

Building and Construction Research in Malaysia: A Bibliometric Analysis

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Abstract: This paper presents a bibliometric analysis of building and construction research authored by researchers reporting an affiliation to institutions in Malaysia from years 2000 to 2015. The objectives are to identify the most productive research institutions and researchers, the research themes at these institutions, the output and impact of the research carried out and the most prolific authors. A search on the Scopus database identified 1,668 articles published during this period. The results indicate that research output was primarily from the five public research universities reflecting their privileged funding model and that output had increased rapidly in recent years. Topics of research were broad ranging from materials and structures in the engineering field, to the more conventional construction management and building science topics. Although numerous authors from Malaysia have high citation counts and *h*-indices, the overall impact of the research was low with many articles either published in low impact journals or received few citations. There is evidence of publication inflation where the increase in publication counts have not been matched by a comparable increase in citation counts. National innovation or research funding policies must rigorously address both the quantity and quality of research outputs to accurately assess impact.

Keywords: Malaysia, Bibliometric study, Research output, Research productivity

INTRODUCTION

Increasingly competition at the global level has motivated the Malaysian construction industry to transform the sector to one that is able to successfully compete for projects locally and abroad. In September 2015, the government launched the Construction Industry Transformation Plan (CITP) 2015–2020 to drive major changes to the construction sector, mainly to bring the local construction industry up to world-class standards. A major tenet of the industry transformation plan was to promote research to drive sustainable practices, reduce waste, increase information and communication technologies (ICT) adoption and advance the use of modern methods of construction (Construction Industry Development Board [CIDB], 2015). This transformation plan also called for the establishment of Centres of Excellence, the promotion of research partnerships between global and local universities and increased collaboration between academia and industry partners to achieve these aims.

Although researchers in Malaysia have carried out numerous studies in the area of building and construction for many decades, no systematic analysis has been carried out to assess the output of the research or to evaluate the impact of

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these works. For example, research into mechanisation and industrialised building systems (IBS) have been conducted since the early 1980s, but adoption of IBS components in buildings remains low (Shaari, 2003) as this method of construction was not necessarily cost effective. With the recent launch of the CITP, an analysis of the research conducted over the previous years would provide a context for framing further research in the area of building and construction. A bibliometric analysis is proposed as it provides both quantitative and qualitative parameters; i.e. number of articles, authors, research organisations, citations, *h*-index and journals and allows the quality and impact of the research to be assessed. Thomson Reuters (2008) defined bibliometric as "the application of quantitative analysis and statistics to publications such as journal articles and their accompanying citation counts". Literature reviews, on the other hand, serve to analyse and synthesise a mature topic where an accumulated body of research exists, or to propose the development of a new conceptual model for an emerging field (Webster and Watson, 2002).

The aim of this bibliometric study is therefore to evaluate the productivity and impact of researchers in Malaysia in the field of building and construction from 2000 to 2015. The objectives are (1) to determine the research productivity of researchers and universities, (2) to determine research themes and (3) to evaluate the impact of these research outputs. This unit of analysis is the "field of research", mainly to establish the breadth and depth of research into building and construction nationally, as opposed to a focus on the "departments of built environment". The results of this study will help building and construction policymakers and researchers to examine the influence of recent funding models and public policy on research productivity and impact and to shape research in the next decade.

BACKGROUND AND LITERATURE REVIEW

Funding for research and development has traditionally been sourced from the public sector in Malaysia. In the 1990s, the government, in an effort to increase research output and improve the competitiveness of the local industry launched a number of research funding schemes (Malaysian Science and Technology Information Centre [MASTIC], 2013). Responsibility for funding for research in "building and construction" has been assigned to the CIDB and funded through a 0.125% levy applied to all construction work contracts that exceed RM 500,000. Between 2001 and 2012, the CIDB funded a total of 49 projects either at the local universities or collaboratively with the Construction Research Institute of Malaysia (CREAM), the research arm of the CIDB (CREAM, 2012).

The most recent statistic on the number of researchers in Malaysia was 58.2 researchers for every 10,000 workers in 2011, which is smaller than the ratio of researchers in comparable economies such as South Korea (142.5) and Singapore (127.4) (MASTIC, 2013). Research output from Malaysia however has increased from 1,048 in 2000 to 5,985 papers (in the areas of Science and Technology) in 2009; an annual growth of more than 50%. Malaysian research capacity is predominantly housed in the five core public universities: Universiti Malaya (UM), Universiti Sains Malaysia (USM), Universiti Kebangsaan Malaysia (UKM), Universiti Putra Malaysia (UPM) and Universiti Teknologi Malaysia (UTM). These five universities produced more than 75% of all science and technology publications from Malaysia between 2001 and 2008 (MASTIC, 2008). A bibliometric study, reported in the same document,

indicated that only 18% of the research outputs were in journals that reported an impact factor.

Recent bibliometric research in the area of "building and construction" were carried out by Canas-Guerrero et al. (2013) specifically for "civil engineering" and Canas-Guerrero et al. (2014) in the category of "construction and building technology". Other bibliometric analyses in this area were limited to research published in a particular journal (Abudayyeh, Dibert-DeYoung and Jaselskis, 2004), on a single topic (Marti-Vargas et al., 2015; Gundes and Aydogan, 2016; Utama et al., 2016) or one country (Rojas-Sola and de San-Antonio-Gomez, 2010).

The first comprehensive bibliometric survey for Malaysia was conducted by Zainab et al. (2012) for six broad areas, using both the Web of Science and Scopus databases. They noted a sharp increase in the number of publications for Science, Engineering and Medicine in 2010 following the government/s recognition of the top five public universities as "research universities" in 2006, the subsequent allocation of substantial research grants and active recruitment of researchers from Malaysia and abroad. In a comparison on the output of the universities in Malaysia, Suryani et al. (2013) observed that UM was ranked first followed by USM, UPM, UKM and UTM. Teng et al. (2014) and Zyoud et al. (2014) were limited to medical research and were not relevant to this current study.

RESEARCH APPROACH

The approach adopted in this study is two pronged: (1) a quantitative analysis of the number of scholarly publications as a measure of output together with tracking of citations to evaluate impact and influence of research and (2) a qualitative review of the publications to identify research themes.

This study refers to data obtained from the Scopus database for authors who declare an affiliation with either a Malaysian university or organisation. The period covered is from 2000 to 2015 which corresponds to the recent drive for greater research performance and output. Publications captured by the Scopus database include articles in both academic journals and conference proceedings, articles in press, books, book chapters, reviews and editorials.

In order to limit the search to research in the area of building and construction, the search for records in the Scopus database is constrained with the keywords "construction" or "building" in either the title or abstract and further limited to subject area of "engineering". The period of study was limited to year 2009 to 2015, both years included.

The following search string was utilised to query the Scopus database on 3 March 2016 and produced a total of 2,568 records:

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(TITLE-ABS-KEY("construction" OR "building") AND
AFFILCOUNTRY(Malaysia)) AND ( LIMIT-TO(PUBYEAR,2015)
OR LIMIT-TO(PUBYEAR,2014) OR LIMIT-TO(PUBYEAR,2013) OR
LIMIT-TO(PUBYEAR,2012) OR LIMIT-TO(PUBYEAR,2011) OR
LIMIT-TO(PUBYEAR,2010) OR LIMIT-TO(PUBYEAR,2009) OR
LIMIT-TO(PUBYEAR,2008) OR LIMIT-TO(PUBYEAR,2007) OR
LIMIT-TO(PUBYEAR,2006) OR LIMIT-TO(PUBYEAR,2005) OR
LIMIT-TO(PUBYEAR,2004) OR LIMIT-TO(PUBYEAR,2003) OR
LIMIT-TO(PUBYEAR,2002) OR LIMIT-TO(PUBYEAR,2001) OR LIMIT-
TO(PUBYEAR,2000) ) AND ( LIMIT-TO(SUBJAREA,"ENGI" ) )
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A total of 1,668 records remained after manually checking these records to remove duplicates and ensure that they were relevant to the research areas. These records were then classified into 13 topics of research within the broader field of building and construction. The affiliations of the authors were automatically mapped to the list of universities and agencies in Malaysia using a keyword search. One credit was given to every author together with a count allocated to the institutions affiliated to these authors.

RESULTS AND FINDINGS

Paper count, which measure productivity, is the most basic bibliometric measure and provides the raw data for all citation analysis (Thomson Reuters, 2008). Ranking these Malaysian institutions in terms of paper count helps to compare the productivity and volume of research output. The number of researchers at each institution was not taken into account as this information was not readily available.

Distribution of Publications by Research Organisations

A total of 56 Malaysian organisations were affiliated to the authors of these 1,668 records including 38 universities, five government agencies (CREAM, CIDB, Department of Occupational Health and Safety [DOSH], Angkatan Koperasi Kebangsaan Malaysia Berhad [Angkasa] or National Co-operative Movement of Malaysia and Social Security Organisation [SOCSO]) and a number of private firms. It is clear from Table 1 that the majority of the output (57%) was from the five public research universities: UM, USM, UTM, UKM and UPM. UTM was clearly the most productive in this area building and construction with a total of 410 publications during the period of study.

Table 1. List of Universities and Agencies Indexed by Scopus

Formal Name of Universities (Name in English – If Available)	Acronym	Publications (2000–2015)
Public Universities		
Universiti Malaya (University of Malaya)	UM	212
Universiti Sains Malaysia (University of Science Malaysia)	USM	201
Universiti Teknologi Malaysia (University of Technology Malaysia)	UTM	410
Universiti Kebangsaan Malaysia (National University of Malaysia)	UKM	152
Universiti Putra Malaysia	UPM	106
Universiti Tun Hussein Onn Malaysia	UTHM	106
Universiti Teknologi MARA	UiTM	186
Universiti Utara Malaysia	UUM	32
Universiti Pertahanan Negara Malaysia	UPNM	10
Universiti Teknikal Melaka	UTeM	19

(continued on next page)

Table 1. (continued)

Formal Name of Universities (Name in English – If Available)	Acronym	Publications (2000–2015)
Universiti Malaysia Pahang	UMP	37
Universiti Pendidikan Sultan Idris	UPSI	10
Universiti Malaysia Perlis	UNIMAP	36
Universiti Islam Antarabangsa (International Islamic University Malaysia)	IUM	25
Universiti Malaysia Terengganu	UMT	10
Universiti Malaysia Sabah	UMS	15
Universiti Malaysia Sarawak	UNIMAS	23
Private Universities		
Universiti Tunku Abdul Rahman	UTAR	47
Universiti Tenaga Nasional	UNITEN	39
Curtin University Sarawak	CURTIN	34
Universiti Teknologi Petronas	UTP	93
University of Nottingham Malaysia	UNM	16
Public Research Agencies		
Centre for Construction Research Malaysia	CREAM	13
Construction Industry Development Board	CIDB	7

Note: Universities or agencies with less than 10 publications were not listed. CIDB deserved a listing as it was the coordinating agency for the construction industry.

Distribution of Publications over Time

The number of publications in building and construction commenced from a very low level (less than 20 annually) before 2005 but increased more than twenty-fold to a peak of 468 in 2014. This sudden surge in research output coincided with the increase in national research output in numerous other areas in 2010 that was reported by Suryani et al. (2013) and Zainab et al. (2012) and also indicative of the greater involvement of the CREAM in promoting and funding research in construction. This rapid increase in research output was led by UTM, UM and USM in 2010, followed by UiTM, UKM and UPM a year later, as shown in Table 2.

The research output in the building and construction area clearly reflects the overall investment into these five research universities. These increases also reflect the success of the additional funding and incentives provided by the government to these research universities to put greater emphasis on research, development and innovation activities. The four-year lag between the designation of the initial group of research universities and allocation of research funding, to the sharp increase in research output is indicative of the period of planning, conducting and writing up these research projects.

Table 2. Number of Publications by University

Year	UTM	UM	USM	UiTM	UKM	UPM	UTHM	UTP	Others	Annual Total
2015	120	35	35	27	31	15	12	10	99	384
2014	102	41	59	43	23	24	31	41	104	468
2013	55	38	19	23	28	11	25	15	72	286
2012	53	28	30	25	16	12	8	9	48	229
2011	29	32	18	45	25	10	9	9	30	207
2010	25	16	17	5	6	3	8	4	15	99
2009	7	4	3	3	4	5	5	0	10	41
2008	6	9	4	3	3	4	2	2	11	44
2007	7	4	4	1	3	5	1	1	6	32
2006	1	4	1	4	3	6	3	0	9	31
2005	3	0	1	3	3	5	2	1	1	19
2004	0	0	2	0	2	4	0	1	3	12
2003	0	0	3	2	2	1	0	0	2	10
2002	0	0	2	0	2	1	0	0	1	6
2001	0	1	3	2	0	0	0	0	0	6
2000	2	0	0	0	1	0	0	0	0	3
Total	410	212	201	186	152	106	106	93	411	1,877

Notes: (1) The total number of publications here adds up to more than 1,668 as an article written by authors from two Malaysian institutions are counted twice; (2) Ranked in descending order: Only top eight universities shown.

Research Themes at Malaysian Universities

The titles and abstracts of these articles were analysed to determine the respective research themes. A full list of the topics is shown in Table 3 together with the number of publications in each area for the top nine universities. The topic with the greatest number of publications was construction management, followed by structural engineering, materials engineering and building science. Given the recent establishment of the faculties of built environment at these universities, the rapid increase in the number of publications in construction management, building science, environmental science and sustainability and energy was not unexpected. The increase in the number of articles in sustainability and energy in 2011 reflects the greater emphasis and public awareness of these topics in recent years. More traditional topics of engineering, quantity surveying and building science also exhibited increases in output but at a slower rate. The increase in the number of articles on construction technology and the industrialised building system is clearly attributed to the initiative by the CIDB and the government to adopt these modern methods of construction to improve productivity (Shaari, 2003).

All five public research universities comprise schools of civil engineering and built environment, leading to their higher publication output in both these areas of research. Research at UTM was in the areas of structural engineering and construction management reflecting the capacity of both these schools to conduct research. The main topics in structural engineering include the performance of cold-formed steel sections, seismic or dynamic behaviour of structures and steel-concrete composite design. A significant number of articles in materials engineering were on the use of industrial waste products such as steel slag, oil palm fuel ash, or oil palm kernel for sustainable concrete production. In the area of construction management, the topics were very varied, ranging from building information modelling (BIM), construction project management, and safety and risk management. UTM was evidently the hub for research into environmental issues, sustainable construction, energy efficiency, quantity surveying, project procurement and IBS with the highest number of publications in these areas nationally. Topics in structural engineering at the UM include seismic base isolation and carbon fibre reinforced concrete while topics in materials engineering included the addition of waste or recycled materials, indigenous materials such as palm kernel, rice husk ash, palm oil clinker, coconut fibres into concrete. Numerous articles were on facility management and building science focusing on buildings in a tropical environment combined with research on natural ventilation.

Another university with a broad range of research topics in the area of construction management is USM. Publications from authors at USM include topics such as lean construction, public-private partnerships, internationalisation, joint ventures, innovation, safety and life cycle costing. A topic that came out strongly in both facility management and construction technology was research on quality and defects in housing. Research at UiTM in the area of construction management was focused on building performance and measurement and waste management, while topics such as natural ventilation, use of historic buildings and case studies of local buildings were common in the area of building science. Engineering research at UKM was focused on a wide range of topics including the performance of wall panels and the use of rice husk and steel slag in concrete and coir fibres as insulating materials. The focus of their building research was on energy demand and green design while the main thrust of their construction management research was on project performance.

As a comprehensive engineering school, research at UPM covered a broad range of topics but with particular emphasis on the performance of buildings and structures subject to earthquakes. Topics in building science were predominantly in the area of indoor environment and performance of green roofs. UTAR was included in this section to reflect its specific focus on quantity surveying and construction management areas. The research output was predominantly in the areas of building costs, contracts and procurement and construction productivity. The remaining two universities, UTHM and UTP offered programs only in engineering were therefore mainly focused on engineering research.

This review of the areas and topics of research indicate that there is broad expertise in a wide range of research areas at the research universities. As expected, research into areas of structural engineering, materials and geotechnical engineering were mainly conducted at the engineering schools while topics in construction management, project management, cost, procurement, building science, sustainability were the forte of built environment schools. Many research topics clearly reflect the importance of local or national issues such as the wider use of public finance initiatives by the government for the procurement of projects, the increased emphasis on IBS to increase construction productivity, the drive to adopt BIM processes in design and project management and wide public interest in constructing more sustainable homes and buildings. Malaysia's location in the tropics also played a role in influencing research on natural ventilation and building integrated photovoltaics. The wide availability of timber resources and the establishment of a fledgling steel downstream industry led to research on timber elements and structures and cold formed steel sections. The abundance of waste agricultural products such as oil palm kernel, rice husks and coconut fibres has led to research into alternative uses of these products either in concrete or as an insulating material.

Publications in Journals and Proceedings

Table 4 lists the top 10 journals where the outputs from the research in building and construction were published. A total of 172 or 10.3% of the total articles were published in *Jurnal Teknologi*, a peer-reviewed international research journal that is published by UTM Press (www.jurnalteknologi.utm.my). Data from the SCImago Journal and Country Rank site (www.scimagojr.com) indicate that the majority of these journals were in the third or fourth quartile of the journals in their respective areas of specialisation with reportedly low *h-indices*. Out of the top 10 journals, only *Construction and Building Materials*, *Energy and Building* and *Building and Environment* were ranked in the first quartile which denotes the top 25% of the impact factor distribution. The total number of articles in these Q1 journals was only 81, corresponding to only 4.9% of total articles. The distribution of conference papers was not discussed because very few of these conference proceedings were included in either www.journalmetrics.com or the www.scimagojr.com journal ranking sites.

Although there is considerable debate on the use of the journal impact factor as a journal-level measure designed to compare the quality of one journal with other journals, it is nonetheless useful as an indicator that broadly corresponds to the hierarchy of journals within a subject area. Seglen (1997) cautioned that journal impact factors are not statistically representative of individual journal articles and that a few highly cited articles account for most of the citations. Nonetheless, research assessment exercises rely extensively on the ranking of journals as a means to provide feedback on the perception of quality. In the first ever attempt to rank the journals in the construction management area, Chau (1997) sought to assess and rank 22. Notwithstanding the time lag between the work by Chau and this study, none of the top 10 journals in this study were in the list suggested by Chau. On closer examination, only 48 articles out of the 1,688 were published in Chau's list of top journals. A more recent study by Brochner and Bjork (2008) identified seven top journals in the construction management area. Again, only 45 articles were published in these seven top journals.

Table 4. Top 10 Most Frequently Published Journals

Source Title	Freq.	Cited by	Cites per Article	2014 SJR (1)	2014 IPP (1)	2014 SNIP (1)	h-index (2)	SJR 2014 Quartile (2)
<i>Jurnal Teknologi (Sciences and Engineering)</i>	172	78	0.45	0.146	0.18	0.319	9	Q3
<i>Research Journal of Applied Sciences, Engineering and Technology</i>	37	24	0.65	0.155	0.176	0.308	12	Q3
<i>Construction and Building Materials</i>	32	418	13.06	1.486	2.761	2.499	81	Q1
<i>Advanced Science Letters</i>	28	27	0.96	0.140	0.223	0.266	18	Q3
<i>Building and Environment</i>	26	360	13.85	1.871	3.65	2.633	86	Q1
<i>Energy and Buildings</i>	23	395	17.17	1.990	3.815	2.799	65	Q1
<i>Malaysian Construction Research Journal</i>	22	27	1.23	0.141	0.235	1.056	3	Q4
<i>Journal of Engineering Science and Technology</i>	21	38	1.81	0.244	0.49	0.994	18	Q2
<i>ARPJ Journal of Engineering and Applied Sciences</i>	19	3	0.16	0.213	0.345	0.668	12	Q3
<i>World Academy of Science, Engineering and Technology</i>	15	14	0.93	0.131	0.16	0.288	16	Q4

Notes: (1) SJR: SCImago journal rank; IPP: Impact per publication; SNIP: Source normalised impact per paper obtained from www.journalmetrics.com; (2) h-index and SJR quartile – where Q1 means highest values and Q4 lowest values obtained from www.scimagojr.com.

Citations and Impact of the Research

Citation analysis has often been used as an objective measure of research performance. A Thomson Reuters (2008) white paper on using bibliometrics argued that citation analysis provides data on all activity in an area and removes characteristics that colour human perceptions of quality. The straightforward publication count in the previous section, even corrected for the size of the departments, will only be a crude indicator of each department/s research performance because they fail to take into account the quality of the publications

(Colman, Dhillon and Coulthard, 1995). Aggregate citation counts over the study period can be useful for comparing and ranking these institutions/ research impact.

Out of a total of 1,668 articles published during the period, 657 articles received a total 3,817 citations as of 3 March 2016 of which 2,940 were from articles published in journals whereas the remaining 877 were for conference papers, notes and reviews. This works out to an average of 2.3 citations per article overall. The 10 most frequently cited journals during 2000–2016 are tabulated in Table 5. Seven out of these 10 journals were listed as first quartile journals indicating the relative success of academics in Malaysia in publishing highly cited articles. The average citations per article for these first quartile journals were more than 10. In contrast, *Jurnal Teknologi*, which was the most frequently published journal, attained a low 0.45 citations per article when compared against other journals when ranked on citations. Of greater concern is the 1,011 articles published that have received no citations indicating a lack of impact for the large proportion of the research conducted by Malaysian academics.

A list of the top 20 cited articles is shown in Table 6. These top 20 articles received a total of 932 citations amounting to about 24% of the total number of citations for the entire dataset. These highly cited articles indicate that the research areas where authors were making significant impact are materials engineering, construction management and building science. The materials engineering research was mainly on concrete with the addition of recycled aggregates, oil palm shell, or polypropylene fibres and for composite ferro-cement-brick panels. Topics in construction management include research into delays and productivity of building projects and built-operate-transfer procurement schemes. Research in the area of building science covered a wide range of topics from natural ventilation, daylighting, indoor thermal comfort especially for buildings in a tropical environment like Malaysia.

The list of the top 20 most prolific authors in building and construction is shown in Table 7. The Google Scholar profiles, if available, for each of these authors are also listed to provide an indication of their citation indices. The author with the highest number of publications during this period is Jaafar M.S. from UPM who publishes mainly in the areas of structural engineering, industrialised building systems and constructability. Jumaat M.Z. from UM has the largest number of total citations of 2,624, an *h*-index of 29 and an *i10*-index of 79 according to Google Scholar on 5th December 2016. With the exception of a small number of authors with no Google Scholar profiles, these authors reported *h*-indexes ranging between 5 and 29. The *h*-index is based on an author's lifetime citedness, which incorporates productivity as well as citation impact (Hirsch, 2005).

Taking all the information from Tables 4 to 7 collectively, it is possible to assess the relative impact made by Malaysian authors in the building and construction research area. The average citation per article of 2.3 overall is rather low compared to averages of 7.03, 4.76 and 3.75 for material science, engineering and social sciences, globally (Thomson Reuters, 2016). The 1,011 articles that attracted no citation are evidently indicative of research output that were produced to fulfil the requirement to publish but was not of a sufficient quality to make any impact. The large number of publications in lower quartile journals that attract few citations suggests that the authors may be motivated by rapid publication, less onerous review processes and not by the reputation of these journals.

Table 5. Top 10 Most Frequently Cited Journals

Source Title	Freq.	Cited by	Cites per Article	2014 SJR (1)	2014 IPP (1)	2014 SNIP (1)	h-index (2)	SJR 2014 Quartile (2)
<i>Construction and Building Materials</i>	32	418	13.06	1.486	2.761	2.499	81	Q1
<i>Energy and Buildings</i>	23	395	17.17	1.990	3.815	2.799	103	Q1
<i>Building and Environment</i>	26	360	13.85	1.871	3.65	2.633	86	Q1
<i>Journal of Construction Engineering and Management</i>	7	136	19.43	1.199	1.394	1.631	71	Q1
<i>Engineering, Construction and Architectural Management</i>	12	121	10.08	0.625	0.86	1.079	27	Q2
<i>Automation in Construction</i>	9	92	10.22	1.572	2.755	2.519	65	Q1
<i>Construction Management and Economics</i>	14	83	5.93	1.189	1.224	1.128	60	Q1
<i>Engineering Structures</i>	8	81	10.13	1.815	2.173	2.396	83	Q1
<i>Jurnal Teknologi (Sciences and Engineering)</i>	172	78	0.45	0.146	0.18	0.319	9	Q3
<i>Structural Survey</i>	13	73	5.62	0.340	0.697	1.266	13	Q3

Notes: (1) SJR: SCImago journal rank; IPP: Impact per publication; SNIP: Source normalised impact per paper obtained from www.journalmetrics.com; (2) h-index and SJR quartile – where Q1 means highest values and Q4 lowest values obtained from www.scimagojr.com; (3) 1 January 2013: The IEEE Transactions on Systems, Man and Cybernetics Part C: Applications and Reviews has been renamed to IEEE Transactions on Human-Machine Systems.

Despite the large volume of low impact research, there exists a core of excellent research outputs. The top 20 cited articles attracted an average of 47 citations per article and many of these were published in the top journals of their respective fields of research. A comparison of the authors in Table 7 indicate that only a small number of these prolific authors were represented in the list of authors of the most cited paper in Table 6. It is also important to note that 15 out of the top 20 cited articles were published before 2011 reflecting the maturity of these research topics at the universities as opposed to the more recent increase in research output from 2011 to 2015.

Table 6. Top 10 Cited Articles

Authors (Year)	Source Title	Times Cited	Area	University
Mahlia T.M.I., Taufiq B.N., Ismail, Masjuki H.H. (2007)	<i>Energy and Buildings</i>	84	Materials engineering	UM
Mannan M.A., Ganapathy C. (2004)	<i>Building and Environment</i>	79	Materials engineering	UMS
Kwan W.H., Ramli M., Kam K.J., Sulieman M.Z. (2012)	<i>Construction and Building Materials</i>	65	Materials engineering	USM
Niithamyong P., Skibniewski M.J. (2006)	<i>Journal of Construction Engineering and Management</i>	60	Construction management	Malaysia University of Science and Technology (MUST)
Osterman E., Tyagi V.V., Butala V., Rahim N.A., Stritih U. (2012)	<i>Energy and Buildings</i>	55	Building science	UM
Kubota T., Miura M., Tominaga Y., Mochida A. (2008)	<i>Building and Environment</i>	50	Building science	UTM
Alaghbari W., Kadir M.R.A., Salim A., Ernawati (2007)	<i>Engineering, Construction and Architectural Management</i>	50	Construction management	UPM
Alam M.R., Reaz M.B.I., Ali M.A.M.(2012)	<i>IEEE Transactions on Systems, Man and Cybernetics. Part C, Applications and Reviews: A Publication of the IEEE Systems, Man and Cybernetics Society</i>	49	Construction technology/ IBS, Industry	UKM
Kubota T., Chyee D.T.H., Ahmad S.(2009)	<i>Energy and Buildings</i>	44	Building science	UTM
Jamshidi A., Hamzah M.O., You Z. (2013)	<i>Construction and Building Materials</i>	40	Materials engineering	USM
Khatib T., Mohamed A., Sopian K., Mahmoud M. (2011)	<i>Energy and Buildings</i>	40	Energy	UKM
Benayoune A., Samad A.A.A., Trikha D.N., Ali A.A.A., Ellinna S.H.M. (2008)	<i>Construction and Building Materials</i>	40	Structural engineering	UPM
Abdul-Rahman H., Berawi M.A., Berawi A.R., Mohamed O., Othman M., Yahya I.A. (2006)	<i>Journal of Construction Engineering and Management</i>	39	Construction management	UM

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Table 6. (continued)

Authors (Year)	Source Title	Times Cited	Area	University
Abdul Kadir M.R., Lee W.P., Jaafar M.S., Sapuan S.M., Ali A.A.A. (2005)	<i>Structural Survey</i>	38	Construction management	UPM
Zain-Ahmed A., Sopian K., Zainol Abidin Z., Othman M.Y.H.2 (2002)	<i>Renewable Energy</i>	38	Building science	UKM
Teo D.C.L., Mannan M.A., Kurian V.J. (2006)	<i>Turkish Journal of Engineering and Environmental Sciences</i>	37	Materials engineering	UMS
Yeoh D., Fragiacomio M., De Franceschi M., Heng Boon K. (2011)	<i>Journal of Structural Engineering</i>	36	Structural engineering	UTHM
Noorzaei J., Bayagoob K.H., Thanoon W.A., Jaafar M.S.(2006)	<i>Engineering Structures</i>	31	Geotechnical engineering	UPM
Abdul-Aziz A.-R. (2001)	<i>Journal of Construction Engineering and Management</i>	29	Construction management	USM
Badir Y.F., Kadir M.R.A., Hashim A.H. (2002)	<i>Journal of Architectural Engineering</i>	28	Construction technology/ IBS, Industry	UPM

DISCUSSION

The main findings from the publication outputs by authors affiliated to universities in Malaysia are that the most productive universities are the five public comprehensive research universities (UM, USM, UPM UTM, UKM) followed by UiTM, UTHM, UTP and UTAR – universities with either civil engineering or built environment research centres. The rapid increase in research output is indicative of the efficacy of the initiatives by the Ministry of Higher Education and other government agencies such as Ministry of Science, Technology and Innovation (MOSTI) and the CIDB to stimulate research.

Numerous centres of excellence have coalesced at Malaysian universities over this period. The most prolific group was centred on steel structures, materials and construction management research at the Faculty of Civil Engineering, UTM. The research the utilisation of oil palm shell and blast furnace slag into concrete at the Department of Civil Engineering, UM has been on-going since the early 2000s, is highly cited and also prolific. Research on concrete materials at the School of Housing, Building and Planning, USM was highly cited together with topics in procurement, labour and construction companies. The research group led by Jaafar M.S. at the Department of Civil Engineering, UPM has received the highest number of citations for their research. The wide research interests of this particular group include construction labour productivity, industrialised building systems, structural

engineering and project management. The focus of the research centres at UKM was on concrete technology, environmental and sustainability issues, building sciences and energy. Other highly cited authors such as Nawi M.N.M., Ismail Z. and Abdul-Rahman H. led research at UUM, UiTM and the IUM-Wales, respectively.

Johnes (1990) highlighted that a reliance on bibliometric studies to assess the research output of departments may generate some degree of controversy, but these are often comparable to exercises based on an "informed peer review". Although it is not the intent of this study to compare the research outputs of each department or university, the distributions indicated by this study has produced a unique data set containing detailed information of research outputs on a national scale. It highlights the different research strategies among academic departments with some researchers focusing on increasing quantity of publications while others aim to obtain a high citation count.

A comparison of these results with previous studies linking public research funding policies reveal several common characteristics and challenges. Researchers who have examined the research outputs in Australia (Butler, 2003; Abbott and Doucouliagos, 2004; Worthington and Lee, 2008; Beerkens, 2013), China (Fu, Frietsch and Tagscherer, 2013), "Asian Tigers" comprising South Korea, Taiwan, Hong Kong and Singapore (Swinbanks and Nathan, 1997) and post-communist EU member states (Juradja et al., 2017) were able to categorise the levels of research performance as follows: (1) an initial low level of research output before the implementation of an innovation or research intensification policy, (2) a rapid increase in research publication output often as a direct result of increased public investment in research combined with incentives such as increased funding, financial reward, career advancement or obtaining advanced degrees for researchers and eventually (3) a gradual increase quality and impact of the research outputs.

The consequence of allocating significant funding based on publication counts often resulted in researchers putting too much emphasis on the aggregate counts and little attention to the impact or quality of that output (Butler, 2003). Fu, Frietsch and Tagscherer (2013) have attributed China's rise from a rank of 37th at the beginning of the 1980s to second behind the US since 2007 to a series of national research funding strategies and reforms over the last three decades. However, the increase in citation share was much lower than that of the publication share, indicating the over-emphasis and over-dependence on publication counts. This period of increasing publication numbers without a corresponding increase in citation numbers was described as "publication inflation" that was attributed to the utilitarian practice of applying these scientific advances to rapidly boost economic growth as opposed to the quest for scientific knowledge. Fu, Frietsch and Tagscherer (2013) observed that although the increase in citations was slower than that of publications for China's top five research universities, their citation shares caught up with or even exceed the publication shares.

The broader implications of the research performance of the construction researchers in Malaysia and wider research community globally were that increased funding and incentives created an environment that supported a rapid increase in publication output. However, in order to improve the quality and impact of research, it will be pertinent to change the assessment system that merely focuses on the number of publications to one that rigorously examines a plurality of outputs, including an informed peer review system, to be defined by at both institutional and national levels.

Table 7. Top 20 Authors in Building and Construction for 2000 to 2015

Google Scholar					
Unique Author Names	Freq.	All Cites	<i>h</i> -index	<i>i10</i> -index	University and Area of Research
Jaafar M.S.	33	1934	24	58	UPM, Structural engineering
Tahir M.M.	28	2013	20	67	UTM, Structural engineering
Abdul-Rahman H.	24	1428	19	42	UM, Construction management
Hainin M.R.	24	959	16	32	UTM, Materials engineering
Jumaat M.Z.	23	3627	33	108	UM, Structural engineering
Noorzai J.	23				(No Google Scholar profile)
Othuman Mydin M.A.	23	612	10	12	USM, Materials engineering
Zin R.M.	22	557	13	19	UTM, Construction management
Ali A.S.	21	891	15	27	UM, Construction technology
Nawi M.N.M.	21	448	11	11	UUM, IBS
Zain M.F.M.	21	2425	25	62	UKM, Materials engineering
Majid M.Z.A.	20	1285	16	32	UTM, Construction management
Tawil N.M.	20	519	10	11	UKM, Housing
Zakaria R.	20	218	8	7	UTM, Construction management
Che-Ani A.I.	18	856	15	21	UKM, Asset management
Kamaruzzaman S.N.	17	686	15	19	UKM, Facilities management
Ismail Z.	16	155	6	3	UiTM, Construction management
Shafiq N.	16	714	13	22	UTP, Materials engineering
Wang C.	16				(No Google Scholar profile)
Jaafar M.	14	1061	16	34	USM, Construction management

CONCLUSIONS

This bibliometric study has confirmed several important findings about productivity and impact of the research by authors affiliated with universities in Malaysia.

Firstly, the research productivity increased exponentially from an extremely low output of three articles per year in 2000 to maximum annual output of 468 articles in 2014. This increase in research output may be attributed to increases in research funding especially targeted at the five research universities and additional emphasis on construction research by the government through research and development (R&D) grants.

Secondly, the areas of research ranged from the more technical engineering topics such as the behaviour of structures due to seismic loads, cold-formed steel structures and the utilisation of local industrial and agricultural by-products into concrete; to management topics such as construction productivity, procurement methods, construction delays, labour, housing, energy, environmental sustainability and project management. Other important areas of research include the design of buildings in the tropics and the assessment of indoor environments in a tropical climate.

Thirdly, the impact of the research conducted by authors in Malaysia was rather limited with a large number of publications uncited. A comparison of these findings to recent bibliometric studies on "construction and building technology", a closely related field, indicate that the average number of citations per article of 2.3 was relatively low compared to between six and seven for the top three countries, United States of America (USA), China and United Kingdom (UK) as reported by Canas-Guerrero et al. (2014). They have also noted the rapid growth rate in the publication outputs from China was increasingly close to the output of the USA in 2011 with a correspondingly decent impact factor.

Fourthly, the level of research performance was assessed to be at the stage of increasing publication outputs and have not reached the level of significant citation shares. There is evidence to suggest that publication inflation caused by an over-emphasis on publication outputs had occurred in this field of research.

These findings can now inform national funding agencies and research centres to assess their performance and outputs within a national context and to determine the effectiveness of recent investments in national research funding. National policies and evaluation systems must be designed to achieve a balance of priorities as a system that is too focused on "quantity" may cause a shift away from "quality". Moed (2007) argued to combine the use of bibliometric indicators within peer-review processes to benefit from the advantages of each methodology.

One limitation of this bibliometric analysis is the accuracy of the terminology used to describe this "field of research". The activities in this field are diverse and often non-standardised which can hamper efficient retrieval of publication records. As this study was the first to investigate the scope and breadth of this field of research nationally, no attempt has been made to benchmark these research outputs internationally. More specific limitation of this study is the lack of information on input factors: no attempt was made to collect data on the number of researchers, quantum of research funding, availability of resources, size of school and number of Doctor of Philosophy (PhD) students. Abbott and Doucouliagos (2004) have reported on the positive correlations between research income, academic and non-academic staff numbers and research output while newer universities lag in research performance.

Future work will be designed to obtain data on input factors and to benchmark research outputs across various countries with a similar national strategy to promote world class research performance. A discipline-level analysis that compares total research performance along the lines of the research assessment exercises in the UK or Australia may be carried out given sufficient performance data.

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REFERENCES

- Abbott, M. and Doucouliagos, H. (2004). Research output of Australian universities. *Education Economics*, 12(3): 251–265. <https://doi.org/10.1080/0964529042000258608>.
- Abudayyeh, O., Dibert-DeYoung, A. and Jaselskis, E. (2004). Analysis of trends in construction research: 1985–2002. *Journal of Construction Engineering and Management*, 130(3): 433–439. [https://doi.org/10.1061/\(asce\)0733-9364\(2004\)130:3\(433\)](https://doi.org/10.1061/(asce)0733-9364(2004)130:3(433)).
- Beerkens, M. (2013). Facts and fads in academic research management: The effect of management practices on research productivity in Australia. *Research Policy*, 42(9): 1679–1693. <https://doi.org/10.1016/j.respol.2013.07.014>.
- Brochner, J.A.N. and Bjork, B.C. (2008). Where to submit? Journal choice by construction management authors. *Construction Management and Economics*, 26(7): 739–749. <https://doi.org/10.1080/01446190802017698>.
- Butler, L. (2003). Explaining Australia's increased share of ISI publications: The effects of a funding formula based on publication counts. *Research Policy*, 32(1): 143–155. [https://doi.org/10.1016/s0048-7333\(02\)00007-0](https://doi.org/10.1016/s0048-7333(02)00007-0).
- Canas-Guerrero, I., Mazarron, F.R., Calleja-Perucho, C. and Pou-Merina, A. (2014). Bibliometric analysis in the international context of the "construction and building technology" category from the Web of Science database. *Construction and Building Materials*, 53: 13–25. <https://doi.org/10.1016/j.conbuildmat.2013.10.098>.
- Canas-Guerrero, I., Mazarron, F.R., Pou-Merina, A., Calleja-Perucho, C. and Suárez-Tejero, M.F. (2013). Analysis of research activity in the field "engineering, civil" through bibliometric methods. *Engineering Structures*, 56: 2273–2286. <https://doi.org/10.1016/j.engstruct.2013.08.038>.
- Chau, K.W. (1997). The ranking of construction management journals. *Construction Management and Economics*, 15(4): 387–398. <https://doi.org/10.1080/014461997372953>.
- Colman, A., Dhillon, D. and Coulthard, B. (1995). A bibliometric evaluation of the research performance of British university politics departments: Publications in leading journals. *Scientometrics*, 32(1): 49–66. <https://doi.org/10.1007/bf02020188>.

- Construction Industry Development Board (CIDB) (2015). *Construction Industry Transformation Programme 2015–2020: Driving Construction Excellence Together*. Kuala Lumpur: CIDB.
- Construction Research Institute of Malaysia (CREAM) (2012). CIDB/CREAM: Construction R&D, Innovation and Commercialisation. Kuala Lumpur: CREAM.
- Fu, J., Frietsch, R. and Tagscherer, U. (2013). Publication activity in the Science Citation Index Expanded (SCIE) database in the context of Chinese science and technology policy from 1977 to 2012. *Fraunhofer ISI Discussion Papers: Innovation Systems and Policy Analysis No. 35*. Karlsruhe, Germany: Fraunhofer Institute for Systems and Innovation Research (ISI).
- Gundes, S. and Aydogan, G. (2016). Bibliometric analysis of research in international construction. *Canadian Journal of Civil Engineering*, 43(4): 304–311. <https://doi.org/10.1139/cjce-2015-0127>.
- Hirsch, J.E. (2005). An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences of the United States of America*, 102(46): 16569–16572. <https://doi.org/10.1073/pnas.0507655102>.
- Johnes, G. (1990). Measures of research output: University departments of economics in the UK, 1984–8. *The Economic Journal*, 100(401): 556–560. <https://doi.org/10.2307/2234141>.
- Jurajda, S., Kozubek, S., Munich, D. and Skoda, S. (2017). Scientific publication performance in post-communist countries: Still lagging far behind. *Scientometrics*, 112(1): 315–328. <https://doi.org/10.1007/s11192-017-2389-8>.
- Malaysian Science and Technology Information Centre (MASTIC) (2013). *Malaysian Science, Technology and Innovation (STI) Indicators Report 2013*. Putrajaya: Ministry of Science, Technology and Innovation (MOSTI).
- . (MASTIC) (2008). *Malaysian Science and Technology Indicators 2008 Report*. Putrajaya: MOSTI.
- Martí-Vargas, J.R., García-Taengua, E., Hale, W.M., ElBatanouny, M.K. and Ziehl, P.H. (2015). Bibliometric analysis of Web of Science-indexed papers on concrete segmental bridges. *PCI Journal*, 60(1): 118–133.
- Moed, H.F. (2007). The future of research evaluation rests with an intelligent combination of advanced metrics and transparent peer review. *Science and Public Policy*, 34(8): 575–583. <https://doi.org/10.3152/030234207x255179>.
- Rojas-Sola, J.I. and de San-Antonio-Gomez, C. (2010). Bibliometric analysis of Spanish scientific publications in the subject construction and building technology in Web of Science database (1997–2008). *Materiales de Construcción*, 60(300): 143–149. <https://doi.org/10.3989/mc.2010.59810>.
- Seglen, P.O. (1997). Why the impact factor of journals should not be used for evaluating research. *British Medical Journal*, 314: 498–502. <https://doi.org/10.1136/bmj.314.7079.497>.
- Shaari, S.N. (2003). *Survey on the Usage of Industrialised Building Systems (IBS) in Malaysian Construction Industry*. Kuala Lumpur: CIDB.
- Suryani, I., Yaacob, A., Hashima, N., Rashid, S.A. and Desa, H. (2013). Research publication output by academicians in public and private universities in Malaysia. *International Journal of Higher Education*, 2(1): 84–90. <https://doi.org/10.5430/ijhe.v2n1p84>.
- Swinbanks, D. and Nathan, R. (1997). Western research assessment meets Asian cultures. *Nature*, 389: 113–117. <https://doi.org/10.1038/38088>.

- Teng, C.L., Zuhariah, M.N., Ng, C.S. and Goh, C.C. (2014). Bibliography of clinical research in Malaysia: Methods and brief results. *The Medical Journal of Malaysia*, 69: 4–7.
- Thomson Reuters (2016). Essential science indicators database, 1 January 2000–31 December 2010. Available at: <https://esi.incites.thomsonreuters.com> [Accessed on 1 December 2016].
- . (2008). *Using Bibliometrics: A Guide to Evaluating Research Performance with Citation Data, Whitepaper*. Toronto: Thomson Reuters.
- Utama, W.P., Chan, A.P., Zahoor, H. and Gao, R. (2016). Review of research trend in international construction projects: A bibliometric analysis. *Construction Economics and Building*, 16(2): 71–82. <https://doi.org/10.5130/ajceb.v16i2.4866>.
- Webster, J. and Watson, R.T. (2002). Analyzing the past to prepare for the future: Writing a literature review. *MIS Quarterly*, 26(2): xiii–xxiii.
- Worthington, A.C. and Lee, B.L. (2008). Efficiency, technology and productivity change in Australian universities, 1998–2003. *Economics of Education Review*, 27(3): 285–298. <https://doi.org/10.1016/j.econedurev.2006.09.012>.
- Zainab, A.N., Edzan, N.N., Abrizah, A., Koh, A.P., Hazidah, N.A. and Asilah, N.N.N.S. (2012). *Malaysian Scientific Performance in the Web of Science 2001 to 2010*. Putrajaya: Malaysian Citation Centre, Ministry of Higher Education.
- Zyoud, S.H., Al-Jabi, S.W., Sweileh, W.M. and Awang, R. (2014). A bibliometric analysis of research productivity of Malaysian publications in leading toxicology journals during a 10-year period (2003–2012). *Human and Experimental Toxicology*, 33(12): 1284–1293. <https://doi.org/10.1177/0960327113514101>.