

SMART CONSTRUCTION TECHNOLOGIES APPLICATION TO IMPROVE HEALTH AND SAFETY IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY: A SYSTEMATIC REVIEW

Ayodeji Olatunji Aiyetan¹, Nathaniel Ayinde Olatunde², Bavelile Myeza³ and Babajide Bohan⁴

¹⁻⁴Construction Management and Quantity Surveying Department, Durban University of Technology, South Africa

DOI: 10.36108/cbpm/2026.0106

Abstract

Purpose: The South African construction industry continues to experience persistent health and safety challenges despite regulatory frameworks. This study systematically reviews the application of smart construction technologies and their potential to improve occupational health and safety outcomes within the South African construction context.

Design/Methodology/approach: A qualitative systematic literature review guided by the PRISMA framework was adopted. Peer-reviewed journal articles, conference papers, and industry reports published between 2015 and 2025 were sourced from Scopus, Web of Science, and SA ePublication databases. A total of 113 eligible studies were analysed using thematic analysis.

Findings: The findings reveal that smart construction technologies—including IoT devices, wearable sensors, BIM, drones, and automated systems—significantly enhance real-time hazard detection, worker monitoring, emergency response, and safety management. However, adoption remains limited due to high initial costs, inadequate technical skills, resistance to change, insufficient infrastructure, and weak regulatory support.

Practical implications: The study highlights the need for targeted training programmes, supportive government policies, and strategic investment to encourage widespread adoption of smart safety technologies across the South African construction industry.

Research Limitations and Implications: The review relies solely on secondary data and reports findings for only one research objective due to space limitations. Future empirical studies are recommended to validate these findings within live construction projects.

Keywords: Construction industry, health and safety, smart construction technologies, South Africa

1. Introduction

The global economy depends heavily on the construction sector, which propels growth and permits the development of infrastructure. However, it is mostly a dangerous field, with a high frequency of serious occurrences and a steady high incidence rate (Hinze, Thurman and Wehle, 2013). There are more than 60,000 construction workers killed worldwide each year, with roughly eight deaths occurring in South Africa's construction sector each month. Occupational health and safety deficiencies, together with problems like inadequate training and noncompliance with rules, are the primary cause of the tragic incidents (Department of Labour 2024). (Zhou, Irizarry and Li, 2013) and (Okpala, Nnaji and Karakhan 2020) argue that safety will continue to exist in the construction industry unless radical mitigations are implemented. It is therefore crucial to establish effective safety management systems and to innovate ways of mitigating risks, thus ensuring workers' safety, and promoting sustainable practices. The Architecture, Engineering and Construction (AEC) industry is still relying on conventional methods for overseeing health

and safety, and this is a huge challenge as manual observation and inspection can be tough since it is difficult to observe the whole construction place and all employees at once (Gao et al. 2022; Guo, Zou and Chen 2018).

Traditional ways of ensuring safety have relied on the vigilance, intuition, and knowledge of the safety manager. Likewise, traditional safety training programs have multiple shortcomings that make them ineffective (Akinradewo, Aigbavboa and Oke, 2020). Most of the time construction workers rely on their experience to identify and respond to safety risks. Hence, a significant challenge for workers is to identify and react when they encounter potential dangers and risks that are hard to anticipate, as these threats are hard to manage and can undermine an effectively structured safety programme (Afzal, Shafiq and Jassmi 2021). Due to the urgent necessity to enhance working conditions and safety outcomes, numerous researchers have investigated the application of technologies in contemporary construction to impact safety on construction sites (Okpala, Nnaji and Karakhan 2020). Currently, a diverse arrangement of safety technologies

¹ Corresponding Author

Email address: ayodejia@dut.ac.za

is available for implementation at construction sites (Teizer, Cheng and Fang, 2013). Existing research has indicated that the adoption of various safety technologies during the construction phase yields considerable benefits. Specifically, monitoring systems, alerts systems, and computer vision technologies have proven its effectiveness in enhancing safety through the delivery of prompt information and notifications about potential dangers (Wang and Razavi, 2016; Son *et al.*, 2019).

This study investigates innovative technology to enhance conventional safety management procedures to reduce some of the issues regarding construction safety. Modern safety methods entail the use of technologies like wearable technology, drones, the Internet of Things (IoT), and big data analytics (Fang *et al.*, 2018). According to existing research, implementing creative solutions can lower workplace accidents and enhance worker safety. However, the adoption of smart construction technologies in South Africa is still limited (Yap *et al.* 2022b). This study will fill the knowledge gap that exists in construction safety field by examining smart construction technologies application to South African Construction to enhance safety. The outcome of this research will improve knowledge capacity and skills of construction professionals on how technology can be applied in different tasks to keep construction sites safe. This research will also show how new technologies are changing and shaping the future of safety within the construction field.

2. Research Methodology

Research methodology refers to the procedures and strategies adopted to conduct a study and achieve its objectives (Kumar, 2019). This study adopted a qualitative research approach because it relied on a

desktop-based systematic literature review (SLR) to examine the application of smart construction technologies for improving health and safety in the South African construction industry. Qualitative research enables the exploration of experiences, meanings, and contextual interpretations presented in existing literature (Busetto, Wick and Gumbinger, 2020; Bryman, 2016). Creswell and Creswell (2018) further noted that qualitative approaches allow researchers to capture contextual influences and nuanced perspectives that cannot easily be quantified.

A systematic literature review was employed as the primary methodological framework because it provides a structured and transparent process for synthesising evidence while minimising bias (Haddaway *et al.*, 2022). Unlike traditional literature reviews, SLRs follow clear and replicable procedures for identifying, screening, and synthesising studies, thereby improving research rigour and reliability (Oke, Aghimien and Aigbavboa, 2021). Kahale *et al.* (2022) also emphasised that systematic reviews enhance credibility through the consistent application of inclusion and exclusion criteria. To ensure transparency and fairness, the review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework during the identification, screening, eligibility, and inclusion stages (Haddaway *et al.*, 2022). Studies were selected based on predefined criteria, including relevance to the research objectives, publication date, and academic credibility. The review focused on literature published between 2015 and 2025 to ensure contemporary and relevant findings (Figure 1).

Data were collected from secondary sources, including peer-reviewed journal articles, conference proceedings, editorials, books, websites, online repositories, and professional publications (Afzal, Shafiq and Al Jassmi,

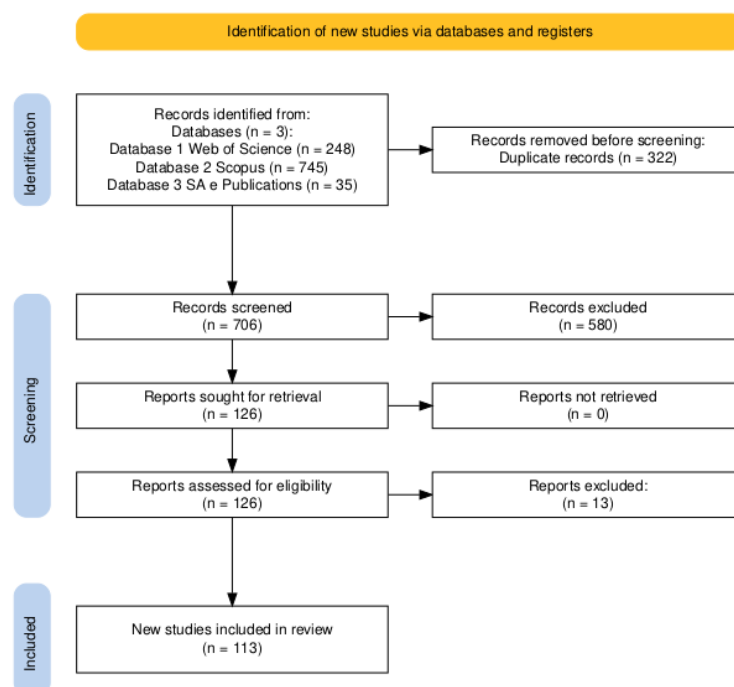


Figure 1: PRISMA flow for article selection

2021). Searches were conducted across databases such as Scopus, Web of Science, and SA ePublication using keywords including “smart construction,” “construction 4.0,” “digital safety management,” “digital construction,” “construction technology,” “construction innovation,” “safety,” “health,” “occupational health and safety,” and “OHS.” The initial search identified 1,028 studies. After removing 322 duplicate records, 706 articles remained for screening. Titles and abstracts were reviewed to assess relevance to the study objectives, particularly factors influencing the application of innovative construction technologies for safety improvement, the effects of non-application, and mitigation strategies. Consequently, 580 articles were excluded for lacking sufficient focus on smart construction technologies and safety improvement. The remaining 126 articles underwent further eligibility assessment through detailed abstract and topic evaluation. Full-text reviews were subsequently conducted to ensure relevance, resulting in a final sample of 113 articles for thematic analysis. The collected qualitative data were analysed using thematic analysis techniques to identify recurring themes, patterns, and insights related to smart construction technologies and occupational health and safety practices in the construction industry.

3. Results

The Table 1 shows the analysis of database sources used for the study. The results indicate that the literature reviewed came from different sources, 13% percent of the literature was published in conference papers and written by researchers from various countries. The conference papers have produced numerous reports detailing the benefits of smart

technologies, their efficiency and sustainability in the construction industry. The conference papers also indicate the positive impact of smart construction technology application to improve safety in South Africa. A further 12% of the literature came from MDPI Buildings journals. These sources provided valuable data on the regulatory and economic frameworks governing smart construction technologies in South Africa, particularly emphasizing the role of government policies, education, and encouraging sustainable building practices. 59% of the sources came from Professional engineering bodies, policy organizations, such as the Engineering, Construction, and Architectural Management Society, the Automation in Construction, and Construction. The process entailed using Smart construction to identify, analyse, and report patterns or themes in the data, carefully selecting those that relate to the research questions and overall theoretical framework.

The remaining 16% of the literature was derived from institutions such as the Journal of Building Engineering, Construction Economics and Building, Journal of Scientific Research and Reports, International Journal of Building, Journal of Materials Engineering, Structures and Computation, Journal of the Institution of Engineers (India) Series A. These institutions contributed critical peer-reviewed studies on the long-term economic effects of sustainable smart construction technology in improving the health and safety in the construction industry in South Africa. From the total of 113 publications that contributed to the accomplishment of the three main objectives of the main study. Of these, 48% contributed to the first objective, which was to examine the factors causing lack of smart construction technologies applications in

Table 1: Frequency of selected paper from the database used in this study

No	Publishers	No of Articles
1	Conference Paper	15
2	MDP I(Buildings)	14
3	Engineering, Construction and Architectural Management	9
4	Automation in Construction	5
5	Journal of Science Safety	3
6	Journal of construction engineering and management	3
7	Journal of Building Engineering	3
8	International Journal of Construction Management	3
9	Journal of smart and sustainable Built Environment	2
10	MDPI (Engineering Proceedings)	2
11	International Journal of Building Pathology and adaption	2
12	Journal of Civil Engineering and Management	2
13	Journal of engineering, project and production management	2
14	University of Johannesburg	2
15	Malaysian Construction Research Journal	2
16	Computers in the industry	2
17	Journal Frontiers in Built Environment	2
18	Others	1 each
19	TOTAL	113

improving health and safety in the South African construction industry. Additionally, 25% contributed to the second objective, which was to identify the effects of non-application of smart construction technologies to improve health and safety in the South African construction industry 27% contributed to the third objective, which was to determine the available mitigating strategies of smart construction technologies in the construction industry to improve health and safety in the South African construction industry. However, due to constraint of space only the findings on the first objective were reported in this article.

A primary finding of the review is that the adoption of smart construction technologies in South Africa's construction industry is progressing slowly and unevenly across all nine of its provinces. Although international studies report significant improvements in safety and productivity through these technologies, local research identifies challenges related to organisational structures, financial constraints, and regulatory frameworks that hinder implementation. The most prevalent barriers include high initial investment costs, a shortage of skilled labour, resistance to change among stakeholders, inadequate infrastructure, and the absence or ambiguity of relevant regulations and policies. The researchers discovered that the lack of application of smart construction technologies to improve health and safety on construction sites is caused by multiple interrelated factors. High initial costs make it difficult for companies to invest in new technologies. Additionally, the absence of government

legislation and commitment during the procurement process limits formal encouragement and mandate for technology use. A lack of technical training further hinders workers' ability to effectively utilize these innovations (Oke, Aghimien and Aigbavboa, 2021).

This finding is confirmed by Yap *et al.* (2022a) who confirms that concerns about data security and cybersecurity, along with a lack of top management and leadership support, reduce confidence in adopting these tools. Smart technologies often suffer compatibility issues with existing procedures, and poor cooperation among built environment professionals obstructs integrated implementation. Moreover, a lack of practical strategies, industry complexity, low digital literacy among some professionals, and limited access to suitable technology and frameworks contribute to slow adoption. Uncertainty about technological outcomes, unclear profit benefits, and environmental factors such as poor weather conditions further diminish enthusiasm. Other challenges include poor data quality, reliability, insufficient awareness, weak inter-organisational integration, lack of vendor support, contractors' limited knowledge, and individual attitudes. Collectively, these factors create significant obstacles to the widespread use of smart construction technologies for health and safety improvements on construction sites.

Figure 2 indicates the percentage contribution of the factors affecting the non-application of smart construction technologies to improve health and safety

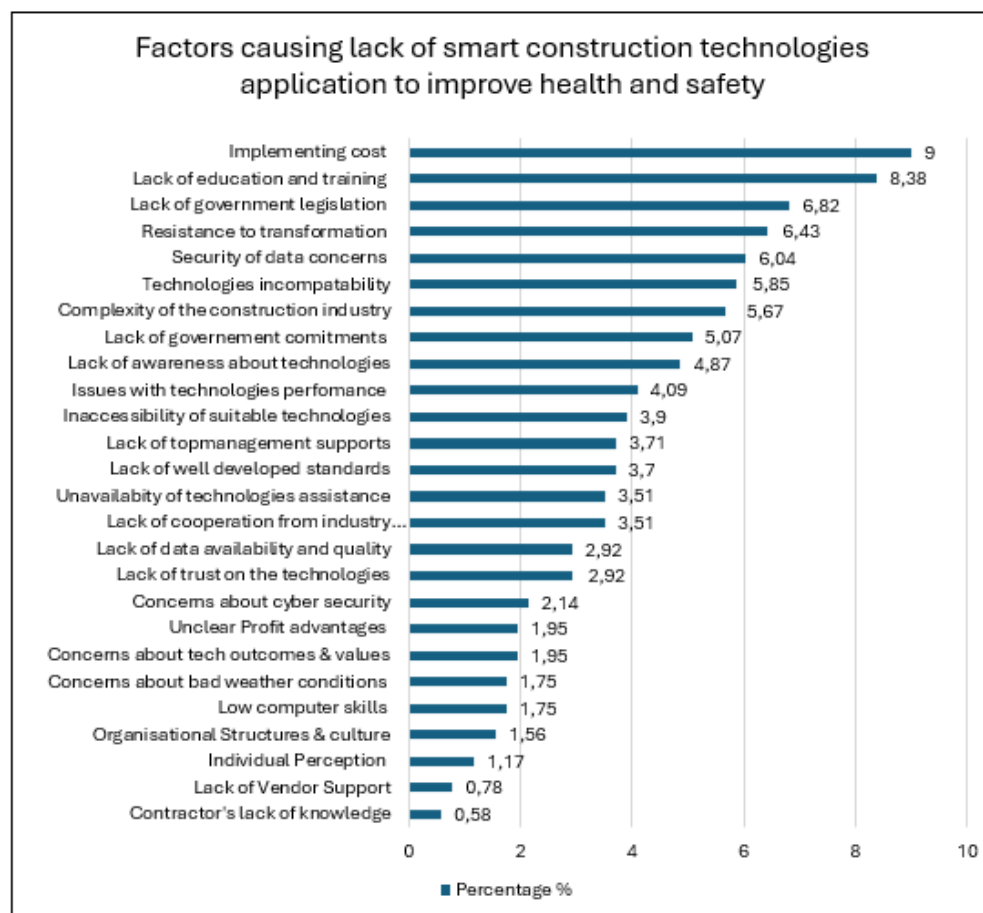


Figure 2: Lack of smart construction technologies application

in the South African construction industry. These range from high implementation cost to purchase the technologies being the most frequently mentioned, making 9 % of the total in different papers. These is also confirmed by Okpala, Nnaji and Karakhan 2020; Malomane, Musonda and Okoro (2022) who also have high initial cost as their top factor causing lack of smart technologies, lack of education and training is the second most common factor accounting to 8.38 % as confirmed by Okpala, Nnaji and Karakhan 2020 who has need for training ranked No.2 , followed by lack of government legislation contributing 6.82%, Resistance to transformation at 6.43%, the security of data concerns accounts for 6.04%, technology incompatibility accounts for 5.85%, the complexity of the construction industry accounts for 5.67%, lack of government commitment is 5.07%, lack of awareness accrued to 4.87%, then there is concerns about the technologies performance contributing 4.09%, inaccessibility of suitable technologies at 3.90%, lack of top management supports at 3.71%, lack of well d developed standards at 3.70%, unavailability of technology assistance at 3.51%, lack of cooperation on built professions at 3.51%, lack of data availability at 2.92%, lack of trust on the technologies at 2.92%, concerns about cyber security at 2.14%, unclear profits at 1.95%, Concerns about technologies outcome and values at 1.95%, concerns about bad weather conditions at 1.75%, low computer skills at 1.75%, organisational structure at 1.56%, individual perception at 1.17%, lack of vendor supports at 0.78% and the least mentioned factor is contractor's lack of knowledge indicating that while these are recognised, they have less frequency as compared to others which make that the least contributory factors.

4. Conclusion

This study examined the application of smart construction technologies for improving health and safety in the South African construction industry through a systematic literature review. The findings demonstrate that smart technologies have considerable

potential to address long-standing safety challenges by enabling proactive hazard identification, continuous worker monitoring, and enhanced safety decision-making. International evidence consistently shows improvements in safety performance and productivity; however, South Africa continues to experience slow and uneven adoption across its provinces.

The review identified high implementation costs, skills shortages, weak regulatory enforcement, resistance to change, and poor technological infrastructure as the most critical barriers to adoption. These challenges are interrelated and collectively undermine efforts to modernise safety management practices. The persistence of traditional, manual safety approaches further limits the industry's capacity to leverage digital innovations effectively. Despite these challenges, the study confirms that smart construction technologies represent a viable pathway for improving occupational health and safety outcomes. Their integration can significantly reduce accidents, enhance compliance, and promote sustainable construction practices. By consolidating existing knowledge, this study contributes to the growing body of literature on construction digitalisation and safety management in developing economies. Based on the findings, the study recommends that government agencies strengthen regulatory frameworks and embed smart technology requirements within procurement and safety policies. Construction firms should prioritise investment in digital infrastructure and continuous professional training to enhance technological competence among workers and managers. Industry stakeholders should also foster collaboration between professionals, technology vendors, and academic institutions to improve awareness, interoperability, and innovation. Future research should adopt empirical methods, such as case studies and field experiments, to assess the real-time effectiveness, cost-benefit implications, and contextual adaptability of smart construction technologies in South African construction projects

Reference

- Afzal, M., Shafiq, M.T. and Al Jassmi, H. (2021) 'Mitigating safety risks in construction using emerging technologies', *Safety Science*, 144, p. 105118. <https://doi.org/10.1016/j.ssci.2021.105118>.
- Ahmad, T., Thaheem, M.J., Anwar, A. and Ullah, F. (2019) 'BIM-based risk management in construction projects', *Journal of Engineering, Design and Technology*, 17(4), pp. 812–829. <https://doi.org/10.1108/JEDT-09-2018-0157>.
- Akinradewo, O., Aigbavboa, C. and Oke, A. (2020) 'Digital technology adoption and construction safety improvement', *International Journal of Construction Management*, 20(7), pp. 617–625. <https://doi.org/10.1080/15623599.2018.1484516>.
- Bryman, A. (2016) *Social research methods*. 5th edn. Oxford: Oxford University Press.
- Busetto, L., Wick, W. and Gumbinger, C. (2020) 'How to use and assess qualitative research methods', *Neurological Research and Practice*, 2(1), p. 14. <https://doi.org/10.1186/s42466-020-00059-z>.

- Creswell, J.W. and Creswell, J.D. (2018) Research design: Qualitative, quantitative, and mixed methods approaches. 5th edn. Thousand Oaks, CA: Sage Publications.
- Department of Labour (2024) *Annual construction safety report*. Pretoria: Department of Labour.
- Fang, Q., Li, H., Luo, X., Ding, L., Luo, H., Rose, T.M. and An, W. (2018) ‘Detecting non-hardhat-use by a deep learning method from far-field surveillance videos’, *Automation in Construction*, 85, pp. 1–9. <https://doi.org/10.1016/j.autcon.2017.09.018>.
- Gao, Y., Li, X., Luo, X. and Zhang, L. (2022) ‘Computer vision-based safety monitoring on construction sites’, *Automation in Construction*, 140, p. 104317. <https://doi.org/10.1016/j.autcon.2022.104317>.
- Guo, H., Zou, Y. and Chen, X. (2018) ‘Safety risk identification using building information modelling’, *Journal of Construction Engineering and Management*, 144(1), p. 04017100. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0001409](https://doi.org/10.1061/(ASCE)CO.1943-7862.0001409).
- Haddaway, N.R., Page, M.J., Pritchard, C.C. and McGuinness, L.A. (2022) ‘PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews’, *BMJ*, 372, n160. <https://doi.org/10.1136/bmj.n160>.
- Hinze, J., Thurman, S. and Wehle, A. (2013) ‘Leading indicators of construction safety performance’, *Safety Science*, 51(1), pp. 23–28. <https://doi.org/10.1016/j.ssci.2012.05.016>.
- Kahale, L.A., Schünemann, H.J. and Akl, E.A. (2022) ‘Guidelines for systematic review methodology’, *Systematic Reviews*, 11(1), p. 191. <https://doi.org/10.1186/s13643-022-02018-1>.
- Kumar, R. (2019) Research methodology: A step-by-step guide for beginners. 5th edn. London: Sage Publications.
- Malomane, T., Musonda, I. and Okoro, C. (2022) ‘Barriers to smart technology adoption in construction’, *Journal of Smart and Sustainable Built Environment*, 11(4), pp. 657–673. <https://doi.org/10.1108/JSSBE-04-2021-0065>.
- Merriam, S.B. and Tisdell, E.J. (2025) *Qualitative research: A guide to design and implementation*. 5th edn. San Francisco: Jossey-Bass.
- Oke, A.E., Aghimien, D.O. and Aigbavboa, C.O. (2021) ‘Drivers of smart construction technology adoption in the construction industry’, *Journal of Engineering, Design and Technology*, 19(6), pp. 1401–1417. <https://doi.org/10.1108/JEDT-07-2020-0289>.
- Okpala, I., Nnaji, C. and Karakhan, A. (2020) ‘Utilising emerging technologies for construction safety improvement’, *Safety Science*, 128, p. 104115. <https://doi.org/10.1016/j.ssci.2020.104115>.
- Son, H., Kim, C. and Hwang, N. (2019) ‘A review of construction safety monitoring using sensing technologies’, *Automation in Construction*, 98, pp. 158–169. <https://doi.org/10.1016/j.autcon.2018.11.015>.
- Teizer, J., Cheng, T. and Fang, Y. (2013) ‘Location tracking and data visualization technology to advance construction ironworkers’ education and training in safety and productivity’, *Automation in Construction*, 35, pp. 53–68. <https://doi.org/10.1016/j.autcon.2013.03.004>.
- Wang, J. and Razavi, S. (2016) ‘Low-power sensing technologies for construction safety monitoring’, *Automation in Construction*, 64, pp. 93–103. <https://doi.org/10.1016/j.autcon.2015.12.007>.
- Yap, J.B.H., Lee, Y.C., Skitmore, M. and Ling, F.Y.Y. (2022a) ‘Barriers to digital technology adoption in construction projects’, *Engineering, Construction and Architectural Management*, 29(2), pp. 678–699. <https://doi.org/10.1108/ECAM-12-2020-1049>.
- Yap, J.B.H., Lee, Y.C., Skitmore, M. and Ling, F.Y.Y. (2022b) ‘Drivers and barriers of digital construction adoption’, *Engineering, Construction and Architectural Management*, 29(8), pp. 3175–3195. <https://doi.org/10.1108/ECAM-07-2021-0661>.
- Zhou, Z., Irizarry, J. and Li, Q. (2013) ‘Applying advanced technology to improve safety management in the construction industry: A literature review’, *Construction Management and Economics*, 31(6), pp. 606–622. <https://doi.org/10.1080/01446193.2013.780662>.