KNOWLEDGE EVOLUTION

and Scholarly Quantification of Collaborative Research in Project Management

ABSTRACT: Both as professional means of business and organisational success and growth and as an area of research, project management has been expanded not only to various sectors, industries and organisations but also across regional and international boundaries. Since the knowledge and practices of project management vary across industries, application areas and regions, collaboration among scholars and practitioners in project management research that transcend regional borders can simultaneously yield scholarly competence and contribute towards knowledge evolution. Similarly, this type of collaboration can provide them access to over a wide range of research datasets, trends, techniques, knowledgebase and methodologies enabling greater exchange of knowledge, innovation and research excellence. Both the economic imperative demands and enrichment of individual's command of resources and techniques to address increasingly interdisciplinary research issues in project management have triggered an upsurge in intra- and inter-country collaborative research trends. To date, the most obvious measurement of international collaboration is quantified from the metadata available in research publications by using methods provided in bibliometrics. Using this meta-information (e.g., affiliations and keywords), accompanying scholarly publications in digital libraries, and bibliometric approach, this study attempted to understand and quantify the research competencies and contributions of different types of collaborative research, topical knowledge evolution, trends of both local and global collaborations, and their impact on research outcomes in project management research.

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1 Introduction

From the historical perspective, project management has been exercised for thousands years, evidently, from the construction of pyramids, Great Wall of China, Greek and Roman architectures, the Hoover Dam project in Nevada, USA in 1930s, Manhattan project in 1940s, Polaris project by the US Navy in 1950s, Apollo moon landing project in 1960s to large engineering and construction megaprojects of the current century. On one side, the diverse, multifaceted professional field of project management including its systematic structures, tools, techniques and principles has longstanding history of applications to complex projects by different organisations. On the other, it has successfully drawn attentions from the researchers and scholars as an academic field in regards to theoretical research, planning oriented techniques, and application of engineering science and optimisation theory (Söderlund, 2004). Hence, both as a profession and a scholarly research arena, project management achieves continuous growth and development by finding new industries and application areas in different countries. Projects, depending on applications and organisational differences, exhibit considerable variations and so do the project management knowledge and practices among industries, organisational-application areas and countries (LH Crawford, 2001). Considering challenges to identify clear theoretical background for project management, scholars draw cross-disciplinary theories from social science, psychology, business administration, organisation theory, management, decision sciences, operation management, engineering (Jugdev, 2008) and network science (Mok, Shen, & Yang, 2015). Subsequently, the research trends in project management are divergent.

Despite considerable interests have been given into analysing the research trends (Lynn Crawford, Pollack, & England, 2006; Padalkar & Gopinath, 2016) and predicting the emerging trends (Uchitpe, Uddin, & Lynn, 2016; Winter, Smith, Morris, & Cicmil, 2006) in project management research, research collaboration patterns and trends across geographically dispersed organisations and countries including their impacts on research productivity and evolution of research topics are yet to be explored and have drawn little attention from the scholars. It is widely perceived that research collaboration is beneficial for increased productivity, technological innovation and regional economic development with the help of sharing knowledge, expertise and resources, leading to the development of numerous policy-driven initiatives to bring geographically dispersed scholars together and forming inter-disciplinary research groups (Katz & Martin, 1997). Therefore, besides its epistemic significance, international collaborative research observes a great deal of upsurge both in regards to quantity of publications and inclusions of research domains and disciplines (W. Y. Low, Ng, Kabir, Koh, & Sinnasamy, 2014). Further, research collaboration delivers both tangible (i.e., flow of funds, researchers and authors as human capital) and intangible (i.e., social trends, shared goals, structural symmetry, and high degree of interactivity, interdependence, and knowledge-flow) benefits to address complex research issues (Edler, Cunningham, & Flanagan, 2009). Despite its importance, international collaborations exert disproportionate influences from the scholarly enterprises of the participating countries and is shaped by factors like geographic proximity, politics and language (Subramanyam, 1983). Collaboration also conveys positive impacts in regards to wider public knowledge perspective since knowledge is better transferred and comingled in this way (Adams, 2012). Consequently, international collaborations take different forms including data sources sharing, exchange of mails and ideas in international conferences or articles and visiting foreign laboratories. However, for decades, co-authorship turned out to be a commendable proxy method and the most tangible aspect of international collaborations. With the help of co-authored UK-USA publications, Jonathan Adams demonstrated that international collaborative research tends to achieve more citation and participated researchers and countries can gain more in comparison to what they would have gained individually (Adams, 2006). Quantitative and statistical evaluations of publications and citation data, known as bibliometrics which is a term first coined by Belgian librarian Paul Otlet in 1934 (Rousseau, 2014), provide methods not only to analyse the structure of interdisciplinary research trend (Choudhury & Uddin, 2016) but also quantify collaboration trends (He, 2009).

Bibliometrics provides essential methods to investigate and evaluate scholarly communications found in the scholarly documentations. It is also an important method to quantitatively evaluate the research performance by policymakers, administrators, librarians and researchers themselves. In the modern research and scientific development area, information dissemination is crucial to knowledge transfer, economic progress and social improvement. Bibliometrics supports quantifying this information through analysing the affiliations of academic and published documents. Among various bibliometric methods, co-word or keyword co-occurrence network is an important technique which is widely used for analysing the knowledge and intellectual structure including knowledge evolution (Ronda-Pupo & Guerras-Martin, 2012) of diverse research fields. This method is a content analysis technique that presumes frequency of a group of aggregated keywords can define the underlying research themes and co-occurrence patterns among these keywords can indicate the association pattern and correlation strength among various themes (Khasseh, Soheili, Moghaddam, & Chelak, 2017). In this study, we attempt to follow bibliometrics approach using the accompanying meta-information of scholarly articles to understand the scholarly contributions of different countries, trends, patterns and productivity of domestic and international collaborative research in project management. With the help of bibliometric analysis over affiliation information and co-word analysis using author-selected keywords, this study sought to quantify the scholarly input and knowledge evolution in regards to project management research during a period of 10 years (2006-2015).

2 Research Dataset and Method

2.1 Research Dataset

This study first extracts all articles from 'Scopus', a digital library, published between 2006 and 2015 (inclusive) in six major project management journals. The data extraction date was February 1, 2017. These six journals are – International Journal of Project Management; Project Management Journal; International Journal of Project Organisation

and Management; International Journal of Managing Projects in Business; International Journal of Information Systems and Project Management; and Journal of Modern Project Management. Few conference proceedings had been published in the special journal issues. This study excludes all those publications. After this refinement, finally, 1939 articles were considered in this study.
To explore trends in research collaborations and research topics, this study split the research dataset into two non-overlapping intervals considering the total duration: (i) 2006-2010 (inclusive); and (ii) 2011-2015 (inclusive). Such split supported the exploration of longitudinal changes in project management research in considerably smaller durations (i.e., 5 years) and therefore provided us a comprehensive and rigorous insight of underlying research evolution.

2.2 Research Method

2.2.1 Country-wise Contribution in Inter-Country (IC) Collaboration

An inter-country (IC) article could have a different number of authors from the participating countries. In one hand, the majority of the authors in an article may belong to one country except for the last one that may belong to a different country. On the other hand, an author of an IC article could have multiple affiliations from more than one country. Considering these, both the number of authors and the number of countries they belong are used in this study to measure the contribution of a country towards an IC article. This study assumes that if there are more authors from a country in an IC article then the contribution of that country to that IC article will be higher, and vice versa. The basic principle of quantifying the contribution of a country to an IC article is to find out the number or ratio of authors of that article from that country. The following formula can serve this purpose:

$$Con(c) = X_c + \sum_{n=2}^{\infty} \frac{MA_n}{n} \qquad \dots (1)$$

Where, Con (C) is the contribution of a country to an IC article, XC is the number of authors from country C having single affiliation and MA_n denotes the number of authors those have multiple (n = 2,3,4,...) country-level affiliations including country C. For an IC article, a value of three for MA_2 indicates that three authors of this article have affiliations in two countries at the same time. Of course, this article may have other authors except for these three authors. A further illustration of the calculation of this formula can be found in **Figure 1**.
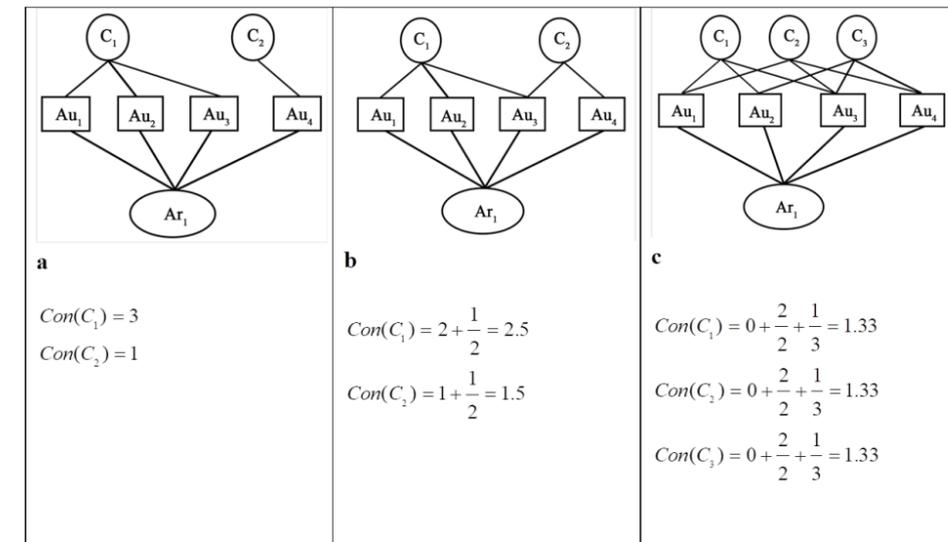

Figure 1. Illustration of how to quantify the contribution of a country to an IC article. 'Ar' stands for Article, 'Au' stands for Author and C stands for Country. (a) Authors do not have multiple affiliation. Ar1 has four authors who are from two countries; (b) An author (Au3) has affiliations in both C1 and C2; and (c) Au1 has affiliations in both C1 and C2, Au2 has affiliations in both C2 and C3, Au3 has affiliations in C1, C2 and C3, and Au4 has affiliations in both C2 and C3.

2.2.2 Normalisation of Citation Count

The citation count of an article indicates how many times that article had been cited by other scientific outlets since its first appearance in the scientific literature. The citation count of an article is significantly correlated with the duration of the availability of that article in the scientific literature (Vanclay, 2013). This study follows the following formula, proposed by Uddin and Khan (2016), to quantify the normalised citation count of an article.

$$Normalised\ Cotation\ Count = \frac{CC}{\frac{DayDifference}{365} + \frac{IN}{NI}} \qquad \dots (2)$$

Where CC indicates the citation count of the article, Day difference represents the number of days between the present date and the first of January of the next year of the article's publication year. IN and NI indicates the issue number and the number of issues of the journal (where the article was published) in the publication year.

3 Results and Observations

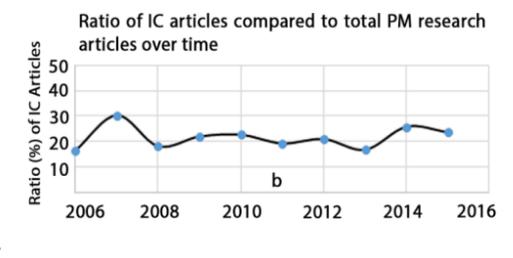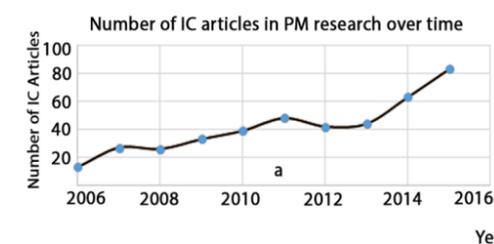### 3.1 Trends in Inter-country Collaboration

Figure 2 illustrates the development of international collaborations in project management research. In Figure 2a, we observe the growth pattern of the number of scholarly articles where the authors are from more than one country. The trend of the inter-country collaboration tends to be higher after 2013. On the other hand, we can observe steady pattern in regards to the ratio of articles from inter-country collaborations in comparison to the total published articles in project management research; however, a growth pattern is observable in the similar manner after 2013.

Figure 2: Trends in inter-country collaborations in project management research (a) Number of published inter-country (IC) articles over time (b) Ratio (in percentage) of published IC articles over total published articles in project management research.
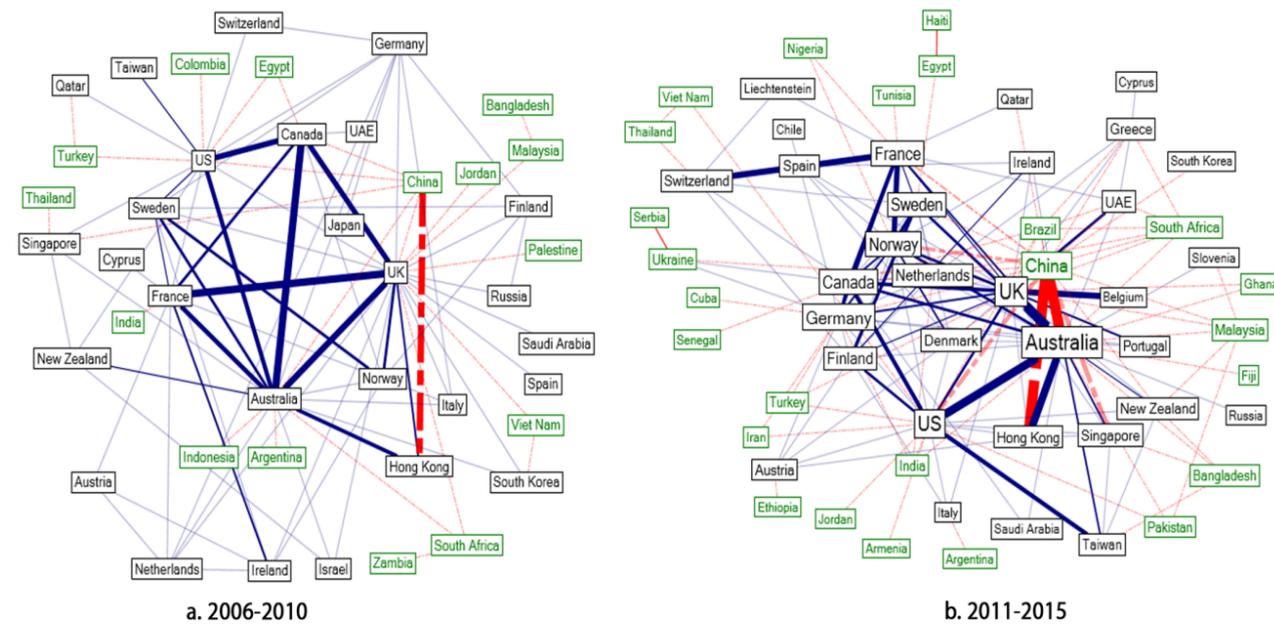
Figure 3. Network representation of inter-country collaborations in two different periods (a) 2006-2010 (inclusive); and (b) 2011-2016 (inclusive). A link between two countries indicates that two author from those two countries co-authored an article. The letter-size of the country's name signifies the number of publications (i.e., degree centrality in the network) and the edge width corresponds to the collaboration strength (i.e., degree of collaborations) between two countries on either end of the edge. The developing countries are labelled as navy-coloured whereas the developed countries as black-coloured. The collaboration between developing and developed countries is denoted by red-coloured edges those are dash-dot lines and between developed countries as navy-coloured edges those are solid lines

In **Figure 3**, this study demonstrated two network diagrams to represent the pattern of inter-country collaborations in project management research where the actors are different countries, extracted from the author affiliation information from the chosen articles in study, and a link between two countries indicates that authors from those two countries co-authored an IC article. Two network diagrams represent the intranational collaborations in two different periods where **Figure 3a** portrays the picture of inter-country scholarly collaborations during 2006-2010 (inclusive) and **Figure 3b** represents the interval 2011-2015 (inclusive). These figures also demonstrate two types of collaboration: (i) collaborations among developed countries (navy-coloured links) and (ii) collaborations between a developed and a developing countries or two developing countries. The former is denoted by navy-colored solid lines and the latter is denoted by red-coloured dash-dot lines. The developed countries are black-lettered whereas the developing ones are green-letterd. The size of the letters in a country's name denotes their degree centrality in the network (i.e., number of collaborative articles) and

the width of the links denotes the collaboration strength or the degree of collaboration.
From **Figure 3a**, we can observe that the dominant actors in international collaborations are Australia and the United Kindom followed by the United States of America. The next level prominent international collaborators are pre-dominantly the European countries, namely, France, Sweden, Germany and Netherlands including their north-american and asian counterparts, Canada and China respectively. On the other hand, in **Figure 3b**, we can observe the emergence of many new actor countries, apart from the dominating actors from the previous period, participated in inter-country scholarly contributions. Two of the most important events in the early 21st century have influenced many newcomers to participate in international collaborations and thus privileged from the technology, tools, and kowledge transfer and simultaneously gained competency enhancement. The first event is the extension of the European union in 2004 when eight former communist countries (i.e., Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia) from central and eastern Europe joined the.

organization. The second event is widely known as'Arab Spring' in 2010 when a series of protest movements were observed in countries of the middle-east and north Africa as an expression of deep-seated resentment at the brutality of state-owned security apparatus, unemployment and corruption. The consequence of these two events was observed as countries like Slovenia, Egypt and Tunisia promoting and advocating the norms and values of pluralist societies. Another reason for collaborative research growth among these countries is attributed to the project named Euro-Mediterranean Network for Economic Studies (EMNES) (University, 2014). The project objectives are to reinforce dialogue and promote socio-economic research and studies on Euro-Mediterranean partnership focusing employment creation and social inclusion of youth generation of the member countries. A new generation of giant and complex buildings and construction systems in the United Arab Emirates, reflecting the latest development in materials, design, sustainability, construction and IT technologies, has led the country's contribution towards project management research soaring high during the second interval (2011-2015). One such example is the world's tallest structure named 'Burz Khalifa' in Dubai.
Evidently, from **Figure 3b**, we observe that many under-developed countries have been playing important roles in international collaboration. Countries like Bangladesh, Pakistan, Haiti, Fiji demostrate significant contributions towards scholarly collaborations in project management research which is uncommon in other types of scientific research. The underlying reason behind this can be attributed to the rapid economic growth, national income enriched with natural mineral resources and exploitive comodities supported by Direct Foreign Investment (FDI) (Aliber, 1970). Engulfed with numerous social, political and economic problem due to the aggravation of poverty, civil and political unrest, inadequate infrastructure and unemployment rate have instigated the development project explosion executed by both governments and other private development agencies. To ameliorate the situation and bring long-anticipated positive changes in the living standard of the people in this developing countries, public and private sectors are partnering myriads
 infrastructural development projects.

These include roads, dams, rural electrification and water supply, schools, houses, hospitals, factories, wastewater facilities, transportation, agriculture, energy, information teconology and telecommunication based projects those beame imperative for the amelioration of socio-economic and political situation of these developing nations. Simulatenously, 'Millenium Development Goals' (MDG), an initiative by all the member countries of the United nations to eradicate half of the world's extreme poverty, control the HIV/AIDS spread and improving universal primary education and maternal health, has also prompted devloped nations to fund development projects in the developing regions and improving infrastructure quality through public private partnership. Consequently, collaborative research among the scholars from both developing and developed nations emerged to enhance the adequate institutional and administrative capacity for successful project execution. This study can further be extended to study and explore the underlying rationales behind such upsurge in international scholarly collaborations from the developed and under-developed nations.
From both networks, this study observed that during the earlier period (i.e., 2006-2010), the leading collaborators from the developed nations are UK, USA and Australia in pursuing collaborations with the devloping nations. European nations tend collaborate more with their continental counerparts within close proximity in comparison to the collaborations with other nations irrespective of being developed or under-developed. In regards to the collaboration among developing nations in project management research during this period, there is only a single example which include the collaboration between Malaysia and Bangladesh. However, during the later period, new participants emerged from the developed nations (e.g., France, Norway and Germany) to develop collaborations with the developing countries as the number of developing countries contributing towards project management research increased. This fact is also true in regards to collaborations among developing nations during the later interval 2011-2015 as the number increases by the collaborative research efforts among countries like Egypt, Haiti, Thailand and Vietnam. In both networks, it is common that the degree of research collaboration is stronger among developed nations. Despite being classified as

developing economies, China has become a prominent collaborator in regards to research collaboration with other countries irrespective of the country's economic condition being developed or developing. In particular, the collaboration between China and Hongkong is retrospectively strong and pervalent. The collaborative trends of China across different regions can be attributed to the following facts: (i) according to the report published by the United Nations Conerence on Trade And Development (UNCTAD), it is the third largest FDI (Direct Foreign Investment) receipient (133.7 billion USD in 2016) in the world after USA and UK since its economy is ranked second most lucrative for the multinational companies after USA (UNCTAD, 2017) and, (ii) the total volume of Outward Foreign Direct Investment (OFDI) of China has exceeded 200 billion USD in the last five years to enhance its presence in the global economy with a continuous search for prospective outlets to invest its over three trillion USD reserve (Tan, 2013).

3.2 Country-wise Contribution to Inter-Country Research Collaboration

To measure contributions of each domiant collaborators, we have used equation (1) described in the method section. In **Table 1**, we evaluate ten most highly contributing countries in international collaborative research in project management.

Country name	Contribution to IC article	
	Raw value	Value in %
Australia	152.10	12.30
UK	144.00	11.65
China	113.00	9.14
US	100.70	8.15
Canada	75.00	6.07
Hong Kong	75.00	6.07
France	69.90	5.65
Norway	51.50	4.17
Sweden	44.00	3.56
Finland	43.30	3.50

Table 1. 10 top countries and their percentage of contributions to the Project management research. IC article represents article written out of international collaborative research.

It is noteworthy that this study considered the entire dataset to compute the values in this table instead of dividing it into two non-overlapping intervals. From this table, we observe that the major contributors in international collaborative research of project management are still the high-income countries. As an OECD (Organisation for European Economic Co-operation) member country, Australia has demonstrated significantly high performance in international collaboration against its European counterparts. Evidently, countries with a very high human development index and commitment towards democracy and market economy, are the major contributors to the international collaborative research of project management. Simultaneously, the European and Scandinavian countries, evidently from the collaboration networks presented before those understand the project management work as a combination of industry-academia partnership (Walker et al., 2008), are also assisting the growth of international collaboration in project management research. Further, these international collaborations from the developed countries promote the sharing of resources, technologies, project management best practices, tools, techniques, expertise among developing nations as well.

In **Figure 4(a)**, we graphically demonstrate the ratio of contributions by different countries in international collaborative research which supports the pareto principle, named under famous Italian economist Vilfredo Pareto, also known as the 80/20 rule.
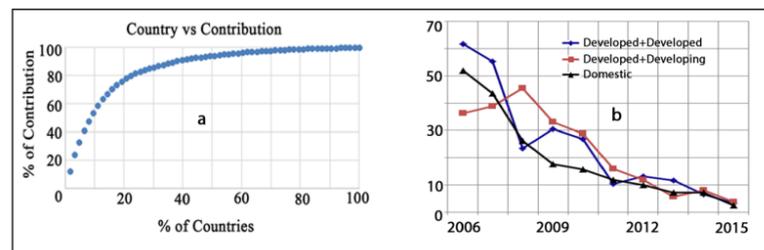

Figure 4. (a) 80/20 distribution of countries and their contribution (in percentage %) in international collaborative research in project management. (b) The average rate of citation count of articles published in collaborative research. Three types of collaboration are defined in this figure, (i) collaboration between developed countries, (ii) collaboration between developed and developing countries, and (iii) domestic collaboration as the collaboration among researchers from a single country

From this figure, we observe that 80% of the contribution in international collaborative project management research comes from 20% of the countries in the world. Mathematically, the Pareto principle is roughly followed by the power-law distribution for a particular set of parameters. In Figure 4(b), this study analysed the average citation count per article published as a result of collaboration. From this visual representation, it is interestingly important that co-authored articles, published in regards to project management research where authors are representatives of both developing and developed nations, tend to achieve more citations and wider acceptability. The underlying reasons can be attributed to the following facts: (i) most high profile projects are more likely to be international and in mega-projects, undertaken by the governments of developing economies, due to the stringent conditions of the donors, it is more likely to engage foreign bidders and contractors, (ii) international collaboration between developing and developed nations is the only way forward for the researchers in

developing countries to improve the quality, context, coverage and impacts of articles, due to the lack of financial resources, peer-review systems, management and operational guidelines of regional journals from developing nations (W.-Y. Low & Ng, 2011), and finally, (iii) researchers already identified that improved research output in developed economies is attributed to the international collaborations (Adams, 2013). It is noteworthy that the number of published articles as a result of collaborative research among developed economies surpassed the number of articles published in collaboration of developing and developed nations. However, the number of articles published as results of domestic or single-country collaborations outnumbered other collaborative research. In Figure 5, we also provide a heat-map of the world containing a geographical distribution of each country's contribution in regards to the number of author-contributions from that country, computed from the affiliation information of articles, in collaborative project management research.
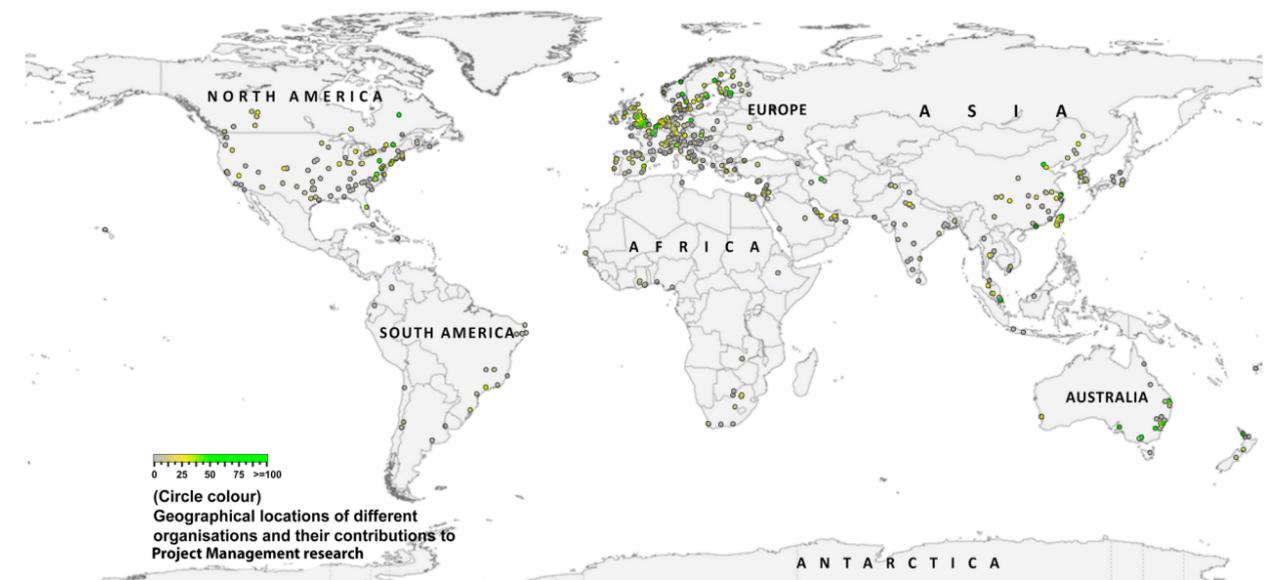

Figure 5. Geographical locations of different organisations and their level of contribution towards PM research. The number of times an organisation has been affiliated with articles represents the level of contribution of that organisation.

3.3 Inter-country versus Single-country Collaboration

This study also attempted to quantify the international collaboration patterns in comparison to the local or domestic collaborations where authors from the same country co-author a scholarly article in project management. To evaluate the scholarly contributions of inter-country collaboration against single-country collaborations, we consider the citation count, the number of author-selected keywords, the length of the article, and the total number of authors per article as unit of measurements. In **Table 2**, we demonstrate the comparable picture of single-country collaborations and inter-country collaborations considering these four units of measurement. In this table, we have used equation (1.2) to normalize the citation count values.

Items	Article type	Mean	Significance of mean difference (from t-test, 2-tailed)
Citation count	Single-country article	2.54	0.000
	IC article	3.37	
Number of keywords	Single-country article	4.50	0.109
	IC article	4.60	
Article length	Single-country article	12.33	0.023
	IC article	13.02	
Number of authors	Single-country article	2.16	0.000
	IC article	3.05	

Table 2. Comparison of citation count, number of keywords, article length and number of authors between inter-country (IC) and single-country collaborative articles

It is apparent from Table 2 that in regards to scholarly contributions, inter-country collaboration is more productive than single-country collaborations. Considering the p-values from t-tests, it is apparent that citation count, article length and the number of authors per article of inter-country collaboration are significantly different from the single-country collaborative research in project management (i.e., p < 0.05). Conversely, in regards to author-selected keywords, the knowledge entities those represent the thematic context of the research article, both types of collaborations almost equally productive.

3.4 Evolution of Research Topics

In academic research, the scholarly concepts or topics are conceptualised by the use of appropriate keywords (Choudhury & Uddin, 2016), also known as descriptors of the scholarly articles. These descriptor keywords are the knowledge entities abstracting the thematic context of the research work. Scholars use these keywords to relate their work to the concepts of research fields they are interested in. Therefore, author-selected keywords, accompanying each article, represent the core concept and summarise the focal topics of the respective article. Consecutively, a group of scholarly articles in a particular domain can develop a conceptual network of keywords where the author-selected keywords work as nodes and their co-appearances or co-occurrences in the same article denote links among them. The underlying reason is that co-occurring keywords within an article are considered to be thematically related and a keyword network conceptualises the pattern of relations among different research themes or topics. Further, keyword network analysis is an efficient analytical technique that can complement the traditional research methods by increasing the objectivity of the corresponding research (J. Kim & Jang, 2017).

In this study, we extracted the author-selected keywords accompanying the research articles used in this study to analyse the topical trends in project management research. In **Figure (6-7)** , we provide two visualisation maps of these keywords considering two different time periods: (i) 2006-2010 (inclusive) and (ii) 2011-2015 (inclusive). Two images in **Figure (6)** represent the topic evolutions in single-country (i.e., domestic) collaborative research in these time periods whereas **Figure (7)** represents the evolution of research topics in project management research considering inter-country (i.e., international) collaborations during these time periods. These visualisation maps were drawn with the help of VOSviewer (Van Eck & Waltman, 2010) that constructs such maps considering a similarity matrix as input. This similarity matrix, obtained from co-occurrences or occurrences of items, denotes similarity between keywords according to their association strength. Using the concept of association strength, the similarity between two keywords is computed as follows:

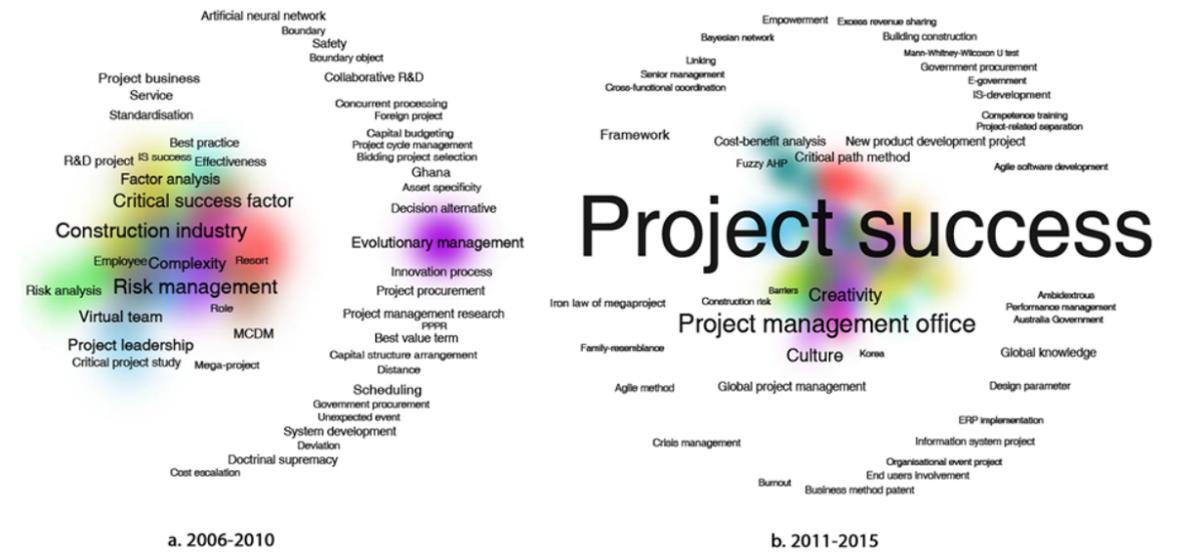$$S_{xy} = \frac{c_{xy}}{w_x w_y} \qquad \ldots (3)$$

Figure 6. Trends and evolutions of research topics in two different periods: 2006-2010 (left) and 2011-2015 (right) considering domestic or single-country collaborative research in project management
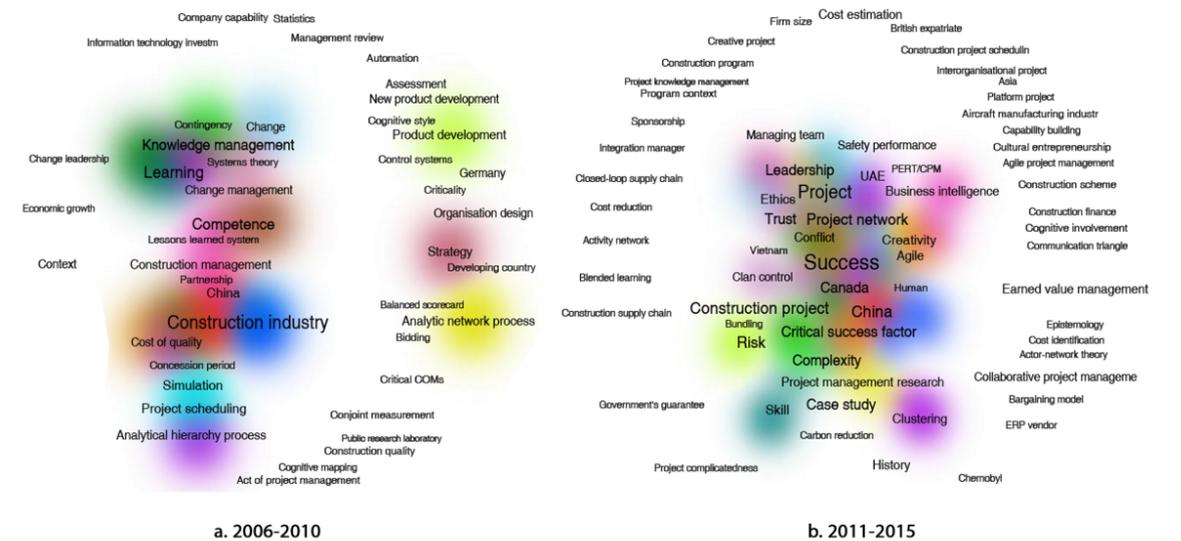

Figure 7. Trends and evolutions of research topics in two different periods: 2006-2010 (left) and 2011-2015 (right) considering inter-country collaborative research in project management.

where S_xy represents similarity between keyword x and y, C_xy denotes the number of co-occurrences of keywords x and y, and w_x ⟦,w⟧_y denote the total number of occurrences of these keywords in this study. Hence, the size of the keyword represents the magnitude of articles related to that particular topic. Among different ways, VOSViewer is capable of displaying bibliometric maps (e.g., label view, density view, cluster density view and scatter view), the keyword maps in **Figure (6-7)** were plotted in cluster density view. The mapping technique of VOSViewer constructs a two-dimensional map of n items where the distance between any two items attempts to reflect their similarity S_xy accurately. Items with high value of S_xy are placed close to each other and with low S_xy value they are far from each other. In cluster density view, items are also assigned into clusters according to their similarity measure and each cluster is assigned a distinct colour. The colour of a keyword in cluster density view is close to a certain cluster if there are a large number of other keywords belonging to the same cluster in that particular keyword's neighbourhood. For details of VOSViewer's functionalities, operations, and colouring scheme, interested readers are directed to a study by van Eck & Waltman in (Van Eck & Waltman, 2010).

The research topics in these maps, represented by keywords, are self-explanatory and demonstrate the perspective of research importance. For example, in regards to domestic (i.e., single-country) collaborative research, scholars were more engaged within traditional project management aspects like 'critical success factor', 'research and development (R&D) projects', 'multi-criteria decision making (MCDM)', and 'risk management'. Designing, controlling and managing project organisations in evolutionary perspective, known as evolutionary management where firms are considered as self-changing, self-evolving and self-organising social institutions (Malik & Probst, 1984) and 'standardisation' have also drawn attention from different collaborators within this type of collaborative research. Few topics of classical project management, such as 'project success' and 'cost-benefit analysis', always gained importance in the research work by the domestic collaborators irrespective of time. These also include 'project scheduling', 'government procurement' and 'information system development'.

During 2011-2015, single country collaborative research also focused on developing new project management methodologies and frameworks like 'agile method', 'break fix model of mega project management', 'domino theory', 'Myers-Briggs indicator', 'Bayesian network', and 'alliance contract'. These can be attributed to the introduction of complex mega-projects emerged both locally and globally as the combined multi-national projects. Some example include the construction of terminal 5 at Heathrow airport, Olympic park for London 2012 Olympic games (Brady & Davies, 2014), the construction of national museum in Canberra (Hauck, Walker, Hampson, & Peters, 2004) and a 3900 km long gas pipeline construction project from eastern border of Turkey to Austria through Bulgaria, Romania and Hungary (Kardes, Ozturk, Cavusgil, & Cavusgil, 2013).

'Ambidexterity' is another topic that has gain considerable interest in single-country collaborative research. In dynamic project management environments, ambidexterity refers to the ability to develop and follow a plan and concurrently, the ability to adapt to a changing environment. Ambidexterity is defined both at the project manager's level (Aubry & Lièvre, 2010) and organisation level (Liu & Leitner, 2012). Apart from the methodological improvements, observed in single-country collaborative research during 2011-2015, in regards to the research context, the visualisation maps in Figure (6) also represent some elementary differences. For example, in the earlier period (i.e., 2006-2010) of this type of research, scholars were predominantly concerned about project risks, project business, research and development (R&D) projects (e.g., collaborative or non-collaborative), budgeting and cash flows, innovation process for new product development and traditional project life cycle management. Among these, project business is an important concept that simultaneously acknowledges the role of projects in undertaking business and vice versa. Artto & Wikström in their biblimetric study defined project business in regards to a section of business related to projects, either directly or indirectly, with a view to attain certain objectives of firm(s) or virtual firm(s), collaboration of different firms with different objectives (Artto & Wikström, 2005).

According to the authors, three principal concepts epitomizing project business are namely (i) part of business,(ii) objectives and finally, (iii) firms. The research in this period also stressed on virtual team formation, a group of geographically dispersed individuals pursuing similar objectives, and project leadership. On the other hand, in the later period (i.e., 2011-2015), researchers from single-country collaborative research were more engaged in information system/information technology based projects, cost-benefit analysis of projects and performance evaluation of innovativeness or new product development process. It also involved the application of emergent social software platforms within enterprise intranet to facilitate improved and effective communication and information sharing within the companies and their customer-bases (McAfee, 2006). Scholars in domestic collaborative research also emphasised on global project management to meet the new project management requirements in the 21st century in the context of global market place (Kini, 2000). Due to changes in customers' expectation, including low-costs, shorter construction periods, low-cost/high quality materials from suppliers around the globe and maintaining schedule in project delivery, companies need new organisational structure and accommodate critical functions (e.g., information system, supplier management and quality assurance) by leveraging global project management.

In regards to inter-country collaborative research, significant importance was given to competency, innovation or new product development, project scheduling to improve the communications in regards to completion of tasks in time and resource constrained projects, project strategy for the concrete definition of plans and goals, project knowledge management since appropriate knowledge is the pre-requisite of effective project management, changes in organisational design and defining methods and approaches for these change management and understanding project partnership. A substantial amount of project management was concerned regarding the construction industry that prompted the extended use of simulation technology. It also included construction quality control and construction management. Most importantly,

it is evident that international collaborative research in project management was also considering project management contexts of developing countries due to their economic growth. In regards to different project methods, we also observe enrichment through introducing Analytic Network Process (ANP), Analytic Hierarchical Process (AHP), conjoint measurement (Green & Rao, 1971) and critical COMs that combines four COMs including comprehension, competence, commitment, and communication those are evidently required for the success of large-scale construction projects (Ogunlana, 2008). Most interestingly from **Figure (7a)**, international collaborative research in the earlier stage during 2006-2010 introduced cognitive styles of decision making (Leybourne & Sadler-Smith, 2006) where keywords like 'cognitive mapping' and cognitive style' support this fact.

During the second period (i.e., 2011-2015) international collaborative research interests were shifted to project cost analyses whereas in the earlier period project scope and scheduling were discussed more. These three items form the iron triangle of project management. Keywords like 'cost estimation', 'cost reduction', 'cost identification' signify the amount of research in this regard. Complex projects at present are high-tech and capital intensive engineering projects with long duration that require firms to perform collaboratively across firm boundaries (Whyte, Stasis, & Lindkvist, 2016). This includes aircraft and railway manufacturing projects. This is evident from Figure (7b) containing keywords like 'aircraft manufacturing industry' and 'platform project'. Due to the adverse impact on climate change from rapid industrialization and increased number of construction and manufacturing projects, recently, researchers concentrate on green-house gas emission and carbon accountability for sustainability management. This has raised the issue of inter-governmental panel on climate change, carbon accounting (Stechemesser & Guenther, 2012) focusing on 'carbon reduction'.

As stated earlier that international collaborative research initiates information, resource, tools and techniques sharing from the competent economies to the developing ones, due to the changing project environment in regards to social, political and economic circumstances, project complicatedness was greatly increased.

Consequently, it raised the level of 'conflict' and 'project complexity' which is evident from **Figure (7b)**. To deal with the increased complexity of the present days' project, researchers tend to incline towards various new methods like 'PERT/CPM', Enterprise Resource Planning (ERP), Agile project management, Earned Value Management (EVM) and closed-loop supply chain those were not introduced in the earlier period. Earned value management is an ingrained technique that can be applied to the management of all capital projects irrespective of their industrial variances (Fleming & Koppelman, 2002) and it supports project control dimension of dynamic scheduling (Vanhoucke, 2013), especially in construction industry. Despite the reluctance in using this method by its core concept, it eventually unfolds every time a construction cost engineer put forth a project baseline plan. Closed loop supply chain differs from its classical form of forward supply chain by combining a reverse supply chain (Govindan, Soleimani, & Kannan, 2015) with the former to maximise the value creation within a system. Similarly, to accommodate changes, inherently embedded with today's complex projects in regards to budget, resource, schedule, competition and customer need, agile project management supports project managers with a view to manage the impact of complexity and uncertainty on projects. It recognises that creativity and learning are imperative to cohere with the project environment (Dybå, Dingsøyr, & Moe, 2014) and the map in **Figure 7(b)** also supports this argument by including keywords like 'Agile' and 'Creativity'. Project management and project leadership are two interlinked concepts since a project manager simultaneously need in one hand project management skills to help him/her plan and control the project in its lifecycle, and on the other, leadership skills to enable him/her influencing and lading the project teams, stakeholders and participants (Burke & Barron, 2014). With the growing number of popular, multi-billion, large-scale and complex mega-infrastructure projects those are usually initiated by different governments but implemented by public-private partnerships, the design, methodology, practice, culture and management aspects of projects epitomizes the complexity in project management (Van Marrewijk, Clegg, Pitsis, & Veenswijk, 2008).

. Due to the involvement of uncertainty, political motivation and a large number of partners in complex internal mega projects, topics like 'Collaborative Project Management', 'Integration Manager' and 'Project Management Research' have also gained considerable interest in this period. As the complexity of project rises, so does the conflict around project implementation effort. With the advent of cognitive decision making and influx of cognitive terms like 'Ethics', 'Trust', project managers are now making decision with the help of intuition and improvisation (Leybourne & Sadler-Smith, 2006).

One common keyword 'China' is visible in both maps of research trends in **Figure (7)**, the country which has observed very fast development for more than 30 years and the keyword 'construction industry' has played a vital role in this aspect. Rapid economic expansion, infrastructure and building space shortages observed during early and mid-90's have instigated numerous construction activities (Sjoholt, 1997) and experienced a continuous growth even during slow economic growth (Littlefair, 2016). Currently, China is recognised as the world's largest construction market which is attributed to the increased urbanisation and national-level commitments for resource conservation and reduction of green-house gas emission. There are three major types of construction workforces working as China's construction contractors: (i) state-owned enterprises (SOE, (ii) urban and rural collectives (URC) and finally, (iii) rural construction teams (RCT). Mounted competition in the local industry led Chinese firms increasingly involved in foreign contracts of engineering projects and reportedly, during 1979-2013, around 219,900 workers travelled overseas to pursue the role of civil contractors in the developing economies (Babatunde & Low, 2015). In the year 2013, Chinese construction industry reached a value amounted as over 1700 billion USD, accounting over 47% of the total construction industry value in Asia-Pacific region. According to Qi & Chen, three management paradigm changes have contributed this development: (i) using internal contract management by the construction companies to increase productivity, (ii) using marketing mechanism and competition in the industry to raise efficiency and finally (ii) relying on the innovation and management for construction projects (Qi & Chen, 2014),.

A new generation of construction structures reflects the growth of UAE's construction industry recently which had the opportunity to employ and adopt the international best practices of project management (Al-Hajj & Sayers, 2014). In the year 2013, Abu Dhabi government committed to a five-year plan for major developments focusing on healthcare, education, housing and strategic transport projects amounted at around 89 billion USD (Kerr, Ryburn, McLaren, & Dentons, 2013). Besides building hospitals and clinics, one of the major projects, undertaken by the government is the development of federal rail system which was tendered in 2012 with an objective to connect Dubai with capital Abu Dhabi by 2016 and followed by a pan-Gulf extension to connect Oman and Saudi Arabia with UAE.

A list of construction projects undertaken by Dubai municipality can be found in their websites that leads UAE as a major contributor in international collaborative project management as observed in the collaboration networks of this study.

Figure 8. Keyword associations in international collaborative research during (a) 2006-2010 and (b) 2011-2015, Keywords are coloured according to their occurrence rate with red being the highest number of occurrences found for one keyword, followed by green and blue labelled keywords. The black labelled keywords have the least significant occurrence rate. The link between keywords denotes their association and the width of the link denotes the number of co-occurrences.

a. 2006 - 2010

b. 2011 - 2015
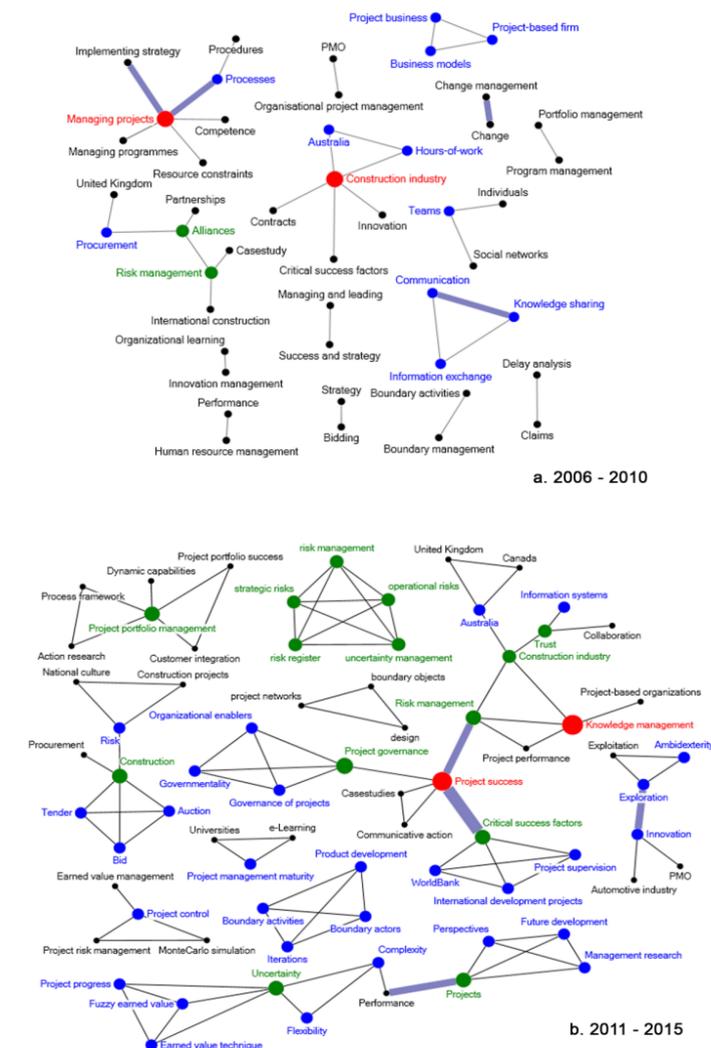
As mentioned earlier, VOSViewer attempts to cluster keywords according to their association strength and neighbourhood. In section one, we also pointed out the importance of co-word or keyword co-occurrence network that signifies the relation between two keywords representing two topics. In scholarly world, scientists hypothesise new research topic by encompassing concepts from multiple domains; for example, amalgamation of various concepts from physics, computer science and social science have contributed to the emergence of new topic named 'network science' (Choudhury & Uddin, 2016). Further, innovative scientific queries can now be answered through aggregation and association of concepts from interdisciplinary domains (van der Eijk, van Mulligen, Kors, Mons, & van den Berg, 2004). Therefore, as a content analysis technique, co-word is believed to not only discern the intrinsic and complex association among different concepts extracted from scientific literature but also model the dynamics of scholarly knowledge structures (Leydesdorff, 2015). The association pattern between author-selected keywords postulates new hypotheses and generates new topics of research. In **Figure (8)**, we present two such keyword associations emerged during two durations (i.e., 2006-2010 and 2011-2015) in international collaborative research to visualise the fluctuations of topical trends. Keywords in this figure are coloured according to their occurrence rates. Highly appeared keywords in most articles are coloured as red followed by green and blue whereas the black-labelled keywords are the least-occurred ones. The links between keywords denote their association or co-occurrence pattern where the width of the links denotes their association strength or number of co-appearances in articles. It is observable that density of this keyword networks and the association patterns of keywords signify the topic dynamics in inter-country collaborative research.

4 Discussion and Conclusion

From the perspective of both anecdotal and empirical evidences, it is noticeable that collaborative research is on the rise and, therefore, researchers suggest large scale collaborative research to improve credibility and efficiency of research (Ioannidis, 2014).

Further, according to Hunter & Leahey, normative and ubiquitious collaborative research prompts associations among science, policy and economic activity, importance of professional networks, and stimulation of innovation (Hunter & Leahey, 2008). Furthermore, collaboration is recognised as indispensable input for innovation and new product development success (Peng, Heim, & Mallick, 2014). Co-authorship in scholarly articles is the best-known measure of such collaborations. This study used meta-information of published articles, the primary and fundamental source providing information regarding the types of collaborations (i.e., intra or inter–country), from six prominent journals supporting project management research with a view to understand the underlying trends and quantify the collaboration outcome. **A major contribution of this study in relation to the collaboration is that articles from inter-country collaborations (i.e., IC articles) have higher citation count than non-IC articles.** The underlying reason behind the increased productivity in collaborative research is that research collaboration supports value propositions (Walker et al., 2008), enhances the quality of research, and enrich research sector by building capability and skills. Collaborative research partnership undertaken in scholarly research is a kind of business collaborations that provide mutual advantages to all partnering entities by sharing knowledge and resources in quest of solutions to both locally and globally relevant issues (Lau et al., 2014). Further, besides deciphering complex research issues it also deliver both economic and scientific benefits (vom Brocke & Lippe, 2015). Furthermore, by providing access to wider range of resources, funding, facilities, ideas, rich datasets and knowledge-bases, in one hand, international collaboration not only promotes rapid knowledge dissemination but also tends to elicit more citation (Adams, 2012). Evidently, this study observed the aforementioned facts with the help of bibliometric analysis in regards to collaborative research that transcends local boundaries.

With the help of both quantitative and statistical analysis to scholarly publications and their accompanying meta-information, one of the most important usages of bibliometric methods is the research performance evaluation that holds a greater importance for policy makers, administrators and researchers themselves.

Bibliometric approaches were applied in this study to analyse and quantify trends and patterns of collaborative research and evolution of research topics considering two types of collaborations (i.e., intra- and inter-country) in the project management research. These bibliometric methods can further be applied for the similar quantification purposes in other disciplines. Apart from both domestic and international research collaborations, this study also performed comparative quantifications of country-wise contributions in international collaborations.

Our bibliometric study found that, despite the lower number of articles from inter-country collaborative research in comparison to the total amount of publications in international journals of project management, there is an upsurge in international collaborations in project management research. We have also observed increased scholarly productivity in regards to citation count, article length and number of authors for articles resulted from international research collaborations. To understand the collaboration pattern and trends in two non-overlapping intervals with the help of network diagrams, this study observed that the major contributors of international collaborative research are the developed economies (e.g., North American and European countries); however, recently, many important actors emerged from the developing economies. Australia, being the major collaborator of international research in project management, has observed significant development in collaborative research. In summary, important findings of this study can be reiterated as follows: (i) collaboration is an increasing trend in project management research so is the case with the number of scholarly contributions, (ii) despite the imbalance in numbers, collaborations between developing and developed economies are emerging simultaneously with the collaboration trends among developed economies, (iii) Australia, UK and USA from the developed countries and China from the developing ones are the dominant collaborators, (iv) articles published in collaboration of authors both from developing and developed countries tend to achieve more citation and wider acceptability, and finally (v) knowledge, represented by the topical keywords representing research themes, evolves with the evolutionary pattern of collaborative research and contexts where the corresponding research is applied to.

Research collaborations among different nations and countries and associated government policies supporting these collaborations, promote technology and knowledge transfer, identify new information that can add value to the existing business process and practices, and integrate new knowledge with the accumulated ones gained by a single nation (Davenport, Davies, & Grimes, 1998). From this study, it can be perceived that collaborative research is beneficial where theories, concepts and methodologies supporting project management research in one country can be enriched and extended to enhance the applicability of the knowledge created in the academic process for practical implementation in real-life project environments in other countries.

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