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Giasolli, Robert; Groen, A. J.; Haak, Robert; Pieck, Martin

*Published in:*
Technological Forecasting and Social Change

*DOI:*
10.1016/j.techfore.2021.121075



*Publication date:*
2021

Technological Forecasting & Social Change 173 (2021) 121075

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

# Identifying Management of Technology and innovation (MOT) and Technology Entrepreneurship (TE) centers of excellence

Robert Giasolli [a,*], Dr. Aard Groen [a], Robert Haak [b], Martin Pieck [a]

[a] Center of Entrepreneurship, (UGCE), University of Groningen, United States
[b] Dutch Institute for Knowledge Intensive Entrepreneurship (NIKOS), University of Twente, the Netherlands

ARTICLE INFO

*Keywords:*
Technology entrepreneurship
Management of technology and innovation
Ranking
Bibliometric
Technology innovation

ABSTRACT

It has been over 15 years since the world's centers of research excellence in the management of technology and innovation (MOT) have been acknowledged. We have updated this area of interest through a new study on the current centers of excellence, furthering our investigation in the sub-field of technology entrepreneurship (TE). We based our study on the boundary conditions utilized in previous research, adding new metrics while retaining several of the old. We limited our data sample to peer-reviewed journal articles in recognized base journals. The centers' research nature and quality were assessed via a series of 37 metrics. We found 809 schools with publications in MOT-recognized base journals and identified 77 non-U.S. centers in Asia, Australia, Europe, South and North America and 21 U.S. centers that meet our criteria for research excellence. Further, a detailed analysis was conducted for the 21 U.S.-based schools, considering metrics such as the number of publications by researchers during the study period, the MOT publication history, editorships of the professors of the centers in the base journals, and number of articles. Similarly, we identified 17 International centers of TE excellence out of the 348 schools that published in TE. We provide tiered results of the top schools excelling in selected areas.

## 1. Introduction

Academic program rankings are important for programs and universities to attract quality students and receive funding to further its research objectives (US Department of Education, 2020; Avery et al., 2004). Large programs like schools of economics (Ideas, 2020; Berger and Scott, 1990; Hartley and Robinson, 1997; Tremblay et al., 1990; ARWU Ranking, 2020; QS Top universities, 2020; Times Higher Education, 2020; u-multirank, 2020), marketing (ARWU Ranking, 2020; QS Top universities, 2020; Times Higher Education, 2020; u-multirank, 2020; Siu, 1996; Niemi, 1988), and engineering (ARWU Ranking, 2020; QS Top universities, 2020; Times Higher Education, 2020; u-multirank, 2020; MINES ParisTech, 2009) are reviewed and ranked regularly by non-for-profit and for-profit organizations. The purpose of these rankings varies but typically includes: recruitment of faculty and students, attraction of government and philanthropic funding, and accolades or advancement of high producing researchers. However, programs in emerging fields like the management of technology and innovation (MOT) are rarely ranked. Scholarly works provide the foundation for a program's reputation and form a substantial part of most ranking systems (Guffy & Harp; 2014; Steward and Lewis, 2010; Bapna and Marsden, 2002; Vastag and Montabon, 2002; Chua et al., 2002). The MOT field has continued to grow over the past 20 years, due to which we extend an earlier MOT work (Linton, 2004) and take a second look at the field with many of the original metrics and some new ones.

The MOT field is perennially emergent because of the nature of technology being inherently so. The significance of MOT has been recognized ever since the field of management was initiated (Thimm, 1992). Its perceived importance increased in the 20th century with foundational works on business cycles (Kondratiev, 1984; Schumpeter, 1939) and economics (Solow, 1957) that were furthered by works in the competency framework (Hamel and Prahalad, 1990) and dynamic capabilities (Teece, 2007; Teece et al., 1997). The MOT field, if anything, is even more important today due to its application in the changing global economy. The interest in identifying MOT centers of knowledge is high due to its specific value for firms, industries, and economic regions in the current Industry 4.0 pivot (Mariani and Borghi, 2019) and, more recently, for preparing firms and economies to meet the challenges of the COVID-induced "low touch" world economy.

It has been 17 years since the last study identified and ranked MOT centers of excellence. Thus, we have identified, provided metrics, and ranked centers of excellence in an emergent and inter-disciplinary field

* Corresponding author.
*E-mail address:* rmgiasolli@miners.utep.edu (R. Giasolli).

https://doi.org/10.1016/j.techfore.2021.121075
Received 16 December 2020; Received in revised form 9 May 2021; Accepted 23 July 2021
Available online 10 August 2021

(MOT). We also provide insights into analyzing technology entrepreneurship (TE) as a sub-field of MOT, and we conduct our study by considering this field's global knowledge production. Due to our own interest, we also provide a more detailed analysis of United States-based schools in MOT. We found that there is a large number of universities globally that publish in the MOT (809) and TE fields (348).

We identified 77 non-U.S. schools worldwide that meet an established criterion determining a center of excellence in MOT. We identified centers of excellence in MOT in Asia, Australia, Europe, South America and North America; at least 297 schools in the U.S. have published in MOT-recognized base journals of the field. Further, we provide a detailed analysis of the 21 schools in the U.S. that meet our criteria for MOT excellence. Moreover, we found a high degree of similarity between schools in the earlier study and ours. Finally, we identified 348 schools worldwide that have published in the MOT sub-field of TE, 17 schools that meet our criteria to be worldwide centers of TE, and the leading researchers in the TE field. One question from the previous study was regarding the stability of the ranking system. Though we add more metrics and rankings in our study, when we compare the most granular effort in both the papers, we find the U.S. centers of excellence to be highly consistent (see Discussion).

## 2. Literature review

There are many sides to the debate on the education-ranking algorithms (ARWU Ranking, 2020; QS Top universities, 2020; Times Higher Education, 2020; u-multirank, 2020; Marope and Wells, 2013). Ranking studies and their associated ranking systems are important and provide the impetus for some academic programs to modify their internal behaviors and increase their standing on the ranked list (Goodall, 2013). Linton (2004) asserted that the MOT field is immature, pointing to just a single MOT pedagogical study (Mallick and Chaudhury, 2000) for evidence. Since then, the field's pedagogy has progressed, first with Yanez et al. (2010) study, and then a special issue in the Technological Forecasting and Social Change journal (Berg et al., 2015). Further evidence of the evolution of the field can be found in Table 1a. Here, we have included the impact factors along with the foundation dates of each journal. Many of the journals have greatly increased their impact factor. For example, the *Journal of Product Innovation Management* had an impact factor of 1.696 in 2014, which grew to 5.270 in 2020. The highest impact journal in the MOT field in 2020 is the *Technological Forecasting and Social Change*, which rose from 3.308 in 2014 to 5.846 in 2020. One of the specialty journals, *Research Policy*, is now on the Financial Times' 50 Best Journals list.

As in previous studies, we found that all academic and many well-known research ranking systems are based on peer-reviewed journals (Financial Times, 2020; ARWU Ranking, 2020; QS Top Universities, 2020; Times Higher Education, 2020; u-multirank, 2020; Guffy & Harp, 2014; Linton, 2004). Many authors outline the challenges involved in developing and using metrics and rankings, such as a focus on research output (ARWU Ranking, 2020; Cancino et al., 2017; Sahoo et al., 2016; Ratinho, 2015; Linton, 2004; Cheng et al., 1999; Liker, 1996). While a more comprehensive reference list for the MOT metrics is provided in Table 2a, early studies used one or two aspects of journal publications, such as the number of articles authored (Baden-Fuller et al., 2000), the total number of citations for all articles authored (Paxton and Bollen, 2003), and the citations per article (Mabry and Sharplin, 1985). The initial MOT ranking provided over 20 such measures that included the abovementioned ones, alongside many others, such as the number of articles per active researcher and number of active authors in the group (Linton, 2004). We add to that by investigating the number of centers of excellence in each country and the number of associate or editor-in-chief positions held by these specific centers of excellence. As with the previous studies (Athey & Plotnicki, 2000; Bradbard & Niebuhr, 1987; Grover et al., 1992; Huang & Hsu, 2005; Im et al., 1998; Jackson & Nath, 1989; Lending & Wetherbe, 1992; Remus, 1991; Shim & English, 1987; Shim et al., 1991; Trower, 1995; Vogel and Wetherbe, 1984; Chua et al., 2002; Linton, 2004) we limit our data sample to peer-reviewed journal articles produced by authors at universities in the recognized base journals since they continue to be essential for reputation, professorial tenure, and promotion standards (Dennis et al., 2006). We utilize metrics from a previous study (Linton, 2004) and add several of our own; a

**Table 1a**
Recognized Base MOT Peer Review Journals, their 2019–2020 Impact Factor, and the year the journal originated.

| Journal Name | Origin Year | 2019–2020 Impact Factor |
|---|---|---|
| Technological Forecasting and Social Change | 1969 | 5.846 |
| Technovation | 1981 | 5.729 |
| Research Policy | 1971 | 5.351 |
| Journal of Product Innovation Management | 1984 | 5.270 |
| R & D Management | 1970 | 2.908 |
| IEEE Transactions on Engineering Management | 1954 | 2.784 |
| Technological Analysis and Strategic Management | 1989 | 1.867 |
| Journal of Engineering and Technology Management | 1984 | 1.957 |
| International Journal of Technology Management | 1986 | 1.348 |

**Table 1b**
Recognized Base TE Peer Review Journals, their 2019–2020 Impact Factor, and the year the journal originated.

| Journal Name | Origin Year | 2019–2020 Impact Factor |
|---|---|---|
| Entrepreneurship Theory and Practice | 1976 | 10.750 |
| Journal of Business Venturing | 1985 | 7.590 |
| Technological Forecasting and Social Change | 1969 | 5.846 |
| Technovation | 1981 | 5.729 |
| Strategic Management Journal | 1980 | 5.463 |
| Research Policy | 1971 | 5.351 |
| Journal of Product Innovation Management | 1984 | 5.270 |
| Small Business Economics | 1989 | 4.803 |
| Journal of Small Business Management | 1963 | 3.120 |
| R & D Management | 1970 | 2.908 |
| Entrepreneurship and Regional Development | 1989 | 2.885 |
| IEEE Transactions on Engineering Management | 1954 | 2.784 |

**Table 2a**
Source references for the metrics used in the MOT review.

| Reference | Metric | International | United States | Value of metric |
|---|---|---|---|---|
| Guffey and Harp (2014), Serenko et al. (2009), Linton and Thongpapanl (2004), Baden-Fuller et al. (2000) | **Total Number of Articles from University** | x | **x** | Measure of breath for research activities at the university |
| Chen (2019), Cancino et al. (2017), Ratinho et al. (2015), Dev et al. (2015), Guffey and Harp (2014), Hsieh and Chang (2009), Baden-Fuller et al. (2000) | **Number of Authorships for Active Researchers** | x | x | Measure of research productivity |
| Guffey and Harp (2014), Serenko et al. (2009), Linton and Thongpapanl (2004) | **Number of Active Researchers at University** | x | x | Measure of breath for research activities at the university |
| Guffey and Harp (2014), Hsieh and Chang (2009), Linton (2004), Baden-Fuller et al. (2000) | **Average Number of Authorships per Researcher** | x | x | Normalized measure of article quantity based on number of researchers |
| Linton (2004), Rupp and McKinney (2002) | **Page Count for Articles** | | x | Measure of research quantity of an article |
| Linton (2004), Laband (1985) | **Researchers that are Editors in Base Journals** | | x | Assessing link of quality and quantity of research expertise vs. editorial control for publications. |
| Retino et al. (2015), Guffey and Harp (2014), Serenko et al. (2009), Hsieh and Chang (2009), Mabry, and Sharplin (1985) | **Average Citation per Article** | | x | Normalized measure of quality & impact that an article has on the research field |
| Cancino et al. (2017), Dev et al. (2015), Ratinho et al. (2015), Guffey and Harp (2014), Serenko et al. (2009), Meho (2007), Saad (2006), Barnes (2005), Paxton and Bollen (2003), Linton (2004), Seglen (1997), Hecht et al. (1998) | **Number of Citing Articles for Active Researchers over Timeframe** | | x | Measure of quality & impact that an article has on the research field |
| Cancino et al. (2017), Ratinho et al. (2015), Dev et al. (2015), Guffey and Harp (2014), Lowry et al. (2007) | **Number Citing Articles at University over Timeframe** | | x | Measure of quality & impact of research done at university |
| Yang and Tao (2012), Serenko et al. (2009) | **Total Article Count Corrected for Authors** | | x | Normalized measure of article quantity by author |
| Halaweh (2020), Linton (2004) | **Page Count Corrected for Authors** | | x | Adjusted count measure of author research quantity |
| Sahoo et al. (2016), Ratinho et al. (2015), Leydesdorff (2008), Barman et al. (2001), Ansari et al. (1992) | **Journal Impact Factor** | x | x | Journal quality |
| Sahoo et al. (2016), Guffey and Harp (2014), Linton (2004) | **Comparing Tiers across Studies** | x | x | Based on Sahoo (2016) |
| Hult et al. (2009), QS Top universities* (2020), Times Higher Education* (2020) | **Schools Remaining as MOT Centers of Excellence** | x | x | Schools with dedicated programs in MOT |
| Sahoo et al. (2016), Guffey and Harp (2014), Linton (2004) | **Generating Tiers within Studies** | x | x | Based on Sahoo (2016) |
| Hult et al. (2009), QS Top universities* (2020), Times Higher Education* (2020), Guffey and Harp (2014) | **Compared Active Research sites Between Studies** | x | x | Comparison against previous sited work |
| CWTS Leiden Ranking* (2020), Times Higher Education* (2020), Guffey and Harp (2014) | **Number of all School Publishing Articles** | | x | Expansion and in the TE research field |
| Hult et al. (2009), ARWU Ranking* (2020), | **TE Centers that are also Centers for MOT Excellence** | x | x | Schools contributing to MOT and TE |
| ARWU Ranking* (2020), QS Top universities* (2020), Times Higher Education* (2020), u-multirank* (2020), MINES ParisTech (2009) | **Continent of Schools of Excellence** | | x | Regional contribution to MOT field |

*- Well-known ranking sites allow the reader to compare fields of study and regional ranking while offering insight to changes in ranking year over year.

full listing of our metrics, along with references, for both the MOT (Table 2a) and TE (Table 2b) fields are provided below.

Though the number of journals in the MOT field has grown, the foundational work of Linton and Thongpapanl (2004) continues to be used for identifying top journals in the MOT field. Their iterative study extended the work of Cheng et al. (1999) and Liker (1996) to determine a stable list of top journals. In Table 1a, a list of the selected MOT journals and their impact factors in 2019–2020 is provided.

TE is also an emergent field. A symposium on TE was held at Purdue University on October 7 and 8, 1970, when formal research in this field had barely just begun (Cooper and Komives, 1972); 12 researchers presented papers that, for the first-time, explored the ideas around and approaches to TE topics. Today, TE is a well-researched field, with papers published by most business schools with MOT programs. We provide a list of selected TE journals and their impact factors in 2019–2020 in Table 1b.

## 3. Methods for MOT and TE schools

We developed a transparent and reproducible method for identifying worldwide centers of excellence by taking a finer granular look at the U.S.-based MOT institutions, in order to answer the question of the stability of results over time, as proposed by the initial ranking effort (Linton, 2004). Furthermore, we analyzed the MOT subfield of TE and reviewed all schools globally by identifying those which have published in top journals in the field of MOT (see Table 1a). We analyzed these school programs and researchers based on 37 metrics, with 24 in MOT (see Table 2a) and 13 in TE (see Table 2b). The articles identified through our search were read to further confirm an accurate counting for both MOT and TE databases. Our sample comprises articles from schools that have been published in the MOT-recognized base journals (Table 1a) over the last six years (2015–2020) or in TE-recognized base journals (Table 1b) over the same time period.

In laying out the methodology of our ranking, we identified a series of metrics (see Table 2a and 2b). We utilized the Web of Science (WoS) due to its inclusion of all the identified top tier journals in MOT, and our ability to track ideas across disciplines and time, from almost 1.9 billion cited references from over 171 million records (Walsh and Groen, 2013). We used the dynamic relation database WoS v.5.35 (Clarivate Analytics, 2020) from November 12, 2020 through March 12, 2021("Web of Science" Web of Science Group, 2020).

### 3.1. Methods specific for MOT ranking

Subsequently, we choose the metrics for our study. We utilized many of the 2004 paper's metrics (Linton, 2004) and justified their choice with the same reasoning as previously presented (Linton, 2004). The metrics we have utilized are (a) total article count, (b) total page count,

**Table 2b**
Source references for the metrics used in the TE review.

| Reference | Metric | International | Value of metric |
|---|---|---|---|
| Chen (2019), Cancino et al.(2017), Ratinho et al. (2015), Dev et al. (2015), Guffey and Harp (2014), Hsieh and Chang (2009), Baden-Fuller et al. (2000) | **Number of Authorships for Active Researchers** | x | Measure of research productivity |
| Guffey and Harp (2014), Serenko et al. (2009), Linton and Thongpapanl (2004) | **Number of Active Researchers at University** | x | Measure of breath for research activities at the university |
| Guffey and Harp (2014), Hsieh and Chang (2009), Linton (2004), Baden-Fuller et al. (2000) | **Average number of Authorships per Researcher** | x | Normalized measure of article quantity based on number of researchers |
| Linton (2004), Rupp and McKinney (2002) | **Page Count for Articles** | x | Measure of research quantity of an article |
| Linton (2004), Laband (1985) | **Researchers that are Editors in base Journals** | x | Assessing link of quality and quantity of research expertise vs editorial control for publications. |
| Yang and Tao (2012), Serenko et al. (2009) | **Total Article Count Corrected for Authors** | x | Normalized measure of article quantity by author |
| Halaweh (2020), Linton (2004) | **Page Count Corrected for Authors** | x | Adjusted count measure of author research quantity |
| Sahoo et al. (2016), Ratinho et al. (2015), Leydesdorff (2008), Barman et al. (2001), Ansari et al. (1992) | **Journal Impact Factor** | x | Journal quality |
| Sahoo et al. (2016), Guffey and Harp (2014), Linton (2004) | **Comparing Tiers across Studies** | x | Based on Sahoo (2016) |
| Hult et al. (2009), QS Top universities* (2020), Times Higher Education* (2020) | **Schools Remaining as MOT Centers of Excellence** | x | Schools with dedicated programs in MOT |
| Sahoo et al. (2016), Guffey & Harp (2014), Linton (2004) | **Generating Tiers within Studies** | x | Based on Sahoo (2016) |
| Hult et al. (2009), QS Top universities* (2020), Times Higher Education* (2020), Guffey and Harp (2014) | **Compared Active Research Sites between Studies** | x | Comparison against previous sited work |
| CWTS Leiden Ranking* (2020), Times Higher Education* (2020), Guffey and Harp (2014) | **Number of all School Ppublishing Articles** | x | Expansion and in the TE research field |
| Hult et al. (2009), ARWU Ranking* (2020) | **TE Centers that are also Centers for MOT Excellence** | x | Schools contributing to MOT and TE |
| ARWU Ranking* (2020), QS Top universities* (2020), Times Higher Education* (2020), u-multirank* (2020), MINES ParisTech (2009) | **Continent of Schools of Excellence** | x | Regional contribution to MOT field |

*- Well-known ranking sites allow the reader to compare fields of study and regional ranking while offering insight to changes in ranking year over year.

(c) total article count corrected for the number of authors, (d) total page count corrected for the number of authors, (e) the total number of times each article was cited, (f) the total number of citations corrected for the number of authors on each article, (g) the total number of citations per page of each article, and h) the total number of citations corrected for the number of authors and the number of pages, *inter alia*. The metrics this paper shares with the previous study are number of active researchers (Table 5, column 2), number of authorships (Table 5, column 3), number of authorships per active researcher (Table 5, column 4), total page count corrected for authors (Table 5, column 5), the average citation per article over the timeframe in all research of the authors (Table 6, column 3), the number of cited articles in all the research of the authors (Table 6, column 4), the number of MOT authorships (Table 6, column 5), the page count for MOT articles (Table 6, column 6), total article count corrected for authors (Table 6, column 7), MOT page count corrected for the number of authors (Table 6, column 8), the total number of U.S. universities in the MOT space, and each of the measures above for each university of excellence in MOT in the US. Additionally, in the MOT US-specific analysis, we included a metric of the number of researchers on the editorial boards of the base journals (Table 5, column 6). For the international universities we provided the total number of universities contributing articles to the base journals in the MOT space, the country of the university (Table 3, column 2), the continent of the university (Table 3, column 3), number of MOT authorships for each researcher and each university (Table 3, column 4), the number of active MOT researchers at each University (Table 3, column 5), the number of authorships in base journals from each active researcher (Table 3, column 6), the total number of authorships in the base journals for each university (Table 3, column 7), and the number of MOT centers for excellence in each continent.

To identify our dataset of MOT centers of excellence, we searched nine journals with the following keywords: commercialization, diffusion, discovery, innovation, intellectual property, IP, invention, knowledge, new product, product development, R&D, research, scientists, technical, technology OR technological. We followed the previous study and defined an active MOT research institution as having at least two affiliated researchers, with at least three MOT articles each in the set of base journals over the last six years. To ensure that our results were comparable, we utilized the search words and definition of centers of excellence to maintain consistency with the earlier study (Linton, 2004).

Linton (2004) did not include citation frequency as a metric due to the concern that it might be a weak metric because the four-year time frame chosen provided little opportunity or too many articles to be cited (Linton, 2004). In our assessment, however, we found an abundance of citations with the leader being MIT with 8842; so, we chose to include three metrics aligned with citation from the schools to contribution to the field. These metrics included the number of cited articles at the university, the number of cited articles for active researchers, and the average citation per article.

We chose to include some universities with active researchers that had less than three articles when the university productivity was highly ranked by either the number of cited articles, the average citation per article, or the total number of articles. We believe that these measures of a university output addresses Linton's (2004) concerns that if a researcher were to leave or stop publishing on MOT, the university output would be cut by half.

### 3.2. *Methods specific for TE ranking*

Here, we change the focus from MOT to the MOT sub-field TE. We use the same methodology to rank TE, which is also a subfield of the generic entrepreneurship field. Here we needed to select journals from both the MOT and entrepreneurship fields. We used the same rationale that we used to study the MOT field in general for the TE field, including the highest impact journals from both the MOT and entrepreneurship fields focusing on TE, as indicated in Ratinho et al. (2015) to accomplish this.

**Table 3**
Non-US MOT centers of excellence.

| University | Country | Continent | MOT Research Activity at University | | Activity in MOT of Active Researchers | |
|---|---|---|---|---|---|---|
| | | | Total Number of MOT Authorships | Number of Active MOT Researchers | Number of Authorships in Base Journals | Base Journal Per Active Researcher |
| Ajou University | South Korea | Asia | 15 | 2 | 18 | 7.5 |
| Polytechnic University of Bari | Italy | Europe | 16 | 3 | 26 | 8.7 |
| Tech University Darmstadt | Germany | Europe | 16 | 2 | 15 | 7.5 |
| University Kassel | Germany | Europe | 17 | 2 | 14 | 7.0 |
| Beijing Normal University | China | Asia | 18 | 2 | 13 | 6.5 |
| Brunel University London | United Kingdom, England | Europe | 16 | 2 | 12 | 6.0 |
| University of Southern Denmark | Denmark | Europe | 32 | 3 | 18 | 6.0 |
| Lund University | Sweden | Europe | 36 | 3 | 17 | 5.7 |
| Tsinghua University, Bejing | China | Asia | 51 | 6 | 33 | 5.5 |
| Polytechnic University of Milan | Italy | Europe | 53 | 10 | 53 | 5.3 |
| Beijing Institute of Technology | China | Asia | 26 | 4 | 21 | 5.3 |
| National Chiao Tung University | Taiwan | Asia | 27 | 4 | 21 | 5.3 |
| Technical University of Berlin | Germany | Europe | 31 | 4 | 21 | 5.3 |
| University Lancaster | United Kongdom, England | Europe | 26 | 3 | 15 | 5.0 |
| Polytechnic University of Turin | Italy | Europe | 26 | 6 | 30 | 5.0 |
| Chinese Academy of Sciences | China | Asia | 31 | 3 | 15 | 5.0 |
| Eindhoven University of Technology | Netherlands | Europe | 41 | 7 | 34 | 4.9 |
| Hse University Ersity - National Research University Of Higher School Of Economics | Russia | Eurasia | 26 | 5 | 24 | 4.8 |
| National Chung Hsing University | Taiwan | Asia | 16 | 3 | 14 | 4.7 |
| Delft University of Technology | Netherlands | Europe | 40 | 3 | 14 | 4.7 |
| Seoul National University | South Korea | Asia | 34 | 8 | 37 | 4.6 |
| University of Manchester | United Kingdom, England | Europe | 65 | 8 | 37 | 4.6 |
| Utrecht University | Netherlands | Europe | 70 | 14 | 64 | 4.6 |
| University of Nottingham | United Kingdom, England | Europe | 34 | 2 | 9 | 4.5 |
| University of Chinese Academy of Sciences, Bejing | China | Asia | 46 | 10 | 45 | 4.5 |
| University St. Gallen | Switzerland | Europe | 20 | 3 | 13 | 4.3 |
| Scuola Superiore Sant'anna | Italy | Europe | 22 | 3 | 13 | 4.3 |
| University of Groningen | Netherlands | Europe | 33 | 3 | 13 | 4.3 |
| Korea Institute of Science & Technology Information | South Korea | Asia | 20 | 4 | 17 | 4.3 |
| University of Twente | Netherlands | Europe | 36 | 4 | 17 | 4.3 |
| Katholieke University Leuven | Belgium | Europe | 34 | 5 | 21 | 4.2 |
| University of Sussex | United Kingdom, England | Europe | 73 | 5 | 21 | 4.2 |
| Technical University of Munich | Germany | Europe | 35 | 6 | 25 | 4.2 |
| University of Cambridge | United Kingdom, England | Europe | 60 | 8 | 33 | 4.1 |
| University of Exeter | United Kingdom, England | Europe | 16 | 2 | 8 | 4.0 |
| University Sao Paulo | Brazil | South America | 17 | 2 | 8 | 4.0 |
| University of Padua | Italy | Europe | 17 | 3 | 12 | 4.0 |
| Lappeenranta University Technollogy | Finland | Europe | 19 | 2 | 8 | 4.0 |
| University Milan | Italy | Europe | 21 | 3 | 12 | 4.0 |
| Swiss Federal Institute of Technology | Switzerland | Europe | 21 | 4 | 16 | 4.0 |
| Ghent University | Belgium | Europe | 22 | 3 | 12 | 4.0 |
| National Research University Higher School of Economics (HSE) | Russia | Eurasia | 23 | 2 | 8 | 4.0 |
| Coventry University | United Kingdom, England | Europe | 24 | 2 | 8 | 4.0 |
| Xi'an Jiao Tong University | China | Asia | 25 | 4 | 16 | 4.0 |
| Chalmers University Technology | Sweden | Europe | 25 | 4 | 16 | 4.0 |
| Korea Advanced Inst Science & Technology (Kaist) | South Korea | Asia | 26 | 3 | 12 | 4.0 |
| University of Tokyo | Japan | Asia | 27 | 4 | 16 | 4.0 |
| Aarhus University | Denmark | Europe | 30 | 3 | 12 | 4.0 |
| Erasmus University | Netherlands | Europe | 37 | 3 | 12 | 4.0 |
| University of Kent | United Kingdom, England | Europe | 42 | 9 | 36 | 4.0 |
| University of Warwick | United Kingdom, England | Europe | 33 | 5 | 19 | 3.8 |
| University Lisbon | Portugal | Europe | 17 | 4 | 15 | 3.8 |
| University of Technology Sydney | Australia | Australia | 23 | 4 | 15 | 3.8 |
| University of Oslo | Norway | Europe | 15 | 3 | 11 | 3.7 |
| | Germany | Europe | 20 | 6 | 22 | 3.7 |

(*continued on next page*)

**Table 3** (*continued*)

| University | Country | Continent | MOT Research Activity at University | | Activity in MOT of Active Researchers | |
|---|---|---|---|---|---|---|
| | | | Total Number of MOT Authorships | Number of Active MOT Researchers | Number of Authorships in Base Journals | Base Journal Per Active Researcher |
| Rhein Westfaelische Technische Hochschule Aachen | | | | | | |
| Collegio Carlo Alberto | Italy | Europe | 20 | 3 | 11 | 3.7 |
| South China University of Technology | China | Asia | 15 | 2 | 7 | 3.5 |
| University Amsterdam | Netherland | Europe | 16 | 2 | 7 | 3.5 |
| University Bologna | Italy | Europe | 20 | 2 | 7 | 3.5 |
| Stockholm School of Economics | Sweden | Europe | 20 | 2 | 7 | 3.5 |
| Zhejiang University | China | Asia | 26 | 2 | 7 | 3.5 |
| Bocconi University | Italy | Europe | 35 | 4 | 13 | 3.3 |
| University College London | United Kingdom, England | Europe | 30 | 6 | 19 | 3.2 |
| National University of Singapore | Singapore | Asia | 32 | 6 | 19 | 3.2 |
| Yuan Ze University | Taiwan | Asia | 15 | 2 | 6 | 3.0 |
| University Bergamo | Italy | Europe | 16 | 2 | 6 | 3.0 |
| Korea University | South Korea | Asia | 17 | 2 | 6 | 3.0 |
| Grenoble Ecole Management | France | Europe | 17 | 2 | 6 | 3.0 |
| Whu Otto Beisheim School Management | Germany | Europe | 19 | 3 | 9 | 3.0 |
| Newcastle University | United Kingdom, England | Europe | 19 | 2 | 6 | 3.0 |
| University Complutense Madrid | Spain | Europe | 20 | 2 | 6 | 3.0 |
| University Turin | Italy | Europe | 25 | 3 | 9 | 3.0 |
| University Strathclyde | United Kongdom, Scotland | Europe | 25 | 2 | 6 | 3.0 |
| University Amsterdam | Netherland | Europe | 25 | 2 | 6 | 3.0 |
| Universitat Politècnica de València | Spain | Europe | 25 | 6 | 18 | 3.0 |
| Maastricht University | Netherlands | Europe | 30 | 2 | 6 | 3.0 |
| Aalto University | Finland | Europe | 33 | 3 | 9 | 3.0 |

**Table 4**
US MOT centers of excellence.

| University | Recent Activity in MOT Number of Authorships | Number of Active Researchers | Authorships/Researcher |
|---|---|---|---|
| Georgia Institute of Tech, Technology Policy & Assessment Center, Atlanta, GA | 28 | 6 | 4.67 |
| University of New Mexico, Anderson School of Management, Albuquerque, NM | 26 | 7 | 3.71 |
| George Washington University, Department of Management Science, Washington, DC | 25 | 6 | 4.17 |
| Northeastern University, Boston, MA | 20 | 6 | 3.33 |
| University of California Berkeley, CA | 17 | 2 | 8.50 |
| Massachusetts Institute of Technology, Sloan School of Management, Cambridge, MA | 15 | 2 | 7.50 |
| Portland State University, Portland, OR | 14 | 2 | 7.00 |
| Arizona State University, College of Business, Tempe, AZ | 12 | 3 | 4.00 |
| Carnegie Mellon University, Pittsburgh, PA | 12 | 4 | 3.00 |
| Rochester Institute of Technology, Rochester, NY | 9 | 5 | 1.80 |
| Old Dominion University, Norfork, VA | 8 | 3 | 2.67 |
| Stanford University, Dept. of Industrial Eng. & Engineering Management, Stanford, CA* | 8 | 6 | 1.33 |
| University of Pittsburgh, Pittsburgh, PA | 8 | 5 | 1.60 |
| Villanova University, Villanova, PA | 8 | 3 | 2.67 |
| Stony Brook University, Stony Brook, NY | 7 | 2 | 3.50 |
| Washington State University, Pullman, WA* | 7 | 3 | 2.33 |
| Pennsylvania State University, State College, PA | 6 | 2 | 3.00 |
| Rensselaer Polytech Institute, Troy, NY* | 6 | 3 | 2.00 |
| University of Memphis, Memphis, TN | 6 | 2 | 3.00 |
| University of Texas, Austin, TX* | 6 | 3 | 2.00 |
| University New Hampshire, Durham, NH* | 5 | 3 | 1.67 |

*-some researchers had less than 3 articles.

We utilized the following metrics for our TE review—the number of TE authorships (Table 8, column 2), the page count for TE articles (Table 8, column 3), the total article count corrected for authors (Table 8, column 4), the total TE page count corrected for authors (Table 8, column 5), the number of active researchers (Table 8, column 6), the average number of authorships per researcher (Table 8, column 7), and the number of researchers that are editors in the base journals at each university internationally (Table 8, column 8).

To identify our dataset of TE centers of excellence, we reviewed Ratinho et al.'s (2015) paper on TE journals and modified the list of journals we used to identify schools of excellence in the TE space (Ratinho et al., 2015). The changes to the journals collected for the MOT review included the removal of the *Journal of Engineering and Technology Management* and *International Journal of Technology Management,* and the inclusion of *Entrepreneurship Theory and Practice, the Journal of Business Venturing, the Strategic Management Journal, Small Business Economics, Journal of Small Business Management*, and *Entrepreneurship and Regional Development*. Although our search for schools of excellence included six TE focused journals and the removal of two non-TE focused journals, we aimed to leverage the methodology used in the earlier research in the field (Table 1b). The keywords were modified to technology AND entrepreneurship and, following the previous research, did searched in ALL fields in the WoS database through the identified 12 base TE journals. During our initial search, it quickly became clear that many

**Table 5**
U.S. MOT centers of excellence. Part 1.

| University | Recent Activity in MOT Number of Active Researchers | Number of Authorships | Authorships per Researcher | Total Page Count Corrected for authors | Number of Researchers that are Editors in the Base Journals |
|---|---|---|---|---|---|
| Arizona State University, College of Business, Tempe, AZ | 3 | 12 | 4.00 | 88 | 1 |
| Carnegie Mellon University, Pittsburgh, PA | 4 | 12 | 3.00 | 117 | 3 |
| George Washington University, Department of Management Science, Washington, DC | 6 | 25 | 4.17 | 152 | 5 |
| Georgia Institute of Tech, Technology Policy & Assessment Center, Atlanta, GA | 6 | 28 | 4.67 | 246 | 6 |
| Massachusetts Institute of Technology, Sloan School of Management, Cambridge, MA | 2 | 15 | 7.50 | 54 | 5 |
| Northeastern University, Boston, MA | 6 | 20 | 3.33 | 52 | 4 |
| Old Dominion University, Norfork, VA | 3 | 8 | 2.67 | 65 | 0 |
| Pennsylvania State University, State College, PA | 2 | 6 | 3.00 | 27 | 0 |
| Portland State University, Portland, OR | 2 | 14 | 7.00 | 148 | 6 |
| Rensselaer Polytech Institute, Troy, NY* | 3 | 6 | 2.00 | 73 | 1 |
| Rochester Institute of Technology, Rochester, NY | 5 | 9 | 1.80 | 64 | 1 |
| Stanford University, Dept. of Industrial Eng. & Engineering Management, Stanford, CA* | 6 | 8 | 1.33 | 60 | 6 |
| Stony Brook University, Stony Brook, NY | 2 | 7 | 3.50 | 48 | 0 |
| University New Hampshire, Durham, NH* | 3 | 5 | 1.67 | 51 | 3 |
| University of California Berkeley, CA | 2 | 17 | 8.50 | 61 | 8 |
| University of Memphis, Memphis, TN | 2 | 6 | 3.00 | 68 | 0 |
| University of New Mexico, Anderson School of Management, Albuquerque, NM* | 7 | 26 | 3.71 | 107 | 6 |
| University of Pittsburgh, Pittsburgh, PA | 5 | 8 | 1.60 | 95 | 0 |
| University of Texas, Austin, TX | 3 | 6 | 2.00 | 94 | 1 |
| Villanova University, Villanova, PA | 3 | 8 | 2.67 | 86 | 0 |
| Washington State University, Pullman, WA* | 3 | 7 | 2.33 | 86 | 1 |

*-some researchers had less than 3 articles.

affiliated researchers had not published three journal articles in the stipulated time frame. This was further evidence that TE was an emerging field of study, and we chose to reduce the inclusion number of articles to two and increase the number of affiliated researchers to three. With this change, we maintained consistency with the previous studies by defining a center of excellence having a minimum of six publications. Therefore, we defined an active center of excellence in TE research as having at least three affiliated researchers who each have at least two articles, identified by searching 12 base journals for the keywords technology AND entrepreneurship in all fields over the last six years, identified through the WoS database.

## 4. Results

Our results provide insights regarding the emergent state of the MOT and TE fields. Our findings reveal that these two fields are flourishing, with 809 schools embracing MOT research and 348 schools TE, as evidenced by their publications in the base journals. We identified centers of excellence in the continents of Asia, Australia, Europe, North America, and South America. We initiate a discussion of our results by discussing the international (non-US) MOT centers of excellence.

### 4.1. Results specific for MOT ranking

We identified 77 international universities that met the criteria for a center of excellence in MOT (see Table 3). We sorted them by the "average number of articles in base journal production per active researcher" metric. Not identified in the original study, but we identified Ajou University in South Korea as an international leader. However, had we sorted on the "number of authorships," the University of Sussex, UK, which was the top leader in the previous study, would still be the leader. On the other hand, had we sorted on the "number of active researchers," as Linton (2004) did, the Utrecht University in the Netherlands, which was not identified by Linton (2004), would emerge at the top. Although some new centers were identified and some centers fell off the list, the data clearly shows that Europe continues to dominate the international field of MOT centers of excellence, with 55 centers compared to 58 centers found in 2004 (Linton, 2004).

We next investigated U.S. schools that meet the criteria for MOT centers of excellence. We analyzed these schools in Tables 4–6. In Table 4, we sorted the U.S. universities by the number of authorships, also providing the number of active researchers and the number of authorships per researcher. In the number of authorships metric, Georgia Institute of Technology (also known as Georgia Tech), moved up from the forth position to the leader since 2004. Sorting according to authorships per researcher shows a newcomer to the list, the University of California, Berkley, as the leader. Finally, we showed that there were eight (down from 14) U.S. business or engineering management schools with 10 or more articles in the base journals, including Georgia Tech, George Washington University, Northeastern University, University of California (Berkley), MIT Sloan, Portland State University, University of New Mexico, and Arizona State University.

We continued analyzing the U.S. schools (Table 5) to review the number of pages of the MOT authorships from the base journals and the number of editorships of all types (other than special issue editors) in the base journals. Here, we saw that the leader in the number of pages remained the same since 2004 with Georgia Tech, and that the leader in the number of editorships was, again, the newcomer to the list—the University of California Berkeley. Moreover, we showed in our new metric that seven schools had five or more editorial roles (other than special issues) in a base journal, viz., Georgia Tech, George Washington University, Northeastern University, University of California, Berkley, MIT Sloan School of Management, Portland State University, and the University of New Mexico.

We continued our investigation of U.S. schools in Table 6, sorting this table alphabetically, since we reviewed the schools on seven metrics, the first three being different from the 2004 study, where we examined the school-wide author publications and their impact on the MOT field.

**Table 6**
U.S. MOT centers of excellence. Part 2.

| University | Assessment of All MOT Research | | | MOT Research Activity | | | |
|---|---|---|---|---|---|---|---|
| | Total Number of Articles from University | Average Citation per Article over Timeframe | Number of Citing Articles over Timeframe | Number of MOT Authorships | Page Count for MOT Articles | Total MOT Article Count Corrected for Authors | MOT Page Count Corrected for Authors |
| Arizona State University, College of Business, Tempe, AZ | 150 | 13.86 | 1477 | 12 | 167 | 8 | 88 |
| Carnegie Mellon University, Pittsburgh, PA | 39 | 19.87 | 722 | 12 | 214 | 9 | 117 |
| George Washington University, Department of Management Science, Washington, DC | 361 | 11.35 | 2503 | 25 | 303 | 13 | 152 |
| Georgia Institute of Tech, Technology Policy & Assessment Center, Atlanta, GA | 99 | 20.11 | 1475 | 28 | 406 | 17 | 246 |
| Massachusetts Institute of Technology, Sloan School of Management, Cambridge, MA | 119 | 58.38 | 8842 | 15 | 185 | 15 | 185 |
| Northeastern University, Boston, MA | 71 | 12.76 | 707 | 20 | 268 | 17 | 223 |
| Old Dominion University, Norfork, VA | 51 | 13.70 | 826 | 8 | 130 | 4 | 65 |
| Pennsylvania State University, State College, PA | 13 | 7.18 | 80 | 6 | 54 | 4 | 27 |
| Portland State University, Portland, OR | 130 | 3.94 | 334 | 14 | 227 | 10 | 148 |
| Rensselaer Polytech Institute, Troy, NY* | 35 | 38.25 | 397 | 6 | 100 | 3 | 73 |
| Rochester Institute of Technology, Rochester, NY | 73 | 0.97 | 51 | 9 | 73 | 8 | 64 |
| Stanford University, Dept. of Industrial Eng. & Engineering Management, Stanford, CA* | 95 | 21.09 | 2526 | 8 | 137 | 6 | 100 |
| Stony Brook University, Stony Brook, NY | 82 | 6.66 | 472 | 7 | 48 | 7 | 48 |
| University New Hampshire, Durham, NH* | 32 | 28.80 | 838 | 5 | 77 | 4 | 51 |
| University of California Berkeley, CA | 83 | 20.82 | 1661 | 17 | 174 | 17 | 174 |
| University of Memphis, Memphis, TN | 59 | 6.20 | 242 | 6 | 68 | 6 | 68 |
| University of New Mexico, Anderson School of Management, Albuquerque, NM | 60 | 4.99 | 332 | 26 | 200 | 13 | 107 |
| University of Pittsburgh, Pittsburgh, PA | 41 | 5.13 | 39 | 8 | 131 | 6 | 95 |
| University of Texas, Austin, TX* | 56 | 5.81 | 356 | 6 | 94 | 6 | 94 |
| Villanova University, Villanova, PA | 118 | 7.06 | 782 | 8 | 99 | 7 | 86 |
| Washington State University, Pullman, WA* | 125 | 15.20 | 2939 | 7 | 132 | 4 | 86 |

*-some researchers had less than 3 articles.

Here, MIT Sloan led in the total number of citations and citations per article and George Washington University in the number of authored papers. We next reviewed the number of MOT authorships, the page count for MOT articles, the total article count corrected for authors, and the MOT page count corrected for authors. Here, Georgia Tech maintained its dominance as the leader in all four metrics related to active researchers at the University. There are seven centers of excellence (down from 11 found 17 years ago) with 10 or more MOT papers corrected for the author, viz., George Washington University, Georgia Tech, MIT Sloan, Northeastern University, Pennsylvania State University, Portland State University, Rensselaer Polytech Institute, Rochester Institute of Technology, Stanford University, NY University Stony Brook, University of New Hampshire, University of California Berkeley, University of Memphis, and University of New Mexico.

In Table 7, we compared the previous study's list of centers of excellence in the U.S. with our own and found that 80% of the first study's tier 1 schools found a place in our study too, while 14 schools were found in our study alone, 14 schools were found in the 2004 study alone, and seven found in both 2021 and 2004. The schools that are in both the studies are George Washington University, Georgia Tech, MIT Sloan, Portland State University, Rensselaer Polytechnic Institute, Stanford, and the University of New Mexico.

### 4.2. Results specific for TE ranking

In our initial review of TE schools of excellence, we followed Linton's (2004) premise that his approach "offers insight into not only ranking of schools with MOT capabilities but also how one can study other immature disciplinary fields such as entrepreneurship" (Linton, 2004). We then imitated the discussion of TE in Table 8 and found 348 schools that had publications on TE in our new base journal set; we further segmented these schools into centers of TE excellence. Here, the University of New Mexico led in the number of TE authorships, and the total article count corrected for authors. Lulea University of Technology took

**Table 7**
U.S. MOT centers of excellence from both 2004 & 2021 studies.

| 2020 Study Results (2015–2020) | Found only in the 2004 study | Found only in the 2020 study | Found in both studies |
|---|---|---|---|
| Arizona State University, College of Business, Tempe, AZ | | X | |
| Carnegie Mellon University, Pittsburgh, PA | | X | |
| Case Western Reserve University, Weatherhead School of Management, OH | x | | |
| Drexel University, LeBow College of Business, PA | x | | |
| George Washington University, Department of Management Science, Washington, DC | | | x |
| Georgia Institute of Tech, Technology Policy & Assessment Center, Atlanta, GA | | | x |
| Harvard University, Graduate School of Business Administration, MA | x | | |
| Massachusetts Institute of Technology, Sloan School of Management, Cambridge, MA | | | x |
| Michigan State University, MI | x | | |
| New Jersey Institute of Technology, School of Management, NJ | x | | |
| North Carolina State University, College of Business Management, NC | x | | |
| Northeastern University, Boston, MA | | x | |
| Old Dominion University, Norfork, VA | | x | |
| Pennsylvania State University, State College, PA | | x | |
| Portland State University, Portland, OR | | | x |
| Rensselaer Polytech Institute, Troy, NY | | | x |
| Rochester Institute of Technology, Rochester, NY | | x | |
| Rockefeller University, NY | x | | |
| Rutgers State University, Faculty of Management, NJ | x | | |
| Stanford University, Dept. of Industrial Eng. & Engineering Management, Stanford, CA | | | x |
| Stevens Institute of Technology, Wesley J Howe School of Technology Management, NJ | x | | |
| Stony Brook University, Stony Brook, NY | | x | |
| University New Hampshire, Durham, NH | | x | |
| University of California Berkeley, CA | | x | |
| University of Memphis, Memphis, TN | | x | |
| University of Michigan, Industry & Operating Engineering College of Engineering, MI | x | | |
| University of Minnesota, Carlson School of Management, MN | x | | |
| University of New Mexico, Anderson School of Management, Albuquerque, NM | | | x |
| University of Pennsylvania, The Wharton School, PA | x | | |
| University of Pittsburgh, Pittsburgh, PA | | x | |
| University of Texas, Austin, TX | | x | |
| University of Washington, WA | x | | |
| Villanova University, Villanova, PA | | x | |
| Washington State University, Pullman, WA | | x | |

**Table 8**
Global technology entrepreneurship centers of excellence.

| University | Research Activity for University of Excellence in TE | | | | | | |
|---|---|---|---|---|---|---|---|
| | Number of TE Authorships | Page Count for TE Articles | Total Article Count Corrected for Authors | TE Page Count Corrected for Authors | Number of Active Researchers | Number of Authorships per Researcher | Number of Researchers that are Editors in the Base Journals |
| Chalmers University of Technology | 11 | 182 | 5 | 86 | 5 | 2.2 | 1 |
| Indiana University | 13 | 221 | 5 | 79 | 6 | 2.2 | 11 |
| Lulea University of Technology | 22 | 318 | 11 | 172 | 6 | 3.7 | 0 |
| Lund University | 8 | 135 | 4 | 67 | 4 | 2.0 | 1 |
| National University of Singapore | 13 | 150 | 7 | 90 | 6 | 2.2 | 4 |
| Northeastern University | 12 | 260 | 8 | 174 | 4 | 3.0 | 3 |
| Politecnico di Milano | 15 | 258 | 10 | 156 | 6 | 2.5 | 6 |
| Syracuse University | 15 | 269 | 7 | 122 | 6 | 2.5 | 1 |
| University Exeter | 6 | 98 | 4 | 60 | 3 | 2.0 | 3 |
| University of Beira Interio | 8 | 100 | 5 | 70 | 4 | 2.0 | 1 |
| University of Ghent | 22 | 311 | 13 | 202 | 5 | 4.4 | 0 |
| University of Kent | 8 | 126 | 6 | 97 | 3 | 2.7 | 1 |
| University of New Mexico | 34 | 283 | 13 | 119 | 8 | 4.3 | 8 |
| University of Oslo | 16 | 206 | 7 | 95 | 6 | 2.7 | 2 |
| University of Southern Denmark | 7 | 93 | 7 | 93 | 3 | 2.3 | 0 |
| University of Twente | 12 | 140 | 11 | 133 | 4 | 3.0 | 4 |
| University of Utrecht | 14 | 200 | 8 | 121 | 5 | 2.8 | 3 |

**Table 9**
Ranking order of the MOT metrics from Tables 3–6.

| | University | Ranking of Active Researchers in MOT | Total Page Count Ranking in MOT | Ranking of Authorships in MOT | Ranking of Researchers that are Editors in the base Journals | MOT authorships per researcher Ranking | Average Citation per Article over timeframe Ranking | Number of Citing Articles over timeframe Ranking |
|---|---|---|---|---|---|---|---|---|
| **Tier 1** | Georgia Institute of Tech, Technology Policy & Assessment Center | 1 | 1 | 1 | 2 | 8 | 6 | 8 |
| | Massachusetts Institute of Technology, Sloan School of Management | 12 | 13 | 5 | 6 | 2 | 1 | 1 |
| | University of California Berkeley | 12 | 11 | 4 | 1 | 1 | 5 | 6 |
| **Tier 2** | Stanford University, Department of Industrial Engineering & Engineering Management | 1 | 12 | 9 | 2 | 20 | 4 | 4 |
| | George Washington University, Department of Management Science | 1 | 2 | 2 | 6 | 10 | 12 | 5 |
| | Arizona State University, College of Business | 6 | 5 | 8 | 11 | 11 | 9 | 7 |
| | Carnegie Mellon University | 17 | 4 | 16 | 9 | 5 | 7 | 12 |
| | Portland State University | 12 | 3 | 6 | 2 | 3 | 20 | 16 |
| | University New Hampshire* | 6 | 16 | 16 | 9 | 19 | 3 | 9 |
| | University of New Mexico, Anderson School of Management | 6 | 18 | 7 | 2 | 9 | 19 | 17 |
| **Tier 3** | California State University, Fresno* | 1 | 17 | 19 | 11 | 21 | 8 | 2 |
| | Northeastern University | 1 | 15 | 3 | 8 | 13 | 11 | 13 |
| | Old Dominion University | 6 | 10 | 9 | 16 | 16 | 10 | 10 |
| | Pennsylvania State University | 12 | 19 | 12 | 16 | 14 | 14 | 19 |
| | Rensselaer Polytech Institute* | 6 | 7 | 12 | 11 | 18 | 2 | 15 |
| | Rochester Institute of Technology | 17 | 21 | 16 | 11 | 5 | 21 | 20 |
| | Stony Brook | 17 | 20 | 16 | 16 | 5 | 16 | 14 |
| | University of Memphis | 12 | 9 | 12 | 16 | 14 | 17 | 18 |
| | University of Pittsburgh | 17 | 14 | 19 | 16 | 11 | 18 | 21 |
| | Villanova University | 17 | 7 | 12 | 16 | 4 | 15 | 11 |
| | Washington State University* | 6 | 6 | 11 | 11 | 17 | 13 | 3 |

the highest rank in the page count for TE articles, while University of Ghent had the highest page count corrected for authors. In total, we identified 17 centers of excellence, with 12 of them showing more than 10 TE authorships, viz., University of New Mexico, Lulea University of Technology, University of Utrecht, University of Ghent, University of Twente, University of Oslo, Northeastern University, National University of Singapore, Syracuse University, Indiana University, Politecnico di Milano, and Chalmers University of Technology.

## 5. Discussion

We offer a tiered system for reviewing MOT schools of excellence and a first-ever tiered system for the MOT sub-field of TE. One interesting finding is that, of the 17 centers of excellence in TE, 12 centers (71%) were also centers of excellence in either international or U.S. centers of MOT excellence (Table 10).

### 5.1. Discussion specific for MOT ranking

One question posed by the former ranking of the MOT centers was the stability of the results over time. We reviewed both the metrics and applied Linton's (2004) tiered approach of the final U.S. schools to answer that question. First, although most schools moved in their position of individual metrics, and that 14 centers were no longer defined as centers of excellence, all schools identified in the three-tiered system in 2004 are still among the schools contributing to the field of MOT, as evidenced by the publications in base journals. Second, 80% of the MOT U.S. centers of excellence tier one schools listed in the 2004 study remained on the 2021-tiered list, and 63% of the MOT U.S. centers of excellence listed in tiers 1 and 2 of the original list remained on the 2021 list. This shows appreciable stability over a 15-year span (Table 9).

We have included a list of 37 metrics and the results from the review of these metrics. In our results, we provided a repeat of Linton's (2004) tiering method for U.S. MOT centers of excellence. Again, to be recognized among 809 (international MOT-published schools in our timeframe) schools as a center of excellence is significant. In the case of the U.S.-MOT schools, only 21 of 297 are ranked as centers of excellence.

Again, for the MOT centers, we used a method consistent to the tiered system adopted by the earlier study (Linton, 2004). To be considered top tier, any U.S.-MOT center of excellence had to rank number 1 in at least two metrics (Table 9). The division of schools into the second and third tiers is based on the sum of the metric rankings. The tier-three schools have a sum of metric ranking greater than double the second-tier school, with the most favorable sum of rankings value in that tier.

### 5.2. Discussion specific for TE ranking

For the TE ranking, we first applied the 2004 ranking method and

**Table 10**
Ranking order of the TE metrics from Table 8.

| Tiers | University | Research Activity for authors of excellence in University of Excellence in TE | | | | | | | | Rank | Also Centers of MOT Excellence |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ranking of TE Authorships | Ranking Page Count for TE Articles | Total Article Count Ranking Corrected for Authors | TE Page Count Ranking Corrected for Authors | Ranking of Number of Active Researchers | Ranking of Number of Authorships per Researcher | Ranking of Number of Researchers that are Editors in the base Journals | Sum of Ranking Numbers | | |
| **Tier 1 (SUM ≤ 30)** | University of New Mexico | 1 | 3 | 1 | 8 | 1 | 2 | 2 | 18 | 1 | x |
| | Lulea University of Technology | 2 | 1 | 3 | 3 | 2 | 3 | 15 | 29 | 2 | |
| | University of Ghent | 2 | 2 | 1 | 1 | 8 | 1 | 15 | 30 | 3 | x |
| **Tier 2 (SUM ≤ 60)** | Politecnico di Milano | 5 | 6 | 5 | 4 | 2 | 9 | 3 | 34 | 4 | x |
| | Syracuse University | 5 | 4 | 8 | 6 | 2 | 9 | 10 | 44 | 5 | |
| | Northeastern University | 10 | 5 | 6 | 2 | 11 | 4 | 6 | 44 | 6 | x |
| | University of Oslo | 4 | 8 | 8 | 10 | 2 | 7 | 9 | 48 | 7 | x |
| | University of Twente | 10 | 12 | 3 | 5 | 11 | 4 | 4 | 49 | 8 | x |
| | University of Utrecht | 7 | 9 | 6 | 7 | 8 | 6 | 6 | 49 | 9 | x |
| | Indiana University | 8 | 7 | 13 | 14 | 2 | 12 | 1 | 57 | 10 | |
| | National University of Singapore | 8 | 11 | 8 | 12 | 2 | 12 | 4 | 57 | 11 | |
| **Tier 3 (SUM >60)** | Chalmers University of Technology | 12 | 10 | 13 | 13 | 8 | 12 | 10 | 78 | 12 | x |
| | University of Kent | 13 | 14 | 12 | 9 | 15 | 7 | 10 | 80 | 13 | x |
| | Lund University | 13 | 13 | 16 | 16 | 11 | 15 | 10 | 94 | 14 | x |
| | University of Beira Interio | 13 | 15 | 13 | 15 | 11 | 15 | 10 | 92 | 15 | |
| | University of Southern Denmark | 16 | 17 | 8 | 11 | 15 | 11 | 15 | 93 | 16 | x |
| | University Exeter | 17 | 16 | 16 | 17 | 15 | 15 | 6 | 102 | 17 | x |

then aimed to reduce the subjective nature of our TE ranking by collecting the summation of ranking order (1–17) for each metric (Table 10). We ordered the schools of excellence starting with the lowest summation total (indicating the highest achieved rank for all categories collectively). Although our TE tiering approach differs slightly from Linton's (2004), the intent was to balance the tiers equally. We achieved this by tiering the schools by those centers of excellence with a summation less than or equal to 30 in tier 1, less than or equal to 60 in tier 2 and greater than 60 in tier 3.

In total, we identified 17 centers of excellence out of 348 schools globally, which is again an admirable accomplishment. The list of journals used in the search for MOT were identified by previous work, and initially we considered applying the same list to identify TE centers of excellence. To better understand the impact the base journal list had on the outcome of the results, we compared results that would have been generated from the MOT journal set against the final list used for identifying the TE centers of excellence. With a moderate modification to the TE base journals list, including the addition of six and removal of two journals (see Table 1b), we identified 150 additional articles published by active researchers. It should be easy to consider that the additional articles might modify the position on the tiers. In fact, we found five universities shifted positions on the list and identified a set of four centers of excellence to add to our final list.

## 6. Conclusion

We have provided the first ranking of MOT centers of excellence in 17 years, finding stability and change in the process. What was stable was that four out of five of the first-tier schools in the 2004 ranking remained in the 2021 ranking; moreover, many of the second-tier schools from 2004 also found a place in the 2021 ranking. What changed was that a single member of the third-tier schools remained in the 2021 ranking, and none of the 2004 ones were identified in the 2021 ranking.

Through the inclusion of six alternate journals to our TE review, we also provided insights into analyzing TE as a sub-field of MOT, and found that TE centers of excellence differed from MOT centers of excellence. This suggests that TE is emerging as a field in its own right.

There was some overlap between TE and MOT. There are 17 centers of TE excellence, three of them based in the U.S., of which two were also U.S. MOT centers of excellence. Of the 11 non-U.S. centers, all but two were MOT centers of excellence. The Lulea University of Technology and the University of Beira Interio were both identified only in the TE centers of excellence list.

With the number of university ranking systems available on the web, we accept that different readers are interested in different dimensions of university performance; therefore, a common notion of "the best university" may not address the readers' needs. We do not intend our study to be the last word in MOT ranking, or the first word in TE ranking. We simply added value by providing a ranking and tiering method utilizing the WoS core collection, with no modifications to the database. We aimed to reduce the subjective nature of our TE ranking by collecting the summation of ranking order (1–17) for each metric and placed the schools of excellence in order, starting with the lowest summation total (indicating the highest achieved rank for all categories collectively). Although our TE tiering approach differs slightly from Linton's (2004), the intent was to balance the tiers equally. We attempted this by tiering the schools by those centers of excellence with a summation less than or equal to 30 in tier one, less than or equal to 60 in tier two and greater than 60 in tier three. Though we showed, in identifying MOT schools of excellence, that the use of the accepted metrics and tiering approach has been stable over 17 years, new metrics and modified tiering were added to expand on the effort of equitable ranking.

Modification to Linton's (2004) ranking methodology was considered but not implemented. The authors decided to remain consistent with the original work but offer the following insight for future work in this area of research. We have read and referenced all the major ranking methods. The literature post 2004 suggests a weighted summation rather than having all ranking measures be of equal weight; for example, page count in the ranking process might not be equal to the number of article and citations, and it cannot be held as a variable that necessarily shows evidence of a paper's impact on the field. The principle of weighting metrics is based on the assumption that some metrics, such as bibliographic references in a paper, are strong indicators of their influence on the citing paper (Sahoo et al., 2016; Ramos-Rodríguez and Ruíz-Navarro, 2004; Cole and Cole, 1972). Thus, repeatedly cited references are thought to be more influential on the intellectual structure of a discipline than less frequently cited articles (Chen et al., 2019; Culnan, 1986). We considered sharing these views such that the measures offer greater insight on a center's impact on the field. We agree with Leband (1985) that the number of associate editors and editors in a field is important for a center of excellence due to their positions in top-tier journals to help direct the fields of discourse. The number of active researchers in a center of excellence is also extremely important. We envision that future works might want to consider these four metrics gaining a higher measure than the remaining metrics. Of note when we applied this weighted average approach to the data set only a few centers of excellence moved position. This could indicate that the metrics collected provides confidence that the volume of work for many of the centers of excellence are distinguishable from each other with or without weighted averages.

Through this work, the authors agree that, in future work, care should be taken in selecting base journals and consideration should be given to additional metrics, weighting of metrics based on impact, and defining the tiers linked to summation of the weighted metrics, as each of these elements may offer valuable insight in the identification of schools of excellence, especially in emerging technologies.

## CRediT authorship contribution statement

**Robert Giasolli:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Data curation. **Dr. Aard Groen:** Conceptualization, Methodology, Validation, Supervision. **Robert Haak:** Data curation, Investigation. **Martin Pieck:** Writing – review & editing, Data curation, Writing – original draft.

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**Robert Giasolli**, is aspiring to be a PhD student at University of Groningen Robert Giasolli is co-founder, Vice President of Research and Development, and Chief Technology Officer of Cagent Vascular. Robert graduated in 1989 from University of Texas with a Sc.B. in Applied Physics with an Engineering Minor. He received his Masters in Manufacturing Systems from the Louisiana Tech University in May 1998, where his thesis focus on designing MEMS devices for manufacturability, packaging, and testing. Robert's technology expertise includes endovascular medical device design, as well as endovascular disease progression, complexity, and methods for disease mitigation. His role as CTO spans technology and intellectual property strategy, technical marketing, fundraising, and business development for advanced projects. One of his companies he co-founded and was responsible for its innovative design was sold to Philips for $360 M in 2020. Robert has authored more than 100 issued or allowed patents and numerous peer-reviewed papers, in the field's endovascular device design and method of controlling complex vascular diseases. He co-edited MANCEF's "The Pharmaceutical Landscape Tool" and "International Micro-Nano Roadmap" 2nd Edition, and is an accomplished author on MEMS including focuses on HARMs and MEMS design. He was awarded Investment of the Year in 2009, by the Hawaii Angels. His technology has been featured in over 50 conferences and in over 10 industry magazines since 2010. He has sat as an elected member on numerous Corporate and Industry Boards. Was a Commissioner for the Commission on Dental Accreditation for 4 years, sat as an external advisor to Purdue's Discovery Learning Center, Albuquerque Technical Institute, and is currently sitting on the ASME Bio Engineering Technology Advisory Panel. Presently he is honored to be a proposed PhD student at the distinguished University of Groningen. In his youth he spent several years traveling as professional Mime Artist and was honored to have spent a Summer learning under Marcel Marceau.

**Dr. Aard Groen**, Dean University of Groningen Center of Entrepreneurship (UGCE) & professor of entrepreneurship & valorization **Research interests:** Innovation & Entrepreneurship in network perspective has been my research topic during my career. More specific I am interested in high tech entrepreneurship, corporate entrepreneurship & innovation, social entrepreneurship and entrepreneurship support methods and techniques. In Groningen next to being full professor of entrepreneurship & valorization, I am dean of entrepreneurship, so I lead the development of UoG as entrepreneurial university. By supporting work anywhere in UoG research, teaching and busines development support methods for the UoG in the University of Groningen Center of Entrepreneurship see www.rug.nl\UGCE Since 1 june 2018 UGCE merged with the faculty UCG, to estabish a school for interdisciplinary approaches of innovation in uncertain and complex challenges in society, UGCE adds to this from the entrepreneurship point of view. Into this UoG position I came as a so called double position with an older similar position @ University of Twente. In Twente I am co-founder of NIKOS the Netherlands Institute for Knowledge Intensive Entrepreneurship (sister of UGCE). Since beginning 2020 I am fully working at UG, but still finishing several PhD students projects in Twente. My research is part of Innovation and organization research program of SOM. I teach entrepreneurship and help other develop programs in many schools of UoG. Developing entrepreneurship support we mainly do in living labs such as Venturelab North in which we support persons and teams who like to develop a growth oriented knowledge intensive enterprise. This is part of our reserarch and teaching portfolio too.

**Robert Haak**, PhD student University of Twente Rob Haak founded the company, Asia Sales Manager, in Singapore in 2006, and has been selling technology products and services in Asia since 1990. During his 30-year career he has been based in San Jose, Seoul, Singapore, Taipei, Tokyo, Beijing, Hong Kong, Kuala Lumpur, and Honolulu. He has traveled in over 100 countries, primarily as a technical sales/marketing representative in industries such as semiconductor equipment and materials, sensors, robotics, nanotech, advanced materials, photonics, automotive, biopharma, medical devices, oil and gas, alternative energy, software, and many, many others. He has written countless technology market studies and technology forecasts in a wide range of industry. Rob is frequently invited as a guest speaker or guest lecturer on international marketing, sales strategy, Asian semiconductor supply chain dynamics, and electronics market and technology trends in Asia. His formal education includes a BS in Engineering from Tulane University in New Orleans, USA and an MBA in Management of Technology and Corporate Finance from the University of New Mexico in Albuquerque, USA, and he has had extensive formal language training in Japanese, Korean, Mandarin, and Bahasa.

**Martin Pieck** is a Scientist, Engineer, and Manager with over 20 years of experience in various areas of Information Technology, Instrumentation, and Controls for particle accelerator applications. Currently, he is the Group Leader in the Accelerator Operations & Technology Division that supports the Los Alamos Neutron Science Center (LANSCE) accelerator complex at Los Alamos National Laboratory. Pieck has received a graduate degree (Diplom-Ingenieur, UNI) in Electrical Engineering from the University of Wuppertal, Germany, a Master's degree in Computer Science from the University of New Mexico, a Master's degree in Business Administration from the New Mexico State University, a Post-Master's Certificate in Management with a concentration on Management of Technology from the University of New Mexico, Anderson School of Management. He is also a certified Project Management Professional and a Lean Six-Sigma Yellow Belt. While at LANL, Pieck has also led efforts outside the particle accelerator community in the development of controls and instrumentation applications with industrial partners and the Department of Homeland Defense. He has co-authored/authored over 20 peer reviewed and conference publications. Pieck is the recipient of the R&D 100 Award. Pieck's research interest focuses on Corporate Entrepreneurship, Technology Entrepreneurship, Technology Innovation, Technology Policy, and Technology Management. Pieck is a proposed PhD Student for the doctoral program in Economics and Business at the University of Groningen, NL.