The relationship between eco-innovation and sustainability in the construction industry: Exploring knowledge networks from the perspective of ANT

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Abstract. Growing awareness of the benefits of the green movement and rapidly increasing sustainable-oriented practices in the construction industry have point academicians and professionals out to eco-innovation and its application in building projects. Research interests in addressing the issues related to innovation have resulted in a great number of publications over the last two decades. Knowledge is considered as a vital ingredient in innovation. Hence, the problem addressed in this study is how knowledge networks having a heterogeneous body must be effectually managed in the firms for achieving the desired success in eco-innovation. In that context, the study attempts to indicate the relationship between the eco-innovations and sustainable construction practices and to explore knowledge networks. In the paper, firstly theoretical background related to eco-innovation is presented as a starting point of the study. Based on insights from the related literature, the determinants of eco-innovation are also detected to better understand the dynamic nature of the knowledge networks. Following that, as a research approach in the study, Actor-Network Theory (ANT) is used. To that end, in this paper, a case study is conducted for three firms that come to the forefront with their innovative activities in the construction industry in order to gain insights into the factors affecting their success in eco-innovation. The findings of this study point out that eco-innovation has positive impacts on sustainability solutions for buildings and also knowledge exchange and knowledge linkages can be seen as key issues in the field of eco-innovation towards the construction industry.

1. Introduction

Evaluations on climate change and energy consumption show that although it has been taken an important step with the existing measures, sustainability practices are not sufficient [1, 2]. In this context, according to the developed scenarios, it is expected to achieve at least an 80% reduction in energy consumption and greenhouse gas emissions by 2050 [3, 4]. This situation has shifted industries' attention to developments in the field of innovation in order to overcome challenging environmental goals [1, 5, and 6]. But, the rate of realization and deployment of eco-innovation and advanced technology in the construction industry is poor compared to other industrial areas. In fact, this clearly demonstrates that the construction industry has difficulty in the field of eco-innovation. From this perspective, the sustainability goals in building projects require the construction industry to succeed more in eco-innovation oriented solutions.
In the SmartMarket report [7], titled World Green Building Trends, published by McGraw-Hill Construction in March 2013, it is emphasized that the innovation-oriented efforts of companies operating in the green building industry will increase rapidly. It is also stated in the report that new knowledge, demand factors, and environmental regulations are the main determinants of innovation to be realized in the context of sustainability. In addition, it is pointed out that the firms will have high growth potential in the global competitive market in the field of environmentally friendly energy-efficient innovations in the forthcoming years.

In the Green Market research reports published by BCC Research [8] and Navigant Research [9], as well as Reuters' news [10] on the developments in the global green market, it is stated that innovation-oriented activities, particularly of smart building materials manufacturers, play a major role in influencing the dynamism of innovation in the sustainability of the construction industry.

These abovementioned reports indicate that firms' eco-innovation achievements have an important potential not only in increasing their competitiveness in the global green market but also in achieving the sustainability targets in the construction sector.

In fact, the concept of innovation has been primarily associated with economic problems, but environmental and social pressures have encouraged the rethinking of innovations in the context of sustainability. Increasingly tighter economic competition and environmental degradation have motivated organizations to go beyond a traditional approach that focuses on solutions that are often linked to market developments [11].

As innovations are seen as a tool for this kind of transition, this study aims to frame the discussion of eco-innovation, knowledge networks, and sustainability by addressing the problem of effectually achieving the sustainability goals in buildings from the vision of eco-innovation.

The remainder of this study is organized as follows: In Section 2, the theoretical background is presented. Section 3 explains the research methodology. The main results and discussions are given in Section 4. Finally, Section 5 outlines the main conclusions and recommendations for future research.

2. Theoretical background
Many efforts towards innovation in the field of sustainability seek to better define eco-innovation and better integrate it into sustainability-oriented solutions. However, integrating sustainability in the environmental, economic and social dimensions into innovations is not an easy task [11, 12, and 13]. Therefore, in this part of the study, the definition of eco-innovation, the determinants of eco-innovation, and the effect of eco-innovations on sustainability in buildings are presented the following paragraphs.

2.1. Definition of Eco-innovation: Terms and concepts
In the literature, eco-innovation is often used as a synonym for environmental innovation in connection with concepts such as sustainable innovation, green innovation, low-carbon innovation, environmental technology, eco-efficiency, eco-efficient innovation. These terms have been generally used interchangeably by scientific communities. The term eco-innovation has been mostly preferred by scholars [14, 15].

Although the term eco-innovation has been widely used over the last two decades, the number of definitions in the academic literature is limited. Some prominent definitions of eco-innovation in the related literature are given in Table 1 in order to see how it has been identified by scientific communities and to gain a better understanding of its distinctive feature.

Given all of these definitions in Table 1, the major goal of eco-innovation is very clear: the reduction of environmental impacts. Insights from the sustainability literature on innovation suggest that any innovation should boost the performance of sustainability including environmental, economic, and social value. Therefore, eco-innovation is seen as one of the crucial issues at the center of sustainable development [6, 16 - 21].
Table 1. Eco-innovation definitions and its distinctive feature highlighted in the definitions

| Source | Definition of Eco-innovation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | The distinctive feature                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| [18, p.7] | “Eco-Innovation means the creation of novel and competitively priced goods, processes, systems, services, and procedures that can satisfy human needs and bring quality of life to all people with a life-cycle-wide minimal use of natural resources (material including energy carriers, and surface area) per unit output, and a minimal release of toxic substances”                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| [20, p. 567] | “…environmental innovations can be defined as innovations that consist of new or modified processes, practices, systems and products which benefit the environment and so contribute to environmental sustainability”                                                                                                                                                                                                                                                                                                                                                                             | The reduction in environmental impacts                                                                                                                                                                                                                                                                                                                                                                                                           |
| [22] cited from [23, p.911] | “New products and processes which provide customer and business value but significantly decrease environmental impacts”                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| [24, p. 332] | “green innovation as hardware or software innovation that is related to green products or processes, including the innovation in technologies that are involved in energy-saving, pollution-prevention, waste recycling, green product designs, or corporate environmental management”                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| [25, p. 9] | “Sustainable innovation is a process where sustainability considerations (environmental, social, financial) are integrated into company systems from idea generation through to research and development (R&D) and commercialisation. This applies to products, services and technologies, as well as new business and organisation models”                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| [26, p. 7] | “Eco-innovation is the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives”                                                                                                                                                                                                 | The reduction in environmental impacts                                                                                                                                                                                                                                                                                                                                                                                                           |
| [27] | “Eco-innovation is any form of innovation aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment or achieving a more efficient and responsible use of natural resources, including energy”                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| [28, p. 11] | “eco-innovation is the production, assimilation or exploitation of a novelty in products, production processes, services or in management and business methods, which aims, throughout its lifecycle, to prevent or substantially reduce environmental risk, pollution and other negative impacts of resource use (including energy)”                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| [29, p. 15] | “Eco-innovation can be generally defined as innovation that results in a reduction of environmental impact, no matter whether or not that effect is intended”                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| [30, p. 34] cited from [31, p. 29] | “It is about innovations with lower environmental impact than relevant alter-natives. The innovations may be technological or non-technological (organizational, institutional or marketing-based). Eco-innovations can be motivated by economic or environmental considerations. The former includes objectives to reduce resource, pollution control, or waste management costs or to sell into the world market for eco-products”                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| [32, p. 5] | “Eco-innovation … is defined as innovations which are able to attract green rents on the market. … the concept is closely related to competitiveness and makes no claim on the greenness of various innovations”                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| [33, p. 1075] | “Eco-innovation is defined … as an innovation that improves environmental performance…, in line with the idea that the reduction in environmental impacts (whether intentional or not) is the main distinguishing feature of eco-innovation”                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
2.2. Determinants of eco-innovation

Sustainability of buildings is a critical and growing concern in the construction industry. In parallel with the increase in sustainable building practices, eco-innovation oriented solutions are progressively gaining more attention from both scholars and practitioners [34]. As shown in Table 2, key determinants of eco-innovation can be identified at the macro, meso, and micro levels for better understanding the interaction in knowledge networks.

Table 2. Key determinants of eco-innovation

| Level                     | Determinants of eco-innovation                              | Source          |
|---------------------------|-------------------------------------------------------------|-----------------|
| Macro level (National level) | Institutions                                               | [35 - 42]       |
|                           | Policy instruments                                          |                 |
|                           | Environmental policy                                        |                 |
|                           | Socio-economic changes                                      |                 |
|                           | The techno-economic paradigm                                |                 |
| Meso level (Sectoral level)| Market dynamics                                             | [36, 38, 40, 41, 43 - 52] |
|                           | Pressure groups                                             |                 |
|                           | Collaborators                                               |                 |
|                           | Knowledge Networks (including firms and institutions)       |                 |
|                           | Environmental regulations                                   |                 |
|                           | Demand factors                                              |                 |
| Micro level (Firm level)   | Environmental regulations and standards                     |                 |
|                           | Corporate social responsibility (CSR): “The societal pressure and demand for environmentally friendly products and processes” [63]. |                 |
|                           | Actor networks                                              | [36, 38, 40, 41, 50, 53 - 55] |
|                           | Collaboration with environmentally concerned stakeholders   |                 |
|                           | Socio-technical changes                                      |                 |
|                           | Managerial vision                                           |                 |
|                           | Organisational capabilities                                 |                 |
|                           | Technological capabilities                                  |                 |
|                           | Absorptive capacity                                          |                 |
|                           | Financial resources                                          |                 |

2.3. Overview of the effect of eco-innovation on sustainability in buildings

Increased awareness of environmental issues has changes priorities in the construction industry. Demands have been increasing for more environmentally friendly energy-efficient products, processes, and advanced construction technologies. One of the growing body of evidence of the effect of eco-innovations on sustainable construction practices is the implementation of innovative products that have environmentally sensitive, energy-efficient, lighter, transparent, self-cleaning surfaces in buildings [56]. Some examples of recently requested products in the sustainable building industry are energy-efficient oriented eco-innovative materials such as phase change material (PCM), electrochromic glasses, ETFE membrane, and building integrated photovoltaic (BIPV). The application of eco-innovative materials can significantly reduce the annual energy consumption and environmental impacts of buildings. In this context, it is noticed that the use of eco-innovations has rapidly increased particularly in green building applications since 2000. For example, in the Pearl River Tower, which was built in Guangzhou, China in 2012, it has been aimed to save approximately 60% energy in annual energy consumption by using BIPV, low-E glass, and micro-wind turbines [57]. Another example is the Media-Tic building, which was completed in 2011 in Barcelona, Spain: carbon emissions are reduced by about half with the effective use of the ETFE membrane [58]. A remarkable example of the effect of eco-innovations on sustainable architecture is the “SmartWrap” material created by Kieran&Timberlake Architecture, which is still in the prototype stage [59, 60]. As for construction technology, 3D printing on the construction scale is an innovative example of advances in automated construction technology [61, 62, and 63].
3. Research methodology

These abovementioned examples show that eco-innovations implemented in the building design and construction processes, building materials/elements, and building construction technologies have a very important part in providing sustainability in the construction industry. It is a fact that the success of the firms in the field of eco-innovation plays a significant role in the realization and implementation of eco-innovations considered as a potential solution for sustainable buildings.

There is still a large gap in our understanding of the success factors of the firms on eco-innovation. This study attempts to gain insights into how knowledge networks having a heterogeneous body must be effectually managed in the firms for achieving the desired success in eco-innovation. Actor Network Theory (ANT) is used as a research perspective in this study and a case study is conducted for three firms in order to find out their success factors in eco-innovation.

3.1. Actor Network Theory (ANT)

The actor network theory (ANT) focuses on the interactions in actor networks. One of the unique features of ANT is its symmetrical approach [64-66]: This involves the treatment in which all human and non-human actors can move around, translate and reconfigure new network entities. According to ANT, the main principles for those who want to improve their innovations are as follows [64-68]: enrolment, knowledge generation, and circulating translations. The first principle that registers actors is strongly related to a common issue in innovative initiatives: to involve relevant stakeholders in the innovation process from the start. ANT researches [68-75], which regard innovation as a translation process, point out that these principles can provide to continue innovation while being improved. ANT investigates and monitors knowledge linkages, knowledge exchange, and knowledge strategies in actor networks having a heterogeneous body including all human and non-human actors. It flattens all distinctions among entities (human and non-human actors) that set out networks. It can be seen how the new ideas and new knowledge are captured in knowledge networks, and then they can be reshaped with new actors.

4. Results and discussion

Within the scope of the case study, three firms that come to the forefront with their innovative activities in the construction industry are analysed. Detailed information provided by the firms on their websites, their annual activity reports and also the reports published by BCC Research and Navigant Research market research groups were used. General information on the eco-innovations created by the case firms is given in Table 3.

| Firm    | Eco-innovation produced by the firm | The feature of eco-innovation                                                                 |
|---------|-----------------------------------|-----------------------------------------------------------------------------------------------|
| Firm 1  | Phase change material (PCM)       | The firm has developed two products with PCM that can be applied in the building floors and facades. Both of them are heat-insulating material with heat storage capacity. |
| Firm 2  | Phase change material (PCM)       | It is used on the building facades. It can provide effective thermal insulation with its thermal mass formation feature. It is stated that it has the potential to significantly reduce the heating and cooling load in buildings. |
| Firm 3  | Electrochromic glass              | The electrochromic glass can change color electronically. It is stated that the electrochromic glass can reduce energy consumption in buildings. |

The findings obtained from all three cases conducted for three firms in order to gain insights into the factors affecting their success in eco-innovation are listed as follows:
### Case study 1: Firm 1
To adopt the principle of meeting customer needs at the highest level by focusing on sustainability principles.

To have an eco-innovation oriented collaborative working and communication network with universities and R&D institutions.

To have a strong communication network between all relevant parties inside and outside the firm for promoting the efficient use of knowledge resources and the emergence of new ideas.

To have human resources capable of following technological developments and creating new ideas.

Prioritizing continually learning in its organizational structure.

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### Case study 2: Firm 2
To meet customer expectations in the best and innovative way.

To apply quality and environmental management as a strategy tool in all its activities.

To ensure the effective use of knowledge linkages.

Prioritizing quality its products and services.

To ensure continuity in cooperation with R&D institutions and universities.

To have a strong communication network.

To have human resources capable of following technological developments and creating new ideas.

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### Case study 3: Firm 3
To focus on user requirements and reduce environmental impact of eco-innovative products.

Adopting a common problem-solving approach in creating eco-innovative products and services by ensuring effective cooperation with all interested parties such as business partners, architects, civil engineers, and contractors.

Prioritizing continually learning in its organizational structure.

To have human resources capable of following technological developments and creating new ideas.

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According to the findings listed above, the factors influencing the success of three firms in eco-innovation can be summarized as follows:

- Providing continuity in the cooperation with R&D institutions and universities.
- Using effectually the knowledge linkages and having a continual learning organization structure
- Supporting the emergence of new ideas by increasing knowledge exchange in their networks.
- Having organizational capabilities for capturing new knowledge and identifying demands of the green building market.
- Focusing on the reduction in environmental impacts and ensuring compliance with environmental regulations in their eco-innovations.
- Adopting the quality-oriented approach in the realization and diffusion of eco-innovation.
- Involving internal and external stakeholders in the eco-innovation process: promoting collaboration with all interested parties such as business partners, architects, and engineers.
- Informing customers and all stakeholders about their eco-innovative solutions.

The results show that two important issues come to the forefront: (1) stakeholder engagement in cooperation, and (2) the need for knowledge transformation. In fact, this is, as ANT says, a way of enrolling new actors and telling them what their interests are. It is inevitable for the firms to continuously and effectually develop their organizational structures in the process of the realization and diffusion of eco-innovation.

### 5. Conclusions and future work
Sustainability in the construction industry has been a prominent driving force for organizations to create their eco-innovation oriented knowledge networks. It is an interactive process that requires the firms to set out a knowledge network encompassing environmental regulations, policies, institutions and all relevant parties affecting their eco-innovation performance in the industry. In this context, knowledge exchange and knowledge linkages can be seen as crucial issues in the field of eco-innovation.

The participatory approach for eco-innovation oriented knowledge networks presented in this study is a baseline of a multi-level approach to allow an analysis of the complexity in the realization and diffusion of eco-innovations in the green building industry. The results of this study indicate that it needs to be made deeper analyses which adopt a multi-level approach including macro, meso, and micro levels for better understanding all determinants and dynamics of eco-innovation, and also knowledge exchange and knowledge linkages.
References

[1] EIO-Eco-Innovation Observatory 2011 Resource-efficient construction: The role of eco-innovation for the construction sector in Europe EIO Theme Report www.eio-innovation.eu
[2] IEA-International Energy Agency 2012 Progress Implementing the IEA 25 Energy Efficiency Policy Recommendations - 2011 Evaluation Paris France http://www.iea.org
[3] ECTP – European Construction Technology Platform 2012 Energy-efficient Buildings PPP beyond 2013 - Research & Innovation Roadmap http://www.ectp.org/cw/params/ectp/download_files/36f2263v1_E2B_Roadmap_Finadays_V.pdf
[4] IEA -International Energy Agency 2013 Energy Technology Perspectives, Technology Roadmap - Energy efficient building envelopes Paris France http://www.iea.org
[5] EIO-Eco-Innovation Observatory 2012 Eco-Innovation in Emerging Markets EIO Theme Report https://www.eio-innovation.eu/
[6] OECD 2012 The future of eco-innovation: The Role of Business Models in Green Transformation OECD Background Paper http://www.oecd.org/innovation/inno/49537036.pdf
[7] McGraw-Hill Construction 2013 World Green Building Trends Smart Market Report http://www.worldgbc.org/files/8613/6295/6420/WGBT_SmartMarket_Report_2013.pdf
[8] BCC Research http://www.bccresearch.com/market-research/advanced-materials
[9] Navigant Research http://www.navigantresearch.com/research/smart-buildings
[10] Reuters http://www.reuters.com/search?blob=leader+firms
[11] Gjoksi N 2011 Innovation and sustainable development: Linkages and perspectives for policies in Europe ESDN Quarterly Report
[12] Hines F and Marin O 2004 Building innovations for sustainability 11th international conference of the Greening of Industry Network Business strategy and the environment 13 (4) 201-208
[13] Ceschin F 2013 Critical factors for implementing and diffusing sustainable product-Service systems: insights from innovation studies and companies' experiences Journal of Cleaner Production 45 74-88
[14] Schiederig T, Tietze F and Herstatt C 2012 Green innovation in technology and innovation management—an exploratory literature review R&D & Innovation Management 10 (2) 180-192
[15] Franceschini S, Farina L G and Jurwotzki R. 2016 Unveiling scientific communities about sustainability and innovation. A bibliometric journey around sustainable terms Journal of Cleaner Production 127 72-83
[16] Hellström T 2007 Dimensions of environmentally sustainable innovation: the structure of eco-innovation concepts Sustainable Development 15 (3) 148-159
[17] Bossle M B, de Barcellos M D, Vieira L M and Sauvé L 2016 The drivers for adoption of eco-innovation Journal of Cleaner Production 113 861-872
[18] Reid A and Miedzinski M 2008 Eco-innovation-final report for Sectoral Innovation Watch. final report to Europe INNOVA initiative Technopolis Group https://www.researchgate.net/profile/Michal_Miedzinski/publication/301520793_Eco-Innovation_Final_Report_for_Sectoral_Innovation_Watch/links/006871592/301520793_Eco-Innovation_Final_Report_for_Sectoral_Innovation_Watch.pdf
[19] Rennings K 2000 Redefining eco-innovation research and the contribution from ecological economics Ecological economics 32 (2) 319-332
[20] Oltra V and Saint M J 2009 Sectoral systems of environmental innovation: an application to the French automotive industry Technological Forecasting and Social Change 76 (4) 567–583
[21] Oltra V, Kemp R and De Vries F 2009 Patents as a Measure for Eco-Innovation Working Papers of GREThA no:2009-05 http://ideas.repec.org/p/grt/wpegrt/2009-05.html
[22] Fussler and James P 1996 Eco-innovation: a breakthrough discipline for innovation and sustainability Pitman: London.
[23] Bartlett D and Trifilova C, 2010 Green technology and eco-innovation: Seven case-studies from a Russian manufacturing context Journal of Manufacturing Technology Management 21 (4) 910-929
[24] Chen Y S, Lai S B and Wu C T 2006 The influence of green innovation performance on corporate advantage in Taiwan Journal of business ethics 67 (4) 331-339
[25] Clark T and Charter M 2007 Sustainable innovation: Key conclusions from sustainable innovation conferences 2003–2006 organised by the centre for sustainable design
[26] Kemp R and Pearson P 2007 Final report M6 project about measuring eco-innovation UM Merit, Maastricht, 10 2
[27] European Commission 2007 Competitiveness and Innovation Framework Programme (2007 to 2013) Brussels
[28] European Commission 2008 Call for Proposals under the eco-innovation 2008 Programme DG Environment http://ec.europa.eu/environment/etap/ecoinnovation/library_en.htm
[29] Organisation for Economic Co-operation and Development (OECD) 2009 Eco-innovation in industry – enabling green growth https://www.oecd.org/sti/3641386522568622906.htm
[30] Arundel A and Kemp R 2009 Measuring ecoinnovation. United Nations University Maastricht Economic and Social Research and Training Centre on Innovation and Technology Maastricht UNU-MERIT #2009-017
[31] Fernandez Y and Wah W X 2017 The impact of eco-innovation drivers on environmental performance: Empirical results from the green technology sector in Malaysia Sustainable Production and Consumption 12 27-43
[32] Anderson M 2008 Eco-innovation: towards a taxonomy and a theory 25th Celebration DRUID Conference on Entrepreneurship and Innovation – Organizations, Institutions, Systems and Regions, Copenhagen, Denmark
[33] Carrillo-Hermosilla J, Del Río P and Kenmōlō T 2010 Diversity of eco-innovations: Reflections from selected case studies Journal of cleaner production 18 (10) 1073-1083
[34] Andersen P H, Cook N and Marceau J 2004 Dynamic innovation strategies and stable networks in the construction industry: Implanting solar energy projects in the Sydney Olympic Village Journal of Business Research 57 (4) 351-360
[35] Ball C, Bart G, De Vries F and Eichhorn S 2018 How environmental protection agencies can promote eco-innovation: The prospect of voluntary reciprocal legitimacy Technological Forecasting and Social Change 129 242-253
[36] Bossink B A 2004 Managing drivers of innovation in construction networks Journal of construction engineering and management 130 (3) 337-345
[37] Chen X, Yi N, Zhang L and Li D 2018 Does institutional pressure foster corporate green innovation? Evidence from China's top 100 companies Journal of cleaner production 188 304-311
[38] Dong Y, Wang X, Jin J, Qiao Y and Shi L 2014 Effects of eco-innovation typology on its performance: Empirical evidence from Chinese enterprises Journal of Engineering and Technology Management 34 78-98
[39] Del Rio P, Carrillo-Hermosilla J and Könnölä T 2010 Policy strategies to promote eco-innovation: An integrated framework Journal of Industrial Ecology 14 (4) 541-557
[40] Hazarika N and Zhang X 2019 Evolving theories of eco-innovation: A systematic review Sustainable Production and Consumption 19 64-78
[41] Kiefer C P, Carrillo-Hermosilla J, Del Rio P and Barroso F J C 2017 Diversity of eco-innovations: A quantitative approach. Journal of cleaner production 166 1494-1506
[42] Yin J, Wang S and Gong J 2018 The effects of factor market distortion and technical innovation on China’s electricity consumption Journal of cleaner production 188 195-202
[43] Beveridge R. and Guy S 2009 Governing through translations: intermediaries and the mediation of the EU’s Urban Waste Water Directive Journal of Environmental Policy & Planning 11 (2) 69-85
[44] Buijendijk H, Blom J, Vermeer J and van der Duin R 2018 Eco-innovation for sustainable tourism transitions as a process of collaborative co-production: the case of a carbon management calculator for the Dutch travel industry Journal of Sustainable Tourism 26 (7) 1222-1240
[45] Golini R and Guandalinis J 2018 An empirical examination of the relationship between globalization, integration and sustainable innovation within manufacturing networks International Journal of Operations & Production Management 38 (3) 874-894
[46] Huang J W and Li Y H 2018 How resource alignment moderates the relationship between environmental innovation strategy and green innovation performance Journal of Business & Industrial Marketing 33 (3) 316-324
[47] Maassen A 2012 Heterogeneity of lock-in and the role of strategic technological interventions in urban infrastructural transformations European Planning Studies 20 (3) 441-460
[48] McLean C and Hassard J 2004 Symmetrical absence/symmetrical absurdity: Critical notes on the production of actor-network accounts Journal of management studies 41 (3) 493-519
[49] Rossignoli F and Lioni A 2018 Network impact on business models for sustainability: Case study in the energy sector Journal of cleaner production 182 694-704
[50] Vallet F, Tyl B, Cluzel F and Loroy Y 2016 Research directions in eco-innovation: a French perspective International Journal on Interactive Design and Manufacturing 10 (3) 309-318
[51] Wang C, Nie P Y, Peng D H and Li Z. H 2017 Green insurance subsidy for promoting clean production innovation Journal of cleaner production 148 111-117
[52] York R and Rosa E A 2003 Key challenges to ecological modernization theory Organization & Environment 16 (3) 273–288
[53] Arena C, Michelon G and Trojanowski G 2018 Big egos can be green: A study of CEO hubris and environmental innovation British Journal of Management 29 (2) 316-336
[54] Peng B, Tu Y and Wei G 2018 Can Environmental Regulations Promote Corporate Environmental Responsibility? Evidence from the Moderated Mediating Effect Model and an Empirical Study in China Sustainability 10 (3) 641
[55] Kesidou E and Demirel P 2012 On the drivers of eco-innovations: Empirical evidence from the UK Research Policy 41 (5) 862-870
[56] Velikov K and Thün G 2013 Responsive building envelopes: characteristics and evolving paradigms Trubiano, F., Design and Construction of High Performance Homes 75-92
[57] Freehete R and Gilchrist R 2008 Towards zero energy: a case study of the Pearl River Tower, Guangzhou, China. In CTBUH: Proceedings of the council on tall buildings and urban habitat’s 8th world congress 7–16
[58] THEPLAN 2014 Media-Tic The Plan Architecture & Technologies in Detail http://www.theplan.it/
[59] Kieran S and Timberlake J 2016 Approaching Innovation Oz 38 (1) 10
[60] Kieran S, Timberlake J and Fairecloth B 2011 Cellophane House: KieranTimberlake KieranTimberlake
[61] Halicioglu F H and Koralay S 2019 Innovative approaches to automated construction: Recent advances and future visions on three-dimensional printing In Proceedings of the CIB World Building Congress: Constructing Smart Cities, Hong Kong, China
[62] Ghaffar S H, Corker J and Fan M 2018 Additive manufacturing technology and its implementation in construction as an eco-innovative solution Automation in Construction 93 1-11
[63] Tay Y W D, Panda B, Paul S C, Noor Mohamed N A, Tan M J and Leong K F 2017 3D printing trends in building and construction industry: a review Virtual and Physical Prototyping 12 (3) 261-276
[64] Latour B 1987 Science in action: How to follow scientists and engineers through society Cambridge, MA: Harvard University Press
[65] Latour B 2005 Reassembling the social: An introduction to actor-network-theory Oxford: Clarendon
[66] Law J 1992 Notes on the theory of the actor-network: Ordering, strategy, and heterogeneity Systems practice 5 (4) 379-393
[67] Arnamoldi M and Spiller N 2011 Actor-network theory and stakeholder collaboration: The case of Cultural Distincts Tourism Management 32 (3) 641-654
[68] Hary C 2005 Innovation in construction: a sociology of technology approach Building Research & Information 33 (6) 512-522
[69] Hary C 2008 Implementing innovation in construction: contexts, relative boundedness and actor-network theory Construction management and economics 26 (10) 1029-1041
[70] Hary C 2010 Implementing innovation: designers, users and actor-networks Technology Analysis & Strategic Management 22 (3) 297-315
[71] Schweber L and Hary C 2010 Actors and objects: a socio-technical networks approach to technology uptake in the construction sector Construction management and economics 28 (6) 657-674
[72] Bresnen M and Hary C 2010 Editorial: Special issue on objects, knowledge sharing and knowledge transformation in projects Construction Management and Economics 28 (6) 549-555
[73] Sage D, Dainty A and Brooks N 2011 How actor-network theories can help in understanding project complexities International Journal of Managing Projects in Business 4 (2) 274-293
[74] Rydin Y 2013 Using Actor-Network Theory to understand planning practice: Exploring relationships between actors in regulating low-carbon commercial development Planning Theory 12 (1) 23-45
[75] Nielsen S B, Hoffmann B, Quitzau M B and Elle M 2009 Mobilizing the courage to implement sustainable design solutions: Danish experiences Architectural Engineering and Design Management 5 (1-2) 53-61