in Figure 1, with an indication of the QA score distribution presented in Figure 2.

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Diagram.

Figure 2. Quality Assessment Scores Overview.
2.3. Data Extraction

Data extracted from each article involved reading through the full contents and completing a form (provided in Table 4) for all. Overall, from the 51 articles, 73 strains are identified, along with 105 barriers and 129 needs in the investigations. These values are then reduced by use of the selection of categories derived through the identification of common themes and the removal of duplicates (and generic terms), resulting in a final count of 38 strains, 86 barriers and 87 needs. Furthermore, the articles discussed 9 of the 16 critical infrastructure domains (with some articles covering multiple domains), and in total there were 18,663 collated participants surveyed across the 51 articles.

Table 4. Data extraction sample.

| Label          | Data Extraction Sample                                      |
|----------------|-------------------------------------------------------------|
| Article ID     | 8                                                           |
| Keywords       | High resolution energy consumption data                     |
| Needs          | Consumer-specific demand response initiatives               |
| Barriers       | Forecasting in residential buildings                        |
| CI-Domain      | Energy                                                      |
| Behaviours     | Consumer demand                                             |
| Strains        | Energy waste                                                |
| Survey         | 96                                                          |
| Limitations    | Short-term electric consumption                              |
| Models         | K-means                                                     |

3. Results

In this section, an overview of the articles involved in the SLR process is provided, followed by a response to the research questions outlined in Section 1.

3.1. Overview

The majority of the articles found in the SLR (and snowballing) approach were open access. Figure 3 details and overview of the count relating to the final 51 articles involved in the investigation, with Table 5 and Figure 4 providing a breakdown of the articles by year. Figure 4 suggests a growing trend in this investigation domain over the five-year period, where the SLR 2021 has more than double the representation of articles than 2018.

Figure 3. Article Accessibility.
| Year | Articles |
|------|---------|
| 2017 | [35–37] |
| 2018 | [38–47] |
| 2019 | [48–53] |
| 2020 | [54–63] |
| 2021 | [64–82] |

Figure 4. Year-wise Distribution of the Studies.

In the following sub-sections, the research questions outlined in Section 1 are addressed by means of a discussion into recurring trends, critical infrastructure domains, needs, barriers, strains and models identified in the SLR.

3.2. (RQ1) Which Critical Infrastructure Domains Are Focused on Primarily?

The 16 critical infrastructure sectors outlined in [1] are presented in Table 6. Within the SLR investigation, 9 critical infrastructure types were investigated. They include Energy, Food, Healthcare, ICT, Telecom, Transport, Waste and Water. Whilst not part of the critical infrastructure classification in [1], homes (that is, residential properties) are also included in the investigation, as other works (for example, [83,84]) discuss the interlinkage of residential properties with critical infrastructures and, therefore, they form part of the discussion.

Table 6. Sixteen Widely Acknowledged Critical Infrastructure Sectors.

| Critical Infrastructure Types | Chemical Sector | Dams | Finance | Information Technology |
|------------------------------|----------------|------|---------|------------------------|
| Commercial facilities        | Defence industrial based sector | Food and agriculture | Nuclear reactors (and materials and waste) |
| Communications               | Emergency services | Government facilities | Transportation systems |
| Critical manufacturing       | Energy           | Healthcare       | Water and wastewater |

As Figure 5 depicts, waste (27), energy (17), food (13) and water (8) are dominant trends within the studies. The lowest representation was ICT, Telecom and Homes with one article each. For example, within the energy domain, Bostenaru Dan et al. [79] discuss thermal power plants in rural areas, and Pulselli et al. [40] discuss energy transition for decarbonising urban neighbourhoods; both authors relate to single specific geographic locations (Romania and Seville, respectively) as a reference for their research into sustainability within the energy domain. Within the waste category, examples of literature include Salem et al. [61], who focus on waste management in one specific geographical location (Gaza Strip), Massoud et al. [73], on waste management practices in low-middle
income countries, and Subiza-Pérez et al. [57], who focus on social acceptance of municipal waste incineration plans. Within the food and water domains, examples include the work by Babbitt et al. [68], who investigate residential food provisioning (specifically during the COVID-19 pandemic), and Prouty et al., [58] who focus on water networks and the implications of extreme weather events on the service provision and infrastructure.

Figure 5. Critical Infrastructure Domains in SLR.

Furthermore, it should be noted that some articles have a duel classification, for example, Kibler et al. [41] investigate Food, Water and Energy, Chung et al. [50] cover both Waste and Health, Maase et al. cover Energy and Transport [43], and Shoukourian et al. [59] focus on both ICT and Energy. Appendix A Table A1 provides an overview of the critical infrastructure domain by author in alphabetical order.

3.3. (RQ2) Do Articles Tend to Involve Participants in the Investigation?

In total, the studies involved 18,336 participants. With the highest level of survey participants in the work by Pulselli et al. [40] on energy transition, with 5364 in total. There were some low participation studies, for example, in the work by Gokarn et al. [35], seven participants were surveyed, but the results were validated by expert panels. This is a similar approach to Chen et al. [80], who surveyed 428 participants and validated the findings by means of 10 experts. Kamble et al. [52] involved 12 participants in the survey but employed a literature search to validate the findings.

Overall, 36 articles involved participants (3 of which did not state the surveyed number) and 15 articles did not involve surveys/participants in the investigation. An overview of the participants per critical infrastructure domain is visualised in Figure 6. Where articles cover multiple domains, the overarching domain type is employed in the graphic (meaning the categories diverge from those presented in Figure 5). The x-axis depicts the survey participants, while the domain types are highlighted on the y-axis.

3.4. (RQ3) What Are the Main Barriers or Needs and the Resulting Strains?

Coelho et al. [44] discuss several needs within the energy sector, for instance, energy-cost saving, efficiency measures, renewable production (at all levels with a local emphasis) or targets for climate actions. These are common traits within other articles in different domains. For example, Barreiro et al. [8] discuss climate action within the urban resilience domain, Deng et al. [66] within the water domain and Ichikoitz et al. [54] within the waste and recycling domain (specifically highlighting the growing volume of e-waste in South Africa). Furthermore, Ichikoitz et al. [54] also discuss climate-related needs. Other notable points include protection of infrastructures from weather in [58], consumer participation in food waste management in [68] and the need for greater education programs for supporting customers with purchases to reduce waste and on waste-sorting programs to reduce the strain on landfill or collection networks [33,48,49].
There is bias in the needs associated with Transport, as only one article in the SLR focused implicitly on transport, in which taxi routes within aviation are discussed. However, articles from other critical infrastructure domains also discussed transport issues, for example Chen et al. [80], who refer to the needs for greater use of local resources to support transport networks. The overall findings from the SLR related to the identified needs are presented in Appendix A Table A2, with a sample of the findings in Table 7.

**Table 7.** Identified needs from overall findings.

| Ecology and Health | Policy | ICT | Transport | Education | Socio-Economic | Infrastructure |
|--------------------|--------|-----|-----------|-----------|----------------|----------------|
| Environmental protection | Enforce regulations | BIM approach | Allocate taxi routes to aircraft | Campaigns/Training Programs | Adverse social reactions | Protection from extreme events |
| Sustainable decisions | Company collaboration | Capture complex system dynamics | Robust taxi time | Education in making purchases and reducing waste | Consumer participation in food waste management | Ease of access to recycling bins |
| Greening industrial waste | Dedicated team (for monitoring and co-ordinating local authorities) | Highly dependent on accurate utilization data | Transportation | Decrease the perceived cost of rural people | Consumer-specific demand response initiatives | Effective use of limited available resources |
| Landscape as a proactive eco-systemic infrastructure | Banning food from landfill | Lack of studies on IoT adoption in food | Use of local resources | Educational interventions | Improve the perceived benefit | Government provision of more infrastructure |
| Reduce greenhouse emissions | Dynamic strategic adjustments | New Technology | Reduce the distribution distances | Greater investment in education | Respondents were more willing to buy a product if it was recyclable | Improved efficiency of industrial processes and equipment |

Regarding the barriers discussed in the 51 articles (of which, Table 8 presents a sample—with the full list of barriers in Appendix A Table A3), the categories of Ecology and Health (16), Policy (16), ICT (16) and Socio-Economic (19) had almost equally prominent representation, with a similar number of barriers identified for Infrastructure (12). Much of the ICT barriers were related to articles discussing the issues surrounding IoT (integration, governance, cost, compatibility, etc.), for example in the work by Kamble et al. [52], where a comprehensive list is provided on the barriers relating to IoT implementation. Regarding Ecology and Health, COVID-19 was discussed in [74, 77, 79], with other topics such as the pervasiveness of takeaway culture in [33] and other people-driven behaviours relating to
the proper sorting and separation of waste [72] causing strain on landfill and collection networks. Uncertainty over weather patterns [56] and climate change [44,54] were also listed as barriers.

**Table 8. Sample list of barriers.**

| Ecology and Health | Policy | ICT | Transport | Education | Socio-Economic | Infrastructure |
|--------------------|--------|-----|-----------|-----------|----------------|----------------|
| Pervasiveness of takeaway culture | Focus on individual country | Suspension on deployment of new data centres | Inadequate vehicle routing | Classification knowledges for WCI | Low participation rate in waste separation (17%) | Sustainable supply |
| Food characteristics | Inefficiencies in planting, harvesting and water use | Adoption of IoT is still in its nascent stage | Uncertainty in other transportation problems | Pharmaceutical products consumed and disposed | Growing urban populations | Many low and middle-income countries |
| Infectious agent may be of zoonotic rather than human | Garbage classification | Exploiting big data sources | Geographical access | Consumers’ awareness | Densely populated regions | Urbanisation |
| High export percentage of circuit boards and plastics recycling | Policy instruments on perceived value | Streamlined communications | Insufficient funds | Attitude to waste disposal | Infrastructure to harness data |
| COVID-19 | Relies on voluntary waste diversion strategies | Lack of government regulations for IoT | Public vs. private sector participation | Imperfect and lack of infrastructure |

The full list of strains identified in the 51 articles is presented in Table 9 below. The dominant categories of strains were within Ecology and Health, Socio-Economic and Infrastructure. In total, 10 articles discuss carbon emissions, with a further 10 discussing landfill/trash and the environment in general. For example, Ichikowitz et al. [54] discuss the strain caused by e-waste, and [64–66] are examples of works discussing the straining impact on the environment. Six articles discuss energy burdens, for instance, Khahro et al. [81] discuss the benefits of Building Information Models (BIM) in this domain, and Xu et al. [47] discuss waste heat recovery in power plants. Regarding further discussions on Infrastructure, strains include growing tourism [39], management at landfill sites [48], water waste [69] and increased production [56].

**Table 9. Strains identified from articles.**

| Ecology and Health | Policy | ICT | Transport | Socio-Economic | Infrastructure |
|--------------------|--------|-----|-----------|----------------|----------------|
| Pollution (plastic/water) | Political pressure | Energy burden | Food networks | Food purchase | Supply of water |
| Sustainability | Waste management | Food security | Food production | Lack of space | Lack of space |
| Climate change | | Informal settlements | Environmental footprints | Water waste | Water waste |
| e-Waste | | Garbage siege | Dumping and burning | Management at landfill | Management at landfill |
| Waste volume | | Collaboration | Carbon emissions | Increased production | Increased production |
| Environmental footprint | | | Environmental health | Growing tourism | Growing tourism |
| Dumping and burning | | | Health strain | Urbanizing water cycle | Urbanizing water cycle |
| Carbon emissions | | | Waste entering landfills | Waste management | Waste management |
| Environmental health | | | Environ. Contamination | Energy consumption | Energy consumption |
| Health strain | | | Water consumption | Energy waste | Energy waste |
| Food waste | | | Water consumption | Energy Efficiency | Energy Efficiency |
| Waste entering landfills | | | Water consumption | Fuel | Fuel |
| Environ. Contamination | | | Water consumption | Supply | Supply |
| Water consumption | | | Water consumption | Variability | Variability |

Informal settlements are outlined as a strain in [53], with garbage siege identified as a strain in [76]. Strains relating to food (production, purchase and security) are also discussed in [35]. Documentation of the strains related to Policy, ICT and Transport were somewhat limited compared to their prominence in the discussion on needs and barriers. However,
Schmitt et al. [70] outline the transport strain on food networks, and Shoukourian et al. [59] outline the energy burden in the ICT domain.

In summary, Figure 7 displays a count-based comparison plot of the strains, barriers and needs within the 51 articles.

**Figure 7.** Count-based comparison plot of strains, barriers and needs.

### 3.5. (RQ4) What Methods of Analysis Are Typically Employed for the Investigations?

In total, 81 methods of analysis are used within the 51 articles. As with the needs, barriers and strains, duplicates are removed, resulting in a final identification of 60 approaches, as listed in Table 10. Many could be categorised under statistical analysis (for example, ANOVA [82], Chi-square [68], Pearson correlation [54], t-test [82], Wilcoxon–Mann–Whitney rank-sum test [37], and Welch [50], etc.). Other categories could include machine learning (k-means [65], and Logistic regression [72], etc.), deep learning (Artificial Neural Network [42]) and model-based (for example, causal loop diagrams [58], agent-based [62]).

In summary, the dominant approach is to adopt a statistical analysis for the evaluation. This would align with the high number of articles involving human-participants in the investigation. Articles also involved simulation, for example, [38,45] accounting for the use of causal-loop diagrams and agent-based modelling investigations.

**Table 10.** Methods of Analysis in Alphabetical Order.
3.6. Discussion

Finally, discussion is provided on behaviours present in the 51 articles in this section. As previously outlined, 18,336 participants were surveyed in 36 of the 51 articles. This provided ample insight into waste behaviour traits that others can build on. For example, a common theme within a portion of the articles relates to consumer behaviour with regard to the classification of rubbish, and the resulting strain this causes on the environment, landfill management and collection networks. As solutions, educational practice is proposed as a way forward to mitigate the resulting ‘garbage siege’ [76] caused by urbanisation. However, poor garbage management behaviours were present outside of residential properties, with Mensah [78] discussing that fisherfolk (in Ghana) have a low level of waste sorting and are unwilling to pay for collection services.

Other behaviour points identified include sustainable consumption, relating to material goods, energy, food and water. As such, González-Briones et al. [42] discuss the benefits a policy driver could play in this domain to reduce food waste and encourage investment in infrastructure. However, the emphasis of many articles is on better educational practice, information sharing, awareness [53], more customer involvement in decision making and better support and policies driven by local authorities. However, in some instances, health is also a cause of behavioural patterns, for instance the wastage behaviour caused by COVID-19 stockpiling [68]. Environmental issues are also a driver for change, not just for residences, but also commercially. Culture, social-expectations, shopping habits and attitudes were also drivers relating to wasteful behaviours that are damaging to the environment, as discussed in [39].

In summary, there were some limitations within the investigation, for example articles which would have been useful for the investigation were omitted due to their unavailability online or restricted payment. Furthermore, 10 articles were requested via ResearchGate, but no response was received after 10 working days. It was also clear that the search string could be strengthened as the snowballing (hand-search) accounted for missing articles. Future approaches could include other search strings incorporating different critical infrastructure types as keywords.

3.7. Going Forward

Within the critical infrastructure domain, it is crucial to develop solutions to support strains through integration of ICT technologies. The approach employed in this paper has recognised limitations, particularly regarding the implementation of IoT [52], cost barriers and infrastructure barriers addressed. Nonetheless, there are clear benefits; for instance, use of machine learning and deep learning techniques that can support preventative maintenance solutions for better infrastructure management. Work in this area is already being conducted within the manufacturing industry, where machine learning is combined with digital twinning technologies to predict and detect failures within the production chain. The full potential of digital twins is yet to be explored, however, the digital twin market exceeded USD 4 billion in 2019 and is predicted to grow by a further 30% by 2026. There is a clear scope for an application of this technology for supporting critical infrastructure management practices.

Water waste is a common problem globally as demonstrated in the broad range of article sources present in this investigation. In addition to including serious mechanical faults (for example, pipes left broken, valves/pumps malfunctioning), water waste also refers to simple home behaviours which cause high levels of excess use (for example, leaving the shower on to warm up before using the water, using half-filled dishwashers and over-use of garden sprinklers). Little research has been conducted into the behavioural profiling of water waste behaviours, and this investigation recognises that it is a core challenge for creating sustainable water resources for the future.

The need to understand the water governance process, in particular, is highly beneficial for society as power, food, health and supply networks rely on this infrastructure [58]. Water deficiencies also have a wide-ranging detrimental impact on the rural areas. With
rural areas being prime sources of food provisioning for the nation as a whole, effective water governance is paramount. In addition to the availability of water, water quality is also under stress, for example, by extreme weather changes that are globally increasing in occurrence and severity due to global warming.

Focusing on resource efficiency is most appropriate, given the challenge of the project (that is, rising urbanisation and reducing water resources). A well-known example of resource efficiency is within the precision farming domain, where digital twin technologies are being used with high success for producing higher crop yield. The techniques used offer key value for resource efficiency, with tremendous benefits for a cheaper and higher crop yield (for example, reduced pesticide/fertiliser/water, increased use of marginalised land, reduced pest damage hence higher market value, lower drought damage). Yet, the approach is only possible with a detailed understanding of the holistic crop management process, supporting a reduction of strains on food production.

4. Conclusions and Future Work

In this article, the needs, barriers, strains, behaviours and methods of investigation relating to critical infrastructures were investigated by means of an SLR using the Scopus digital library. From an initial search result of 364 articles, 51 were selected for review following the selection criteria and quality assessment process. Key findings are outlined by discussing four research questions in Sections 3.2–3.5: (RQ1) which critical infrastructure domains are focused on primarily? (RQ2) Do articles tend to involve participants in the investigation? (RQ3) What are the main barriers or needs and the resulting strains? (RQ4) What models are typically employed for the investigations? Reflections on the findings and subsequent discussion provided in Sections 3.6 and 3.7 lead the authors to consider possible approaches for overcoming the barriers identified. Namely processes and further research into the standardisation (and optimal regulation) for the deployment of IoT would better facilitate automation that would result in a reduction in waste and higher level of resilience for critical infrastructures. Education and streamlined communication are also crucial for overcoming several barriers, not only in terms of skills training on IoT technologies, but also for a greater general public awareness on waste volume, waste attitudes and behaviours and the impact the micro level has on a macro scale.

Limitations of this work relate to the search string, meaning future directions for the work include expanding the search query by incorporating other related terms, such as sustainability, modelling, etc. Furthermore, some of the 16 critical infrastructure domains identified in [1] are under-represented in this search (for example, Transport and ICT) as, amongst the 51 articles, only 9 discussed these domains. Possible future directions for the study could, therefore, also include investigations into the under-represented critical infrastructure domains in this article by incorporating grey literature into the findings.

**Author Contributions:** Conceptualization, W.H. and B.K.; methodology, W.H.; software, W.H.; validation, W.H.; formal analysis, W.H.; investigation, W.H.; resources, W.H.; data curation, W.H.; writing—original draft preparation, W.H., K.E.B., B.K. and T.M.; writing—review and editing, W.H., K.E.B., B.K. and T.M; visualization, W.H. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Conflicts of Interest:** The authors declare no conflict of interest.

**Appendix A**

**Table A1.** Critical Infrastructure Domain by Author.

| Author     | Critical Infrastructure Domain       |
|------------|---------------------------------------|
| Degenstein [64] | Waste and Recycling                   |
| Sidhu [65]          | Waste and Recycling                   |
Table A1. Cont.

| Author                  | Critical Infrastructure Domain                                      |
|-------------------------|---------------------------------------------------------------------|
| Brownlee [38]           | Transport                                                           |
| de Bruyn [28]           | Energy                                                              |
| Deng [66]               | Water and Energy                                                    |
| Khan [67]               | Energy                                                              |
| Gokarn [35]             | Food                                                                |
| Barreiro [6]            | Water, Energy, Transport, Waste, Telecom, Environment               |
| Babbit [68]             | Food                                                                |
| Jamal [48]              | Waste and Recycling                                                |
| Ee [39]                 | Food                                                                |
| Ichikowtitz [54]        | Waste and Recycling                                                |
| Karadagli [69]          | Water and Wastewater                                               |
| Schmidt [70]            | Food and Health                                                    |
| Gausa [55]              | Food                                                                |
| Perakis [56]            | Food                                                                |
| Zhang [71]              | Waste and Recycling                                                |
| Heydari [72]            | Waste and Recycling                                                |
| Massoud [73]            | Waste and Recycling                                                |
| Zheng [74]              | Waste and Recycling                                                |
| Pulseli [40]            | Energy                                                             |
| Sandhu [33]             | Waste and Recycling                                                |
| Subiza-Pérez [57]       | Waste and Recycling                                                |
| Končar [75]             | Transport                                                           |
| Prouty                  | Water                                                               |
| Peng [76]               | Recycling                                                           |
| Burton [77]             | Water                                                               |
| Mensah [78]             | Waste and Recycling, Food, Health                                  |
| Kibler [41]             | Food and Energy                                                    |
| Shoukourian [59]        | ICT, Energy                                                         |
| Bostenaru Dan [79]      | Energy                                                              |
| González-Briones [42]   | Energy                                                              |
| Chen [80]               | Food                                                                |
| Morone [49]             | Health, Waste and Recycling                                        |
| Chung [50]              | Food and Recycling                                                  |
| Amirudin [51]           | Waste and Recycling                                                |
| Niles [60]              | Food                                                                |
| Kamble [52]             | Energy                                                              |
| Khabro [81]             | Waste and Recycling                                                |
| Sinthumule              | Energy and Transport                                               |
| Maase [43]              | Waste and Recycling                                                |
| AlHaj [82]              | Waste and Recycling                                                |
| Salem [61]              | Waste and Recycling                                                |
| Hansmann [36]           | Waste and Recycling                                                |
| Allen [62]              | Homes                                                               |
| Coelho [44]             | Energy                                                              |
| Gao [45]                | Energy                                                              |
| Barnes [46]             | Water                                                               |
| Ma [63]                 | Waste and Recycling                                                |
| Geislar [37]            | Food                                                                |
| Xu [47]                 | Energy                                                              |
| Ecology and Health               | Policy                               | ICT                                      | Transport                                  | Education                                           | Socio-Economic                          | Infrastructure                        |
|---------------------------------|--------------------------------------|------------------------------------------|--------------------------------------------|---------------------------------------------------|-----------------------------------------|---------------------------------------|
| Environmental protection        | Enforce regulations                  | BIM approach                             | Allocate taxi routes to aircraft           | Campaigns/Training Programs                       | Adverse social reactions                | Protection from extreme events        |
| Sustainable decisions           | Company collaboration                 | Capture complex system dynamics          | Robust taxi time                           | Education in making purchases and reducing waste | Consumer participation in food waste management | Ease of access to recycling bins      |
| Greening industrial waste       | Dedicated team (for monitoring and co-ordinating local authorities) | Highly dependent on accurate utilization data | Transportation                            | Decrease the perceived cost of rural people       | Consumer-specific demand response initiatives | Effective use of limited available resources |
| Landscape as a proactive eco-systemic infrastructure | Banning food from landfill | Lack of studies on IoT adoption in food | Use of local resources                      | Educational interventions                        | Improve the perceived benefit          | Government provision of more infrastructure |
| Reduce greenhouse emissions     | Dynamic strategic adjustments         | New Technology                           | Reduce the distribution distances          | Greater investment in education                    | Respondents were more willing to buy a product if it was recyclable | Improved efficiency of industrial processes and equipment |
| Source segregation of food waste | Effective policy drivers              | Pairing social and technical innovations | Efficient collection of plastic waste      | Importance of information                         | Take into account public perceptions     | Infrastructure to strengthen the intention-behaviour conversion |
|                                  |                                      |                                          | Weight sensors to measure the bin levels   | Increase citizens’ awareness and responsibility toward solid waste source separation | Urbanisation (in 2050, 68% of the population will be living in cities) | More convenient and sustainable options for clothing disposal |
| Fair support for local farmers  |                                      |                                          |                                           | Little is known about FEW impacts of managing food waste after it has been disposed | More money to the township government         | Optimising agriculture and livestock  |
| Food-specific policy and regulation |                                      |                                          |                                           | Programs targeted to individual behaviours embedded within | Proper treatment facilities for pharmaceutical waste |                                       |
| Formalisation by EU directives |                                      |                                          |                                           | Promote publicity and education                   | Provide more waste disposal infrastructure |                                       |
| Government collaboration with experts |                                      |                                          |                                           | Promotion of safe animal contact focusing on the management of human waste. | Roll out food waste bins within a community |                                       |
| Government fines                |                                      |                                          |                                           | Promote the active cooperation of investors       | Successful implementation of source segregation of food waste |                                       |
| Impacts from extreme weather integrated into infrastructure decision making |                                      |                                          |                                           | Public education for handling pharmaceutical waste | Strengthen the infrastructure construction |                                       |
| Interrelated policy measures    |                                      |                                          |                                           | Strong environmental messaging                   | Supply chain innovation and infrastructure |                                       |

**Table A2. Full List of Identified Needs.**
### Table A2. Cont.

| Ecology and Health | Policy | ICT | Transport | Education | Socio-Economic | Infrastructure |
|--------------------|--------|-----|-----------|-----------|----------------|----------------|
|                     |        |     |           |           |                | Interventions for assuring the correct development |
|                     |        |     |           |           |                | Standardisation |
|                     |        |     |           |           |                | Local policy decisions and initiatives |
|                     |        |     |           |           |                | Managing food waste to minimize its introduction into the waste stream |
|                     |        |     |           |           |                | Multi-level governance |
|                     |        |     |           |           |                | Need for a roll-out of a public charging infrastructure |
|                     |        |     |           |           |                | Packaging eco-labeling certification |
|                     |        |     |           |           |                | Policy-making and standardisation |
|                     |        |     |           |           |                | Private initiatives to reduce the amount of food waste |
|                     |        |     |           |           |                | Reduce the probability of government supervision |
|                     |        |     |           |           |                | Tailored approaches to food waste management in rural regions |
|                     |        |     |           |           |                | Water, sanitation, and hygiene strategies to reduce diarrheal disease |
|                     |        |     |           |           |                | Sustainability targeted polices for Data Centres |

### Table A3. Full list of Identified Barriers.

| Ecology and Health | Policy | ICT | Transport | Education | Socio-Economic | Infrastructure |
|--------------------|--------|-----|-----------|-----------|----------------|----------------|
| Pervasiveness of takeaway culture | Focus on individual country | Suspension on deployment of new data centres | Inadequate vehicle routing | Classification knowledges for WCI | Low participation rate in waste separation (17%) | Sustainable supply |
| Food characteristics | Inefficiencies in planting, harvesting and water use | Adoption of IoT is still in its nascent stage | Uncertainty in other transportation problems | Pharmaceutical products consumed and disposed | Growing urban populations | Many low and middle-income countries |
| Infectious agent may be of zoonotic rather than human | Garbage classification | Exploiting big data sources | Geographical access | Consumers’ awareness | Densely populated regions | Urbanisation |
Table A3. Cont.

| Ecology and Health | Policy | ICT | Transport | Education | Socio-Economic | Infrastructure |
|--------------------|--------|-----|-----------|-----------|----------------|----------------|
| High export percentage of circuit boards and plastics recycling | Policy instruments (infrastructure/information) on perceived value (perceived benefit/cost) | Streamlined communications | Insufficient funds | | Attitude to waste disposal | Infrastructure to harness data |
| COVID-19 | Relies on voluntary waste diversion strategies | Lack of government regulations for IoT | | | Public vs. private sector participation | Imperfect and lack of infrastructure |
| Preventable/unpreventable food waste has different mechanisms | Actualizing energy and climate change policies | Lack of standardisation for IoT | | | Behavioural decision-making of individuals | Enough storage space |
| Proper sorting and separation of waste | The diverse priorities of stakeholders (e.g., recycling, efficiency, and effectiveness) | High energy consumption for IoT | | | Waste separation behaviours | Inadequate clean water resources |
| Reduced animal contributions | Decision-making about transitioning critical infrastructure across scale | IoT security and privacy | | | Public adverse reaction to new plants | Access to garbage collection |
| Uncertainty about weather | Decision-makers are confronted with too many challenges (societal disparities or economic instability) | IoT high operating and adoption costs | | | Supply chain innovation | Electric consumption forecasting in residential buildings |
| Low acceptance rate | Policy or societal change data | IoT long payback period | | | Lack of ability to shop in person | High load on the power grid |
| More consumption outdoors | Structural intervention | IoT lack of internet infrastructure | | | Cost of growing crops in a greenhouse is very high | Scarce space |
| Food waste management in rural regions is less studied | Impact measurement within the sector incredibly complex | IoT lack of human skill availability | | | Consumer demand | Behaviour variability |
| Existing practices that affected social sustainability | Solid waste management (SWM) systems remain weak and lack standardization | IoT compatibility issues | | | Cost is significantly negatively related to WSB | |
| Waste results in less fish-catch | Absence of guiding policies | IoT scalability | | | Unwilling to pay anything additional | |
| Climate change | Food policy and regulation | IoT architecture | | | Weak public knowledge | |
| Perception of a high risk for human health | An improved treatment portfolio is complex | IoT lack of validation and identification | | | Supply chain uncertainty | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
References

1. Cybersecurity and Infrastructure Security Agency, Critical Infrastructure Sectors, CISA. 21 October 2020. Available online: https://www.cisa.gov/critical-infrastructure-sectors (accessed on 29 December 2021).

2. Fausto, A.; Gaggero, G.; Patrone, F.; Girdirio, P.; Marchese, M. Toward the Integration of Cyber and Physical Security Monitoring Systems for Critical Infrastructures. Sensors 2021, 21, 6970. [CrossRef] [PubMed]

3. Almaleh, A.; Tipper, D. Risk-Based Criticality Assessment for Smart Critical Infrastructures. Infrastructures 2022, 7, 3. [CrossRef]

4. Guo, D.; Shan, M.; Owusu, E. Resilience Assessment Frameworks of Critical Infrastructures: State-of-the-Art Review. Buildings 2021, 11, 464. [CrossRef]

5. Tzouvaras, M. Statistical Time-Series Analysis of Interferometric Coherence from Sentinel-1 Sensors for Landslide Detection and Early Warning. Sensors 2021, 21, 6799. [CrossRef] [PubMed]

6. Mignan, A.; Wang, Z. Exploring the Space of Possibilities in Cascading Disasters with Catastrophe Dynamics. Int. J. Environ. Res. Public Health 2020, 17, 7317. [CrossRef]

7. United Nations. The 2019 Revision of World Population Prospects, Department of Economic and Social Affairs. 2019. Available online: https://population.un.org/wpp (accessed on 29 December 2021).

8. Barreiro, J.; Lopes, R.; Ferreira, F.; Brito, R.; Telhado, M.; Matos, J.; Matos, R. Assessing Urban Resilience in Complex and Dynamic Systems: The RESCCUE Project Approach in Lisbon Research Site. Sustainability 2020, 12, 8931. [CrossRef]

9. Sänger, N.; Heinzel, C.; Sandholz, S. Advancing Resilience of Critical Health Infrastructures to Cascading Impacts of Water Supply Outages—Insights from a Systematic Literature Review. Infrastructures 2021, 6, 177. [CrossRef]

10. Chan, Y.S.; Wang, H.-P.; Xiang, P. Optical Fiber Sensors for Monitoring Railway Infrastructures: A Review towards Smart Concept. Symmetry 2021, 13, 2251. [CrossRef]

11. Mlambo, V.H. An overview of rural-urban migration in South Africa: Its causes and implications. Arch. Bus. Res. 2018, 6, 63–70. [CrossRef]

12. Reliefweb. Climate Change, Water and the Spread of Diseases: Connecting the Dots Differently. The Conversation. 16 September 2018. Available online: https://reliefweb.int/report/world/climate-change-water-and-spread-diseases-connecting-dots-differently (accessed on 29 December 2021).

13. SAnews. Warning Against Illegal Water Connections. 8 November 2011. Available online: https://www.sanews.gov.za/south-africa/warning-against-illegal-water-connections (accessed on 29 December 2021).

14. Páez-Curtidor, N.; Keilmann-Gondhalekar, D.; Drewes, J. Application of the Water–Energy–Food Nexus Approach to the Climate-Resilient Water Safety Plan of Leb Town, India. Sustainability 2021, 13, 10550. [CrossRef]

15. Abdelkader, E.; Al-Sakkaf, A.; Elshaboury, N.; Alfalah, G. Hybrid Grey Wolf Optimization-Based Gaussian Process Regression Model for Simulating Deterioration Behavior of Highway Tunnel Components. Processes 2022, 10, 36. [CrossRef]

16. Maraveas, C.; Bartzanas, T. Sensors for Structural Health Monitoring of Agricultural Structures. Sensors 2021, 21, 314. [CrossRef]

17. Tekinerdogan, B.; Verdouw, C. Systems Architecture Design Pattern Catalog for Developing Digital Twins. Sensors 2020, 20, 5103. [CrossRef]

18. Bujari, A.; Calvio, A.; Foscini, L.; Sabbioni, A.; Corradi, A. A Digital Twin Decision Support System for the Urban Facility Management Process. Sensors 2021, 21, 8460. [CrossRef]

19. Gough, M.B.; Santos, S.F.; AlSkaif, T.; Jawadi, M.S.; Castro, R.; Catalão, J.P.S. Preserving Privacy of Smart Meter Data in a Smart Grid Environment. IEEE Trans. Ind. Inform. 2022, 18, 707–718. [CrossRef]

20. Sachit, M.; Shafrir, H.; Abdullab, A.; Rafie, A. Combining Re-Analyzed Climate Data and Landcover Products to Assess the Temporal Complementarity of Wind and Solar Resources in Iraq. Sustainability 2022, 14, 388. [CrossRef]

21. Couto, L.C.; Campos, L.C.; Fonseca-Zang, W.; Zang, J.; Bleischwitz, R. Water, waste, energy and food nexus in Brazil: Identifying a resource interlinkage research agenda through a systematic review. Renew. Sustain. Energy Rev. 2021, 138, 110554. [CrossRef]

22. Chowdhury, N. CS Measures for Nuclear Power Plant Protection: A Systematic Literature Review. Signals 2021, 2, 803–819. [CrossRef]

23. Tummers, J.; Kassahun, A.; Tekinerdogan, B. Obstacles and features of Farm Management Information Systems: A systematic literature review. Comput. Electron. Agric. 2019, 157, 189–204. [CrossRef]

24. Kitchenham, B. Procedures for performing systematic reviews. Keele Univ. 2004, 33, 1–26.

25. Boar, A.; Bastida, R.; Marimon, F. A Systematic Literature Review. Relationships between the Sharing Economy, Sustainability and Sustainable Development Goals. Sustainability 2020, 12, 6744. [CrossRef]

26. Anibaldi, R.; Rundle-Thiele, S.; David, P.; Roemer, C. Theoretical Underpinnings in Research Investigating Barriers for Implementing Environmentally Sustainable Farming Practices: Insights from a Systematic Literature Review. Land 2021, 10, 386. [CrossRef]

27. Lepasepp, T.; Hurst, W. A Systematic Literature Review of Industry 4.0 Technologies within Medical Device Manufacturing. Future Internet 2021, 13, 264. [CrossRef]

28. De Bruyn, D.N.; Kotze, B.; Hurst, W. A Hidden Markov Model and Fuzzy Logic Forecasting Approach for Solar Geyser Water Heating. Infrastructures 2021, 6, 67. [CrossRef]

29. Thiel, M.; de Veer, D.; Espinoza-Fuenzalida, N.L.; Espinoza, C.; Gallardo, C.; Hinojosa, I.A.; Kiessling, T.; Rojas, J.; Sanchez, A.; Sotomayor, F.; et al. COVID lessons from the global south—Face masks invading tourist beaches and recommendations for the outdoor seasons. Sci. Total Environ. 2021, 786, 147486. [CrossRef]
30. Yaghoubi, E.; Sudarsanan, N.; Arulrajah, A. Stress-strain response analysis of demolition wastes as aggregate base course of pavements. *Transp. Geotech.* 2021, 30, 100599. [CrossRef]

31. Cabrera, M.; López-Alonso, M.; Garach, L.; Alegre, J. Feasible use of recycled concrete aggregates with alumina waste in road construction. *Materials* 2021, 14, 1466. [CrossRef]

32. Gwenzii, W.; Rzymski, P. When silence goes viral, Africa sneezes! A perspective on Africa’s subdued research response to COVID-19 and a call for local scientific evidence. *Environ. Res.* 2021, 194, 110637. [CrossRef]

33. Sandhu, S.; Lodhia, S.; Potts, A.; Crocker, R. Environment friendly takeaway coffee cup use: Individual and institutional enablers and barriers. *J. Clean. Prod.* 2021, 291, 125271. [CrossRef]

34. Wang, Z.; Duan, Y.; Huo, J. Maximal covering location problem of smart recycling infrastructure for recyclable waste in an uncertain environment. *Waste Manag.* 2021, 39, 396–404. [CrossRef]

35. Gokarn, S.; Kuthambalayan, T.S. Analysis of challenges inhibiting the reduction of waste in food supply chain. *J. Clean. Prod.* 2017, 168, 595–604. [CrossRef]

36. Hanssens, R.; Steimer, N. Subjective reasons for littering: A self-serving attribution bias as justification process in an environmental behaviour model, Environmental Research. *Eng. Manag.* 2017, 73, 8–19. [CrossRef]

37. Geislar, S. The new norms of food waste at the curb: Evidence-based policy tools to address benefits and barriers. *Waste Manag.* 2017, 68, 571–580. [CrossRef]

38. Brownlee, A.E.I.; Weiszer, M.; Chen, J.; Ravizza, S.; Woodward, J.R.; Burke, E.K. A fuzzy approach to addressing uncertainty in Airport Ground Operation optimization. *Transp. Res. Part C Emerg. Technol.* 2018, 92, 150–175. [CrossRef]

39. Ee, G.J.; Ze, B.W.T. Comparing the self-reported data and observed behaviour of food waste separation: A study of the 29th Southeast Asia (SEA) games. *Asia-Pac. J. Innov. Hosp. Tour.* 2018, 7, 107–130.

40. Pulseli, R.M.; Maccanti, M.; Marchetti, N.; Marrero, M.; Dobbelsteen, A.V.D.; Martin, C. Energy transition for the decarbonisation of urban neighborhoods: A case study in Seville, Spain. *WIT Trans. Ecol. Environ.* 2018, 217, 893–901.

41. Kibler, K.M.; Reinhart, D.; Hawkins, C.; Motlagh, A.M.; Wright, J. Food waste and the food-energy-water nexus: A review of food waste management alternatives. *Waste Manag.* 2018, 74, 52–62. [CrossRef]

42. González-Briones, A.; Chamoso, P.; Yoe, H.; Corchado, J. GreenVMAS: Virtual Organization Based Platform for Heating Greenhouses Using Waste Energy from Power Plants. *Sensors* 2018, 18, 861. [PubMed]

43. Maase, S.; Dilrosun, X.; Kooi, M.; van den Hoed, R. Performance of Electric Vehicle charging infrastructure: Development of an assessment platform based on charging data. *World Electr. Veh. J.* 2018, 9, 25. [CrossRef]

44. Coelho, S.; Russo, M.; Oliveira, R.; Monteiro, A.; Lopes, M.; Borrego, C. Sustainable energy action plans at city level: A Portuguese experience and perception. *J. Clean. Prod.* 2018, 1223, 2018, 176–1230. [CrossRef]

45. Gao, L.; Zhao, Z.-Y. System dynamics analysis of evolutionary game strategies between the government and investors based on new energy power construction public-private-partnership (PPP) project. *Sustainability* 2018, 10, 2533. [CrossRef]

46. Barnes, A.N.; Anderson, J.D.; Mumma, J.; Mahmud, Z.H.; Cumming, O. The association between domestic animal presence and household drinking water contamination among peri-urban communities of Kisumu, Kenya. *PloS ONE* 2018, 13, e0197587. [CrossRef] [PubMed]

47. Xu, Z.; Mao, H.; Liu, D.; Wang, R.Z. Waste heat recovery of power plant with large scale serial absorption heat pumps. *Energy* 2019, 1079, 2018, 165–1105. [CrossRef]

48. Jamal, M.; Szefler, A.; Kelly, C.; Bond, N. Commercial and household food waste separation behaviour and the role of Local Authority: A case study. *Int. J. Recycl. Org. Waste Agric.* 2019, 8, 281–290. [CrossRef]

49. Morone, P.; Falcone, P.M.; Lopolito, A. How to promote a new and sustainable food consumption model: A fuzzy cognitive map study. *J. Clean. Prod.* 2019, 208, 563–574. [CrossRef]

50. Chung, S.S.; Brooks, B.W. Identifying household pharmaceutical waste characteristics and population behaviors in one of the most densely populated global cities. *Resour. Conserv. Recycl.* 2019, 140, 267–277. [CrossRef]

51. Amirudin, N.; Gim, T.-H.T. Impact of perceived food accessibility on household food waste behaviors: A case of the Klang Valley, Malaysia. *Resour. Conserv. Recycl.* 2019, 151, 104335. [CrossRef]

52. Kamlbe, S.S.; Gunasekaran, A.; Parekh, H.; Joshi, S. Modeling the internet of things adoption barriers in food retail supply chains. *J. Retail. Consum. Serv.* 2019, 48, 154–168. [CrossRef]

53. Sinthumule, N.I.; Mkumbuzi, S.H. Participation in community-based solid waste management in Nkulumane Suburb, Bulawayo, Zimbabwe. *Resources* 2019, 8, 30. [CrossRef]

54. Ichikowitz, R.; Hattingh, T.S. Consumer e-waste recycling in South Africa. *S. Afr. J. Ind. Eng.* 2020, 31, 44–57. [CrossRef]

55. Gause, M.N.; Pericu, S.; Canessa, N.; Tucci, G. Creative Food Cycles: A Cultural Approach to the Food Life-Cycles in Cities. *Sustainability* 2020, 12, 6487. [CrossRef]

56. Peraquis, O.; Lampathaki, F.; Nikas, K.; Georgiou, Y.; Marko, O.; Maselyne, J. CYBELE—Fostering precision agriculture & livestock farming through secure access to large-scale HPC enabled virtual industrial experimentation environments fostering scalable big data analytics. *Comput. Netw.* 2020, 168, 107035. [CrossRef]

57. Subiza-Pérez, M.; Marina, L.S.; Gallastegi, A.M.; Anabitarte, A.; Babarro, N.U.; Molinuove, A.; Vivoznediano, L.; Ibarlueza, J. Explaining social acceptance of a municipal waste incineration plant through sociodemographic and psycho-environmental variables. *Environ. Pollut.* 2020, 263, 114504. [CrossRef]
58. Prouty, C.; Mohebbi, S.; Zhang, Q. Extreme weather events and wastewater infrastructure: A system dynamics model of a multi-level, socio-technical transition. Sci. Total Environ. 2020, 714, 136685. [CrossRef]

59. Shoukourian, H.; Kranzlmueller, D. Forecasting power-efficiency related key performance indicators for modern data centers using LSTMs. Future Gener. Comput. Syst. 2020, 112, 362–382. [CrossRef]

60. Niles, M.T. Majority of Rural Residents Compost Food Waste: Policy and Waste Management Implications for Rural Regions, Front. Sustain. Food Syst. 2020, 3, 123. [CrossRef]

61. Salem, M.; Raab, K.; Wagner, R. Solid waste management: The disposal behavior of poor people living in Gaza Strip refugee camps. Resources Conserv. Recycl. 2020, 153, 104550. [CrossRef]

62. Allen, P.; Butans, E.; Robinson, M.; Varga, L. Sustainability from household and infrastructure innovations. Sustain. Sci. 2020, 15, 1753–1766. [CrossRef]

63. Ma, Y.; Wang, H.; Kong, R. The effect of policy instruments on rural households’ solid waste separation behavior and the mediation of perceived value using SEM. Environ. Sci. Polit. Res. 2020, 27, 19398–19409. [CrossRef]

64. Degenstein, L.M.; McQueen, R.H.; Krogman, N.T. ‘What goes where?’ Characterizing Edmonton’s municipal clothing waste stream and consumer clothing disposal. J. Clean. Prod. 2021, 296, 126516. [CrossRef]

65. Sidhu, N.; Pons-Butazzo, A.; Muñoz, A.; Terredo-Saez, F. A Collaborative Application for Assisting the Management of Household Plastic Waste through Smart Bins: A Case of Study in the Philippines. Sensors 2021, 21, 4534. [CrossRef]

66. Deng, H.; Navarre-Stitchler, A.; Heil, E.; Peters, C. Addressing Water and Energy Challenges with Reactive Transport Modeling. Environ. Eng. Sci. 2021, 38, 109–114. [CrossRef]

67. Khan, A.-N.; Iqbal, N.; Rizwan, A.; Ahmad, R.; Kim, D.-H. An Ensemble Energy Consumption Forecasting Model Based on Spatial-Temporal Clustering Analysis in Residential Buildings. Energies 2021, 14, 3020. [CrossRef]

68. Babbitt, C.W.; Babbitt, G.A.; Oehman, J.M. Behavioral impacts on residential food provisioning, use, and waste during the COVID-19 pandemic. Sustain. Prod. Consum. 2021, 28, 315–325. [CrossRef]

69. Karadagli, F.; Theofanidis, F.; Eren, B. Consumers’ evaluation of flushable products with respect to post-disposal effects in wastewater infrastructures. J. Clean. Prod. 2021, 128, 123680. [CrossRef]

70. Schmitt, V.; Cequea, M.; Neyra, J.V.; Ferasso, M. Consumption Behavior and Residential Food Waste during the COVID-19 Pandemic Outbreak in Brazil. Sustainability 2021, 13, 3702. [CrossRef]

71. Zhang, S.; Hu, D.; Lin, T.; Li, W.; Zhao, R.; Yang, H.; Pei, Y.; Jiang, L. Determinants affecting residents’ waste classification intention and behavior: A study based on TPB and A-B-C methodology. J. Environ. Manag. 2021, 290, 112591. [CrossRef]

72. Esmat, H.; Mahnaz, S.; Janani, I.; Farzadkia, M. Determinants of Sustainability in Recycling of Municipal Solid Waste: Application of Community-Based Social Marketing (CBMS). Chall. Sustain. 2021, 9, 16–27.

73. Massoud, M.; Lameh, G.; Bardus, M.; Alameddine, I. Determinants of Waste Management Practices and Willingness to Pay for Improving Waste Services in a Low-Middle Income Country. Environ. Manag. 2021, 68, 198–209. [CrossRef]

74. Zheng, B.; Wan, S.; Wen, J.; Ye, L.; Lv, K. Do Public Awareness and Behaviors in Rural Domestic Waste Classification Help Reduce COVID-19? A Case Study in China. Pol. J. Environ. Stud. 2021, 30, 3897–3906. [CrossRef]

75. Končar, J.; Marić, R.; Vukmirović, G.; Vučenović, S. Exploring Pro-Environmental Behaviour in FMCG Supply Chain. Teh. Vjesn. 2021, 28, 2060–2071.

76. Peng, H.; Shen, N.; Ying, H.; Wang, Q. Factor analysis and policy simulation of domestic waste classification behavior based on a multiagent study—Taking Shanghai’s garbage classification as an example. Environ. Impact Assess. Rev. 2021, 89, 106598. [CrossRef]

77. Burton, J.; Patel, D.; Landry, G. Failure of the “Gold Standard”: The Role of a Mixed Methods Research Toolkit and Human-Centered Design in Transformative WASH. Environ. Health Insights 2021, 15, 1–4. [CrossRef] [PubMed]

78. Mensah, J. Fisherkfolk’s Perception of and Attitude to Solid Waste Disposal: Implications for Health, Aquatic Resources, and Sustainable Development. J. Environ. Public Health 2021, 2021, 8853669. [CrossRef]

79. Dan, M.B.; Bostenaru-Dan, M. Greening the Brownfields of Thermal Power Plants in Rural Areas, an Example from Romania, Set in the Context of Developments in the Industrialized Country of Germany. Sustainabilities 2021, 13, 3800.

80. Chen, C.-C.; Sujanto, R.; Tseng, M.-L.; Chiu, A.; Lim, M. How Is the Sustainable Consumption Intention Model in Food Industry Under Preference Uncertainties? The Consumer Willingness to Pay on Recycled Packaging Material. Sustainability 2021, 13, 11578. [CrossRef]

81. Khaheh, S.; Kumar, D.; Siddiqui, F.; Ali, T.; Raza, M.; Khoso, A. Optimizing Energy Use, Cost and Carbon Emission through Building Information Modelling and a Sustainability Approach: A Case-Study of a Hospital Building. Sustainability 2021, 13, 3675. [CrossRef]

82. Ali, S.A.; Kawaf, I.; Masadeh, I.; Saffarini, Z.; Abdullah, R.; Barqawi, H. Predictors of recycling behavior: A survey-based study in the city of Sharjah, United Arab Emirates. J. Health Res. 2021, 1–9.

83. Okoro, C.S.; Musonda, I.; Agumba, J. Identifying Barriers to Urban Residential Infrastructure Development: A Literature Review. In Proceedings of the International Conference on Infrastructure Development in Africa, Yogyakarta, Indonesia, 10–12 July 2016.

84. Loiko, V.; Teremetskiy, V.; Mallar, S.; Rudenko, V. Critical infrastructure of the housing sector of the national economy: Economic and legal aspect. Amazon. Investig. 2021, 10, 278–287. [CrossRef]