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# Identification of, and knowledge communication among core safety science journals

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ABSTRACT

Safety science is an emerging discipline and research field, whose results have been traditionally spread over many journals, drawn both from the new discipline and its constituent underlying disciplines. Citation analysis was used to identify core safety science journals and map the knowledge communication between them. Using co-citation analysis and VOS methods, 51 safety-related journals and 8 clusters were extracted from the references of the journal *Safety Science*, which was taken as a representative core journal. Furthermore, the *safety science* citation report 2012 and 2013 were used to analyse the knowledge communication between different safety related journals. The results demonstrated that Safety Science as journal currently sits closer to management and psychology journals than to technology journals. The 8 clusters derived from the co-citation analysis show the multidisciplinarity of the safety science field as do the analyses of the citing by and of Safety Science as journal.

The paper is designed to show the potential of this sort of analysis for generating and studying questions about the structure and development of the discipline of safety science through its publication history.



## 1. Introduction

Safety science has developed over the last 50 years from a loose collection of topics scattered over many monodisciplinary journals, where they formed a minority of papers against the background of other research subjects, into a more or less consistent multidisciplinary discipline with its own core journals. This paper uses journal metrics to illustrate that process, indicate which are the core safety science journals and show how knowledge, in the form of citations of articles, flows between *Safety Science* (SS) and these journals.

Li has listed nearly 50 safety journals indexed by either SCI (Science Citation Index), SSCI (Social Science Citation Index), EI (Engineering Index) or other online sources, by using the keywords "safety", "accident", "risk", "disaster" and "injury" to be found in the title of the journal (Li, 2014). In a previous study (Reniers and Anthone, 2012) used a similar on-line keyword search method to identify 35 safety-related journals. They then correlated the journals' impact factors (Garfield, 1999) with the results of a questionnaire study sent to safety researchers to gauge their perception of which of the journals were of the highest quality. *Journal of Loss Control in the Process Industries* (JLPPI), was the safety researchers' most highly rated journal for quality, but when both impact factor and research assessment were taken into account the top 5 journals emerged as: *Journal of Hazardous Materials* (JHM), *Reliability Engineering and System Safety* (RESS), *Risk Analysis* (RA), *Accident Analysis and Prevention* (AAP) and SS. From our observations of the content of the journals, we see that JLPPI, JHM and RESS have a focus on major hazard activities, AAP on traffic safety and SS on a broader remit stemming from occupational safety across many industries, with a more recent bias towards safety management and culture questions.

The methods used in the Reniers and Athone study focus on quality. We were interested here in a slightly different question, namely what corpus of knowledge and research defines the multidisciplinary discipline of safety science. What are its core journals and how does knowledge flow between journals at the core and those more peripheral, or those providing underlying knowledge? For these questions it is more appropriate to use citation analysis methods which trace what studies and theories influence later

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research and where that is published. In order to make this analysis it is convenient to choose one journal as the core of the analysis and map its relations with other related journals. Because it has such a broad range of safety research topics on which papers are published and for reasons of the second author's connection to *Safety Science*, as a former chief editor, this journal was chosen from the half dozen top safety journals identified by Reniers and Athone to fulfil that role. Future analyses can study what if any differences in the pictures derived here there might be if another core safety science journal were to be chosen for that role.

This paper considers the following questions:

- Which are the core safety journals around SS, using this citation analysis?
- How do they cluster with other safety-related journals and how do they position themselves in the general web of science?
- What is the flow of knowledge between *Safety Science* and the other safety-related journals?

## 2. Data and methodology

Currently, there are four possible ways to try to identify safety journals. These are:

1. The Journal Metrics System (JMS),[1] which has been developed by Elsevier B.V. The journal data included for analysis are based on the Scopus bibliographic database produced by Elsevier. It has no categorisation of the journals by subject. The information about journal parameters which can be retrieved from the system includes the Source Normalised Impact per Paper (SNIP), the Impact per Publication (IPP), and the SCImago Journal Rank (SJR) metrics.
2. Leiden Journal Indicators System (JIS)[2] otherwise known as the ASJC (All Science Journal Classification), which has been developed by the Centre for Science and Technology Studies of Leiden University. The data source is also the Scopus bibliographic database. The ASJC also includes a classification of journals, into a main area and subarea of discipline. This includes a category of 'safety research' The journal parameters provided include the number of publications, the raw impact per publication (PRIP), the source normalised impact per publication (SNIP) and the percentage of journal self-citations (% self Cit).
3. SCImago journal system[3] which has been developed by the University of Granada. Journals can be searched and ranked in this system, which also has a category of 'safety research'. Moreover, SCImago has developed a new function, the so called "Shape of Science", which is an information visualisation project whose aim is to reveal the structure of science.[4]
4. ISI Journal Citation Report (ISI-JCR),[5] which comes in a science and a social science version, and which has been developed by Thomson Reuters. JCR is the most famous journal metrics system, which publishes journal impact factors every year around July. It is possible to retrieve from the ISI-JCR not only the basic journal parameters (Impact Factor, Immediacy Index, Cited Half-life and Eigen factor® Metrics, etc.) but also the detailed information of the journals *cited* by the journal in question and those *citing* the journal in question.

For detailed information on the journal parameters refer to Appendix B.

All of the journal systems are on open access except the underlying Scopus database for the ISI-JCR systems. The ISI-JCR, ASJC and SCImago journal systems categorise the journals into scientific domains. The ASJC and SCImago journal systems have the journal category "Safety research", but the ISI-JCR system does not. However, study of the list of journals in that category in the other systems shows that their use of the word 'safety' is very broad and not validated by any other analysis. In the ASJC system category there are a significant number which have 'security' or related terms in their titles, a topic which falls outside our study, though raising interesting questions as to the relationship of 'safety' with 'security'. We return briefly to that point at the end of the paper. We therefore decided not to use either existing domain categorisation but to derive our own list based on the more objective evidence of citation analysis.

Compared with the other three systems, the ISI-JCR system is the only one which has the detailed citation data of each journal, which are essential for our research question. For our purposes the most suitable source of data are therefore the Web of Science and JCR system, through which to access the SS journal index data and SS journal citation reports. Hence the citation data sets of SS (both as journal being cited by other journals and citing those other journals, were retrieved from JCR see Table 1). We also downloaded from the Web of Science the full records of papers (including cited references) published in SS during the years 1991–2013. For the detailed steps to download the Web of Science data please refer to the webpages cited in Appendix B.

The following methods were used for the analysis (more details can be found on the webpages cited in Appendix B):

1. *Citation analysis* is one of the most important indicators used in science evaluation. This focusses on the work which is cited by authors as support or reference for their work, methods, models and results. Although there are different reasons for citing a particular work (Garfield, 1965), this process has been found to be a valuable, though still controversial measure of influence, see e.g. (Kostoff, 1998; MacRoberts and MacRoberts, 2010). Citation is a two way process: it covers the citing behaviour of the authors in the journal in question – in our case SS (who is cited by them?) called 'citing analysis' and the citing by authors in other journals of SS papers (who cites them?), called 'cited analysis'. The communication between SS and other journals can be divided into these two directions, forming the knowledge input to and output from SS. The SS journal citation reports for 2012 and 2013 were used to analyse this knowledge communication between SS and other safety related journals.
2. *Co-citation* analyses the scientific papers that are cited together in the same paper by an author; the more two papers or authors, or in our case, two journals, are cited together by an author, the more similarity between the authors and topics of those two journals there is assumed to be. This is based on analysis of the knowledge unit of the individual document in the reference, There are three types of co-citation analysis, document co-citation analysis (DCA), author co-citation analysis (ACA) and journal co-citation analysis (JCA) (Gmür, 2003; Tsay et al., 2003a,b). In this study we have just focused on a journal-related analysis, rather than an author related analysis.

We analysed the citing journal, the cited journal and journal co-citation analysis. The VOSviewer tool (a free bibliometrics mapping tool[6]) was used for the journals co-citation analysis (Van Eck and

[1] Freely accessible from JMS http://www.journalmetrics.com/index.php.
[2] Freely accessible via CWTS Journal indicators http://www.journalindicators.com/indicators.
[3] Freely accessible via SCImago Journal and Country Rank, http://www.scimagojr.com.
[4] Freely accessible via SCImago The Shape of Science http://www.scimagojr.com/shapeofscience.
[5] Access to the JCR system requires permission.
[6] The software can be freely downloaded from http://vosviewer.com/download/.

**Table 1**
Data set of this study.

| Data set and subject | Data source | Records | Records used |
|---|---|---|---|
| Web of science articles | *Safety Science* (SS) journal (1991–2013)[a] | 1827 | 1827 |
| Cited journal = *SS* | Journal citation report (2012, 2013)[b] | 190; 222 | Top 20 of each year |
| Citing journal = *SS* | Journal citation report (2012, 2013) | 733; 856 | Top 20 of each year |

[a] The earlier articles from 1976 of the journal, previously published under the name 'Journal of Occupational Accidents', have no reference in the data set.
[b] JCR 2012 was published in 2013, and JCR 2013 was published 30th July 2014.

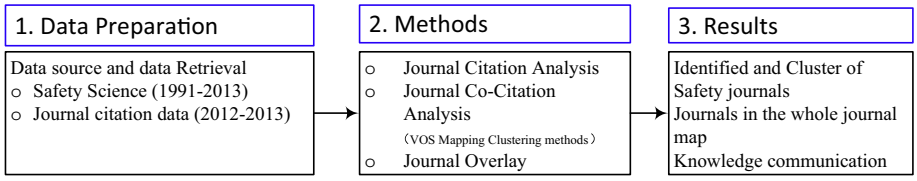


**Fig. 1.** Steps of research.

Waltman, 2010). It automatically extracts the journal co-citation matrix and normalises it using the association strength. Then VOS mapping and clustering techniques were applied to give the position of the node in a two dimensional map together with clustering with different colours. More information about how it works can be found at (Van Eck and Waltman, 2010), http://www.vosviewer.com, and http://www.cwts.nl/Advanced-Bibliometric-Methods.

For the basic steps in this study see Fig. 1.

## 3. Results and discussion

### 3.1. Global view of safety journals

The results of the co-citation analysis of SS are shown in Fig. 1. In order to make the figure legible, some of the less important overlapping labels are left off the map. 20,516 sources (including book titles, journal titles and conference publication titles) were extracted from the references to all articles in SS from 1991 to 2013. In order to present as clear a picture as possible, a cut-off was imposed of a minimum of 20 citations of a source by papers in SS for it to be included. Of the 20,516 sources, 186 met this threshold criterion and so represent the core and periphery around SS. These were clustered using the VOS method (Waltman et al., 2010) and were visualised with VOSviewer.

The output of the mapping tool is twofold: a two dimensional map showing physical distances between journals and a grouping by colour. The former is a compression into two dimensions of the multidimensional plot which produces the different coloured clusters (Waltman et al., 2010). Hence there are some same coloured dots which are apparently at a great distance from their colourmates on the two-dimensional plot. The main interpretation of the picture is based on the colours, with the distance being best interpreted as the distance between the centres of the coloured clusters. The size of the coloured dots reflects the volume of citations (see also Table 2 for the number of citations per journal which has been cited.)

Core safety science journals identified from other analyses are to be found on this mapping, including AAP, JSR, RESS, JHM and RA. These 186 sources resolve themselves into 8 clusters or colours in Fig. 1. Table 2 gives the five most highly cited sources in each cluster, whilst Table 3 gives the full list of journals with more than 50 citations, ordered by their weight (number of citations). These journals co-cited by authors in SS, represent the major knowledge flows from other journals and books (sources) to SS.

This clustering shows how multidisciplinary Safety Science is as journal, being fed by journals with a wide range of different disciplines. SS is located in cluster 1, which means that the topics of SS have been more closely related to psychology, related social science and management than to the other clusters. Cluster 2 is mainly in public health, overlapping with occupational hygiene. Cluster 3 is the major hazard cluster, focusing on quantitative analysis of risk. Cluster 4 is in the area of traffic safety, with a focus also on human factors, and psychology. Cluster 5 relates to the fundamental physics and engineering sciences, but also takes in fire safety. Cluster 6 combines construction safety with the professional and scientific journals based in the USA. Cluster 7 consists mainly of ergonomics-related journals. Cluster 8 is also of traffic related journals, including AAP, but distinguishes itself from cluster 4 by having less direct recourse to human factors.

**Table 2**
Detailed clustering of information of sources in SS co-citations analysis. Numbers in brackets are the number of citations to that journal from SS.

| Cluster | List of sources (number of citations) |
|---|---|
| 1 | *J Appl Psychol* (549), *Work Stress* (278), *J Occup Health Psychol* (135), *Managing Risks Org A* (119), *J Organ Behave* (108) |
| 2 | *Am J Ind Med* (241), *J Occup Environ Med* (165), *Scand J Work Env Hea* (112), *Am J Public Health* (109), *Injury Prev* (106) |
| 3 | *Reliab Eng Syst Safe* (497), *Risk Anal* (315), *J Loss Prevent Proc* (300), *J Hazard Mater* (240), *J Risk Res* (90) |
| 4 | *Hum Factors* (322), *Transport Res F-Traf* (196), *Psychol Bull* (113), *J Pers Soc Psychol* (97), *Int J Aviat Psychol* (80) |
| 5 | *Fire Safety J* (113), *Physica A* (80), *Int J Rock Mech Min* (54), *Phys Rev E* (50), *Nature* (48) |
| 6 | *J Safety Res* (905), *J Constr Eng M Asce* (229), *Prof Saf* (97), *Construction Managem* (52), *Int J Proj Manag* (39) |
| 7 | *Ergonomics* (742), *Appl Ergon* (304), *Int J Ind Ergonom* (228), *Traffic Inj Prev* (59), *Gait Posture* (35) |
| 8 | *Accident Anal Prev* (1554), *Transport Res Rec* (236), *J Transp Eng-Asce* (48), *Transport Res A-Pol* (35), *Transp Res Record* (28) |

*Note:* See Appendix A for the abbreviations of the journals.

The full list of the journals in the analysis which are cited more than 50 times by SS is shown in Table 3. This list consists of two sorts of journals: the core safety journals other than SS, where the citations are evidence of use and development of work in parallel journals; and the journals containing the underlying theory and practice on which the multidisciplinary discipline of safety research draws. The first ten in Table 3 might be seen as the core around SS, particularly JSR and AAP. RESS, JLPPI and RA are a little more separated from SS, representing the quantitative, technology-related, in contrast to the more qualitative, style of research. It is notable that the JHM falls outside of that top 10 despite its presence in the top 5 in the earlier work of Reniers and Athone.

**Table 3**
Co-cited sources identified from SS journal (weight = number of citations, cut-off 50).

| No. | Sources | Weight | Cluster | No. | Sources | Weight | Cluster |
|---|---|---|---|---|---|---|---|
| 1 | *Safety Sci (SS)* | 3540 | 1 | 30 | *Prof Saf* | 97 | 6 |
| 2 | *Accident Anal Prev (AAP)* | 1554 | 8 | 31 | *Acad Manage J* | 96 | 1 |
| 3 | *J Safety Res (JSR)* | 905 | 6 | 32 | *Brit Med J* | 96 | 2 |
| 4 | *Ergonomics* | 742 | 7 | 33 | *Admin Sci Quart* | 91 | 1 |
| 5 | *J Appl Psychol* | 549 | 1 | 34 | *J Risk Res* | 90 | 3 |
| 6 | *Reliab Eng Syst Safe (RESS)* | 497 | 3 | 35 | *Occup Environ Med* | 89 | 2 |
| 7 | *Hum Factors* | 322 | 4 | 36 | *Eur J Oper Res* | 86 | 3 |
| 8 | *Risk Anal (RA)* | 315 | 3 | 37 | *Int J Aviat Psychol* | 80 | 4 |
| 9 | *Appl Ergon* | 304 | 7 | 38 | *Physica A* | 80 | 5 |
| 10 | *J Loss Prevent Proc (JLPPI)* | 300 | 3 | 39 | *J Occup Health* | 77 | 2 |
| 11 | *Work Stress* | 278 | 1 | 40 | *Qual Saf Health Care* | 77 | 1 |
| 12 | *Am J Ind Med* | 241 | 2 | 41 | *Resilience Eng Conce* | 77 | 1 |
| 13 | *J Hazard Mater (JHM)* | 240 | 3 | 42 | *Soc Sci Med* | 75 | 2 |
| 14 | *Transport Res Rec* | 236 | 8 | 43 | *Pers Psychol* | 72 | 1 |
| 15 | *J Constr Eng M Asce* | 229 | 6 | 44 | *Science* | 66 | 3 |
| 16 | *Int J Ind Ergonom* | 228 | 7 | 45 | *Hum Relat* | 63 | 1 |
| 17 | *Transport Res F-Traf* | 196 | 4 | 46 | *Expert Syst Appl* | 62 | 3 |
| 18 | *J Occup Environ Med* | 165 | 2 | 47 | *Aviat Space Envir Md* | 61 | 4 |
| 19 | *J Occup Health Psychol* | 135 | 1 | 48 | *J Occup Organ Psych* | 59 | 1 |
| 20 | *Managing Risks Org A* | 119 | 1 | 49 | *Traffic Inj Prev* | 59 | 7 |
| 21 | *Fire Safety J* | 113 | 5 | 50 | *Normal Accidents* | 58 | 1 |
| 22 | *Psychol Bull* | 113 | 4 | 51 | *Ind Accident Prevent* | 55 | 2 |
| 23 | *Scand J Work Env Hea* | 112 | 2 | 52 | *Int J Rock Mech Min* | 54 | 5 |
| 24 | *Human Error* | 112 | 1 | 53 | *Occup Med-Oxford* | 54 | 2 |
| 25 | *Am J Public Health* | 109 | 2 | 54 | *Construction Managem* | 52 | 6 |
| 26 | *J Organ Behav* | 108 | 1 | 55 | *J Contingencies Cris* | 52 | 1 |
| 27 | *Injury Prev* | 106 | 2 | 56 | *Psychol Rev* | 52 | 4 |
| 28 | *Acad Manage Rev* | 97 | 1 | 57 | *Man Made Disasters* | 51 | 1 |
| 29 | *J Pers Soc Psychol* | 97 | 4 | | | | |

*NB:* Sources with dark background are books; the full titles of all of these sources are listed in Appendix A.

The closeness of SS to the field of ergonomics is also clear from the three journals in the top 10 which represent that discipline. In that context it is interesting that the domain of 'ergonomics' in the JCR system does not list SS as a member. This would appear to be an incorrect categorisation on our evidence. It is a moot point whether these three should be regarded as parallel core journals for safety research or as underlying sources of methods and theories. The same question can be posed in relation to the *Journal of Applied Psychology*, which comes fifth in Table 3, although it is clearer that this should be seen as an underpinning journal for safety culture and risk perception studies, rather than a core safety research journal.

The topics of occupational health/medicine and injury prevention, fire safety and health care safety are far less in the core around SS at present, though this could change in the future, certainly with the considerable research effort in patient safety in the last decade. It would appear that development of patient safety is not (yet) reflected in a closer link between SS and journals underpinning that research.

The remaining journals can best be seen as feeding methods and theories from their disciplines into safety research. We will take up this issue again in the final section of the results. It is also interesting to see the most influential books confirmed as those of Reason (1990, 1997), Heinrich et al. (1950), Perrow (1984), Turner and Pidgeon (1978), and Hollnagel et al. (2006).

As a further attempt to understand these relationships, we drew upon another analysis to place the journals cited by SS in the context of the total of journals indexed on the Web of Science (WoS). We based this on a co-citation analysis that has been made by Leydesdorff et al., and mapping of 10,253 journals indexed in the WoS. This master map is shown in Fig. 3 (Leydesdorff et al., 2013). It shows the full picture of the shape of science across all disciplines and journals, giving each journal a fixed place dependent on how it relates to all other journals on the WoS. This contrasts with the local map of Fig. 2 which uses SS as its starting point and distributes the other journals only in relation to that one.

For the detailed information for creating the journal overlay map refer to the sites in Appendix B.

Using overlay techniques (Leydesdorff et al., 2013) it is possible to highlight the journals on that master map which are referenced in one given journal and suppress those journals not cited. Fig. 4 shows the results of doing this, using the journals cited by SS as the overlay.

This shows a different perspective and hence a different pattern to Fig. 2. It is a global map encompassing the whole field of science, rather than the local map in Fig. 2, which maps only the local relationships of the safety journals. In this perspective SS clearly clusters close to transport journals (a clustering that Elsevier, its publisher, used for many years in its publicity material) and to technology journals like JHM and *Journal of Fire Safety*. It is placed diametrically opposite to the medical journals and quite some distance from the psychological journals. *Ergonomics* bridges the psychology – medicine divide and also lies far away from SS, in contrast to our earlier analyses, whilst some management journals form a small bridge between SS and the human factors journals. It is not entirely clear how to interpret this mapping, but one hypothesis might be that this clustering refers back to the more classically dominant divide between the human (social science and medicine) and technical worlds. SS and the practice of safety came from that technical background, reflected in its much more technical content in its days as the *Journal of Occupational Accidents*. It grew disproportionally in later years on the management and human factors sides to become much more of a multidisciplinary journal, as our earlier co-citation analysis has shown. However, we would have expected this to have resulted in a shift of SS much closer to journals such as AAP and *Journal of Applied Psychology*. The two analyses therefore reflect different pictures which require reconciliation.

### 3.2. Knowledge communication

The results in Section 3.1 have already shown a first analysis of the knowledge flow from other sources (journals and books) to SS.

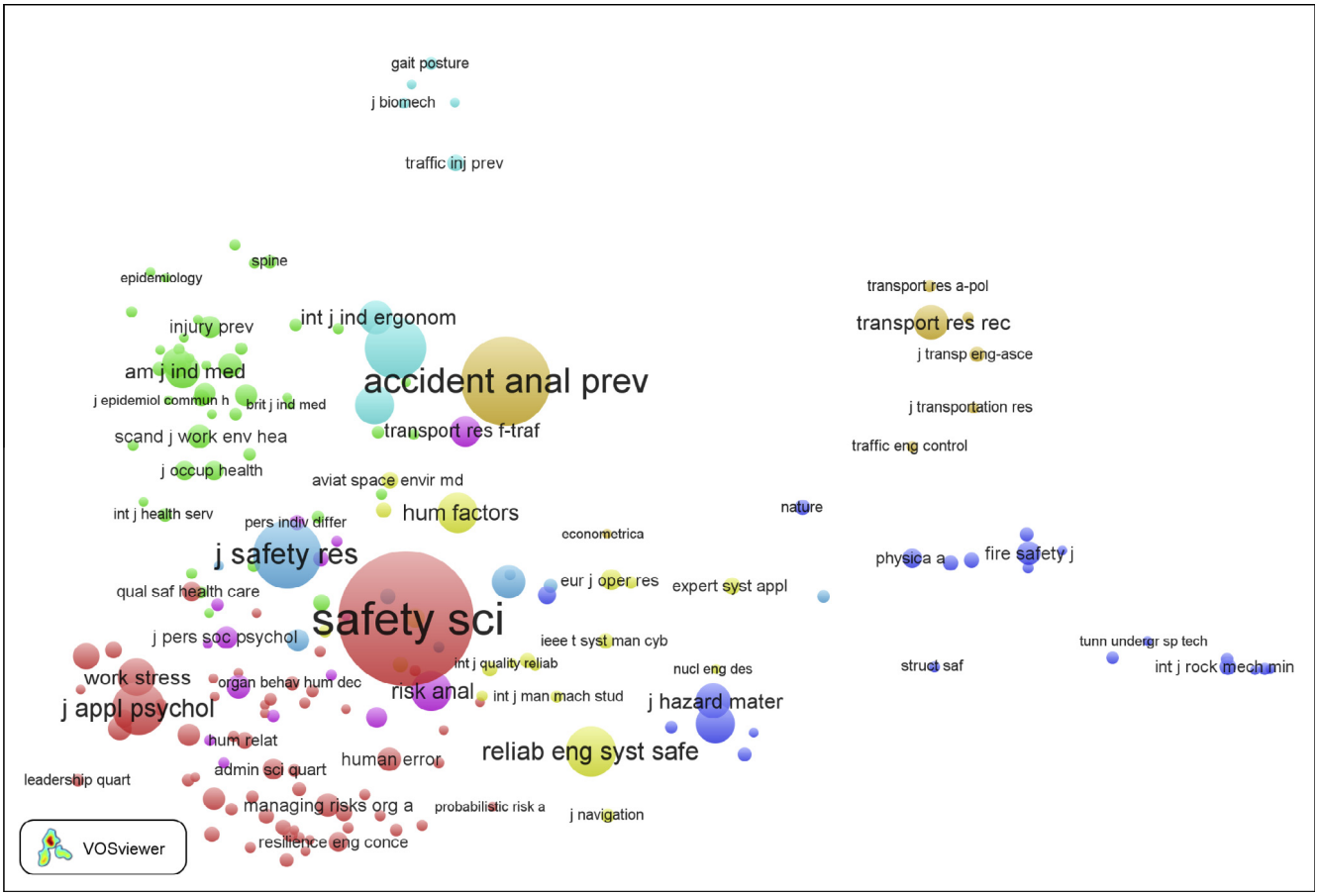


**Fig. 2.** Co-citation (source) analysis of *Safety Science*. *Note:* In the co-citation analysis *Journal of Occupational Accident* was merged in SS, since the latter is simply a retitling of the former. The increasing font size and circle size of each journal in Fig. 1 indicate the increasing number of citations; the colours of the circles indicate the clusters. The coloured figure can be viewed online https://drive.google.com/file/d/0B0HnDMi5NBF8VFFMSzZNalUtV28/edit?usp=sharing. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

However, this analysis could not show the knowledge flow from SS to other journals. Therefore, citing and cited data of SS were retrieved from the Journal Citation Reports (JCR) of SS for 2012 and 2013 to show both sides of the knowledge communication of SS, the inputs and outputs – SS as citing journal shows the inputs and as cited journal, the outputs. (For the way to get journal citation data please refer to the websites given in Appendix B).

In the 2012 JCR Science Edition, SS was cited 2393 times, in 190 indexed journals, whilst SS cited 733 other journals 8323 times. In JCR 2013, the figures were higher; SS was cited 3181 times by 222 journals and SS cited 856 other journals 9215 times. The cited and citing data for the two years show that SS absorbed knowledge from many more journals than it exported to other scientific journals. This may reflect the fact that another potential outflow, to professional and practice-oriented magazines and journals is not represented in this analysis. It may also reflect that safety research is an applied activity which takes in fundamental monodisciplinary knowledge and applies it, rather than being deeply involved in feeding back safety issues for resolution by the monodisciplinary subjects.

The two sections of Figs. 5 and 6 show the knowledge flow to and from SS and its related journals in 2012 and 2013 respectively. The top 20 citing and cited journals are given in each case. The left side of the figures shows which journals were cited the most by SS, reflecting the knowledge from these journals flowing to SS. The right side of the figures shows the journals from those indexed by the Web of Science that were citing SS in their articles, reflecting the knowledge flow from SS to other journals.

In all cases, both inputs and outputs, the dominant citing and cited journal is SS itself, this pattern of self-citation is common among journals, but indicates that safety research also does drive its own research field. The fact that AAP, JLPPI, JSR and RESS are also present in the top 20 on both input and output sides in both years, reflects their presence in the overall core of safety research, whilst RA (2 outputs lists, 1 input list) and *Journal of Risk Research* (1 output list) appear to be further from this core. The same closeness to the core applies, however to *Applied Ergonomics* (on all 4 top 20 lists), whilst *Ergonomics* is on three of them (2 inputs and one output). This strengthens the conclusion that safety and ergonomics are very closely allied. The relatively close link to transportation journals is shown by the presence of one or both of the cited transportation journals (*Transport Research Record* and/or *Transportation Research Part F*) on all four top 20 lists.

The importance of safety in the construction industry is shown by the presence of the *Journal of Construction Engineering and Management* also on all four top 20 lists, both as input and output, perhaps indicating a very desirable close link between theory and practice in this dangerous industry.

These conclusions need to be viewed with some caution, as the joint journal citation reports for the two years show that the top 20 lists on both input and output sides are quite unstable, only 9 out of 20 journals on the input side appear in both years and 11 of 20 on the output side. It may be better to combine several years of inputs and outputs to arrive at a more stable picture. On the other hand analysis of individual years over a longer period may show interesting shifts of the focus of the journal.

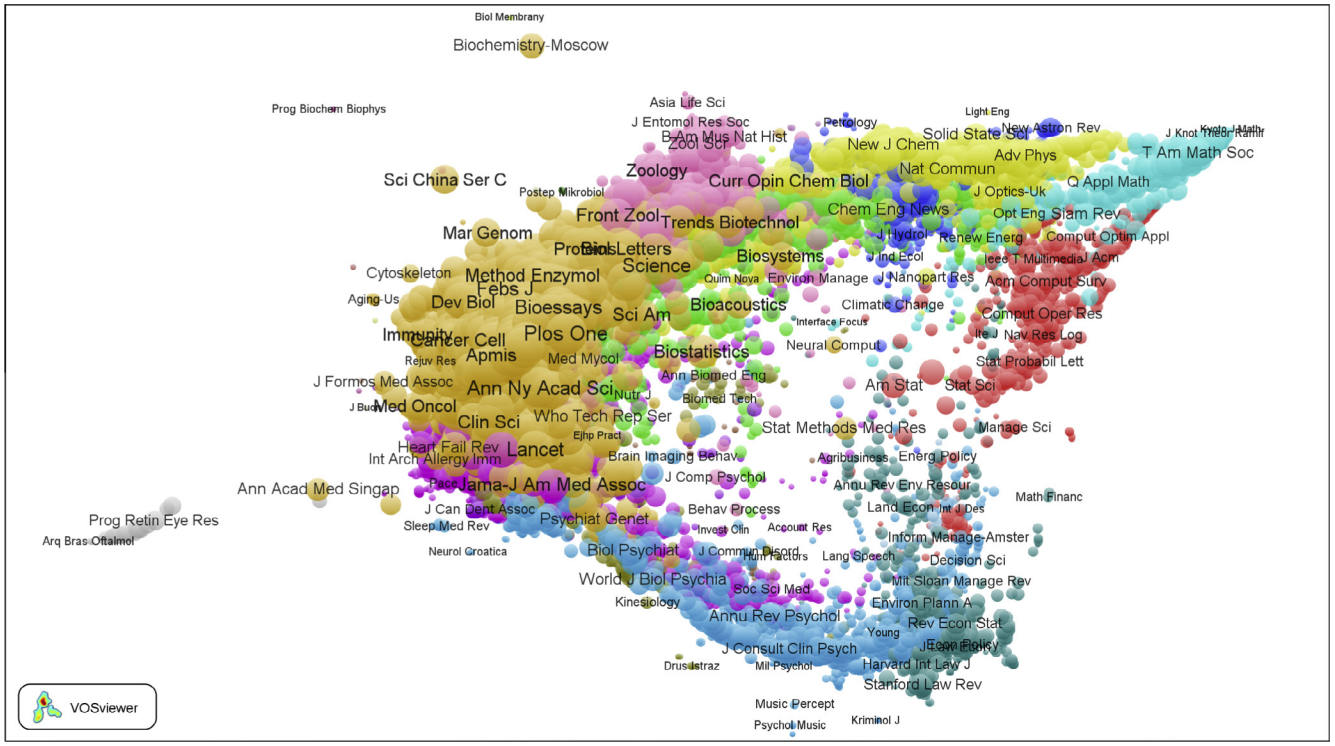


**Fig. 3.** Of 10,253 journals similar in their cited patterns (this layer of the map was created by Leydesdorff and can be freely download and opened with VOSviewer. http://www.vosviewer.com/vosviewer.php?map=http://www.leydesdorff.net/journals11/cited_all.txt). *Note:* Coloured figure can be viewed online https://drive.google.com/file/d/0B0HnDMi5NBF8MlpKdWVNVmdHdEk/edit?usp=sharing. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

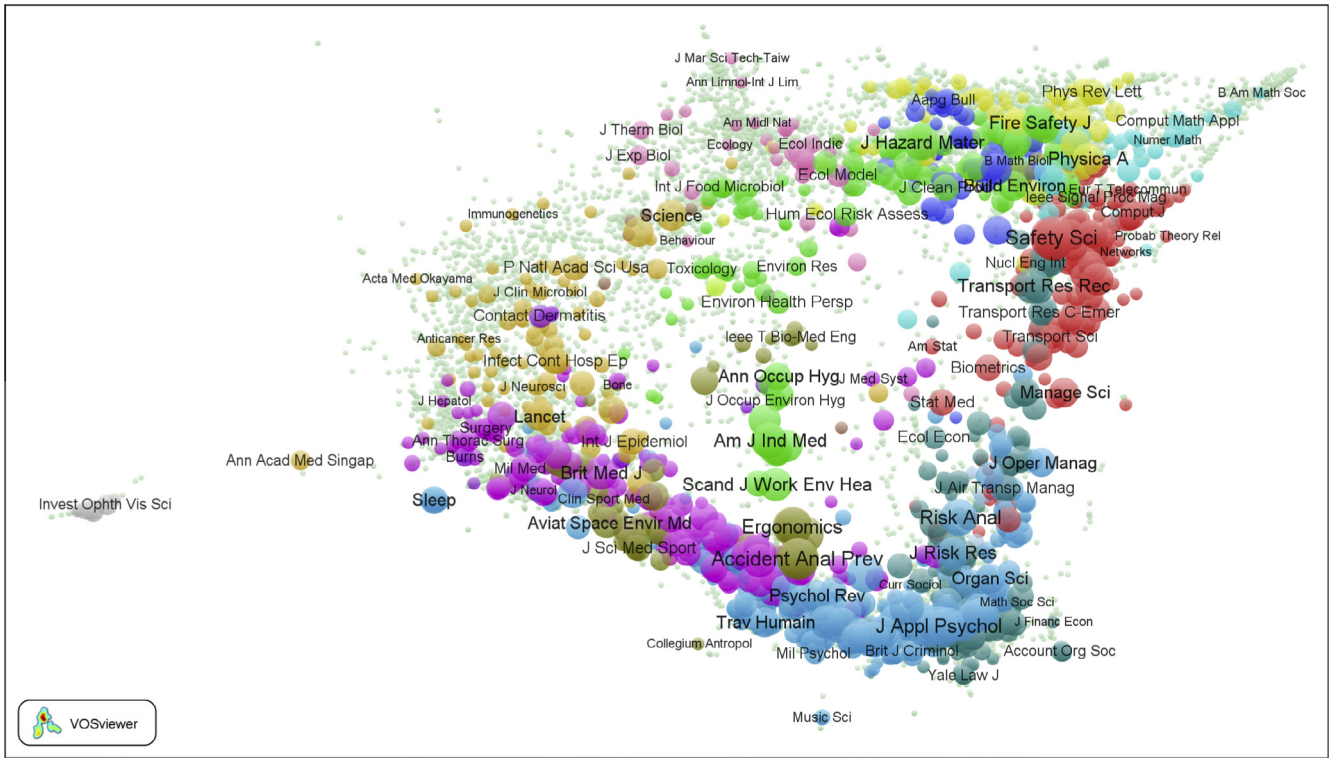


**Fig. 4.** Location of journals which were cited by SS form 1991 to 2013. *Note:* Coloured figure can be viewed online https://drive.google.com/file/d/0B0HnDMi5NBF8-ci1Ub0phQkc1b3M/edit?usp=sharing. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

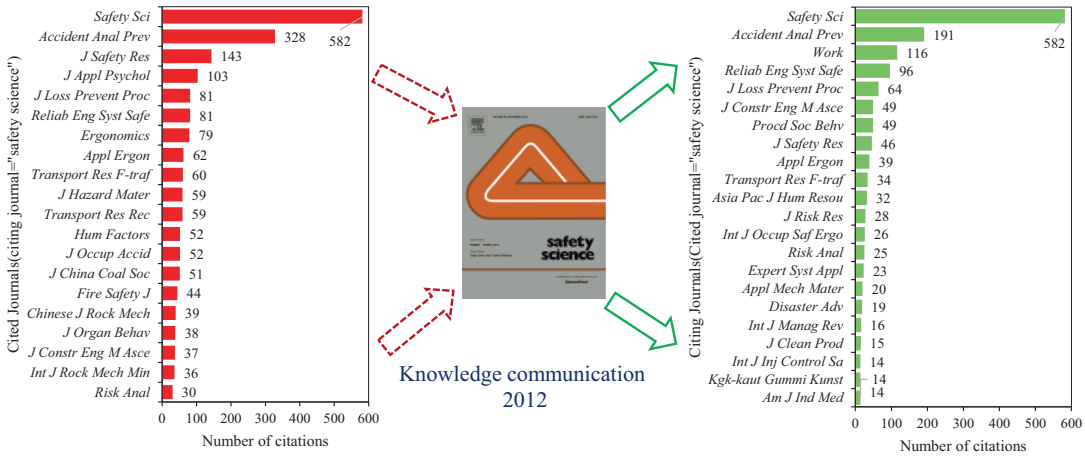


**Fig. 5.** Knowledge communication between *Safety Science* and other sources in 2012.

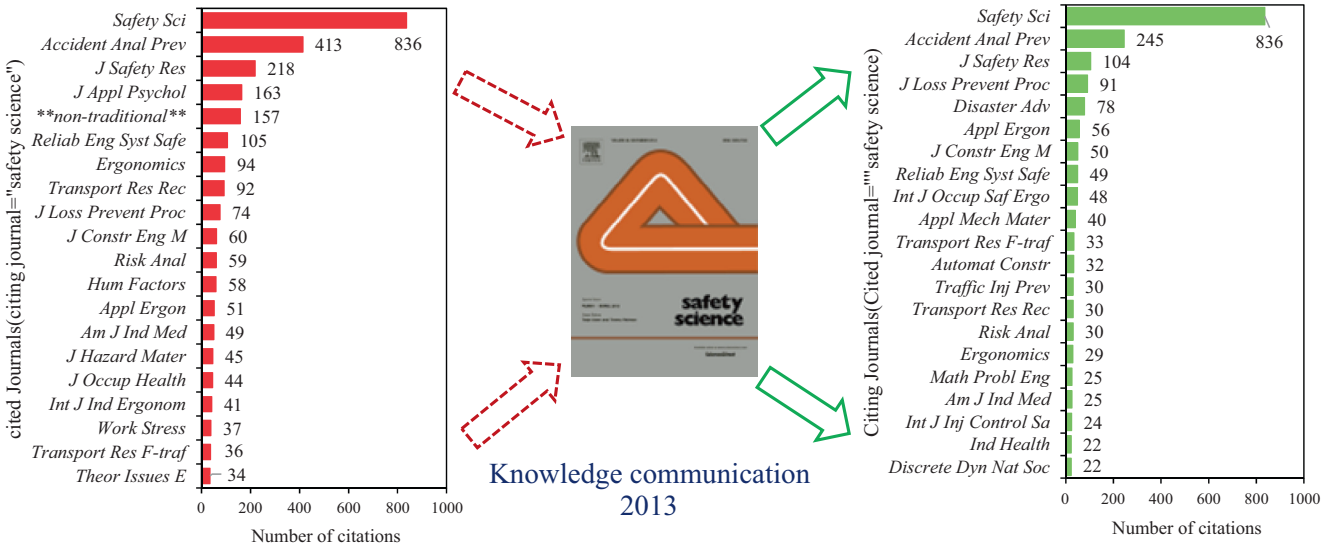


**Fig. 6.** Knowledge communication between *Safety Science* and other sources in 2013. *Note: **NON-TRADITIONAL*** and *THEOR ISSUES E* cannot be identified. Other full titles of sources are listed in Appendix A.

Only 7 journals in 2012 and 10 in 2013 appear on both input and output sides indicating that SS is a journal which also cross-fertilises different fields of research and practice.

## 4. Conclusions and further work

We have analysed in several different ways the question as to which journals form the core of safety research. We have approached the question from the vantage point of the journal SS. We have sought the answer in an as objective as possible way by using co-citation analysis and joint journal citation reports. A consistent picture emerges of the core safety journals, with AAP and JSR being the closest to SS, with RESS and JLPPI being almost as close and RA and JHM being somewhat more distant. The interactions between these journals, shown by the inputs to and outputs from SS and the co-citations, demonstrate that the first 5 form a coherent and interactive group, feeding each other. However, the same conclusion can be made about the ergonomic journals, particularly *Applied Ergonomics* and *Ergonomics*, which interact with, feed and are fed by the same core group of 5, at least when seen from the perspective of SS. It is therefore to be recommended that SS should be listed by the ISI-JCR system as an ergonomics journals. These results largely confirm Reniers and Athone's (op cit) findings about core safety journals, but place them on a more solid and objective basis than their expert judgment analysis.

Our analyses also show clearly that the safety research in SS is multidisciplinary, drawing on 8 clusters of journals spanning technology (construction and engineering), public health and occupational hygiene, psychology and management, ergonomics, traffic safety and quantitative approaches around major hazards. The journal SS sits most strongly in the management and psychology area.

We find no security journals closely related to SS on either the input or output sides, indicating that a close relation between safety and security research is not yet manifest and may be difficult to develop. Neither is patient safety in health care as yet very visible on the maps we have constructed, despite the major research efforts the last 10 years in that area.

As indicated, our study has taken the journal SS as its defined focus. The same analyses using each of the other core journals we have identified will show if that picture changes significantly from those vantage points. We hope that the analyses presented here will encourage others to make such studies.

There are also other methods for constructing maps of research areas which we have not used here. One such is relatedness analysis (Pudovkin and Garfield, 2002), which would take our knowledge flow analysis a step further. We also see the value in making similar analyses but with different time slices. These would show whether and how safety journals shift their focus and their communication flows over time. This would follow up analyses made by Hale (2006) showing the shift in attention in safety research from technological approaches to human factors and management, see also Hale and Hovden (1998).

## Appendix A. Sources and abbreviations

The full names of the journals or books given as abbreviations in the tables of the paper are given in Table A1 A1. The books are marked with a star (★). Where initial letter abbreviations of the main core journals are used in the text, these are given also in this table.

**Table A1**
Sources and abbreviations.

| Journal | Abbreviation |
|---|---|
| A | |
| *Academy of Management Journal* | *Acad Manage J* |
| *Academy of Management Review* | *Acad Manage Rev* |
| *Accident Analysis & Prevention* | *Accident Anal Prev (AAP)* |
| *Administrative Science Quarterly* | *Admin Sci Quart* |
| *American Journal of Industrial Medicine* | *Am J Ind Med* |
| *American Journal of Public Health* | *Am J Public Health* |
| *Applied Ergonomics* | *Appl Ergon* |
| *Applied Mechanics and Materials* | *Appl Mech Mater* |
| *Asia Pacific Journal of Human Resources* | *Asia Pac J Hum Resou* |
| *Automation In Construction* | *Automat Constr* |
| *Aviation, Space, and Environmental Medicine* | *Aviat Space Envir Md* |
| B | |
| *British Medical Journal* | *Brit Med J* |
| *British Medical Journal: Quality & Safety in Health Care* | *Qual Saf Health Care* |
| C | |
| *Chinese Journal of rock Mechanics and Engineering* | *Chinese J Rock Mech* |
| *Construction Management and Economics* | *Construction Managem* |
| D | |
| *Disaster Advances* | *Disaster Adv* |
| *Discrete Dynamics In Nature And Society* | *Discrete Dyn Nat Soc* |
| E | |
| *Ergonomics* | *Ergonomics* |
| *European Journal of Operational Research* | *Eur J Oper Res* |
| *Expert Systems with Applications* | *Expert Syst Appl* |
| F | |
| *Fire Safety Journal* | *Fire Safety J* |
| H | |
| Human Error (Reason, 1990) ★ | *Human Error* |
| *Human Factors* | *Hum Factors* |
| *Human Relations* | *Hum Relat* |
| I | |
| Industrial accident prevention (Heinrich et al., 1950) ★ | *Ind Accident Prevent* |
| *Industrial Health* | *Ind Health* |
| *Injury Prevention* | *Injury Prev* |
| *International Journal of Aviation Psychology* | *Int J Aviat Psychol* |
| *International Journal of Industrial Ergonomics* | *Int J Ind Ergonom* |
| *International Journal of Injury Control and Safety Promotion* | *Int J Inj Control SA* |
| *International Journal of Management Reviews* | *Int J Manag Rev* |
| *International Journal of Rock Mechanics and Mining Sciences* | *Int J Rock Mech Min* |
| J | |
| *Journal of Applied Psychology* | *J Appl Psychol* |
| *Journal of Cleaner Production* | *J Clean Prod* |
| *Journal of Construction Engineering and Management* | *J Constr Eng M Asce* |
| *Journal of Contingencies and Crisis Management* | *J Contingencies Cris* |
| *Journal of Hazardous Materials* | *J Hazard Mater (JHM)* |
| *Journal of Loss Prevention in the Process Industries* | *J Loss Prevent Proc (JLPPI)* |
| *Journal of Occupational & Environmental Medicine* | *J Occup Environ Med* |
| *Journal of Occupational Accidents* | *J Occup Accid* |
| *Journal of Occupational and Organizational Psychology* | *J Occup Organ Psych* |
| *Journal of Occupational Health* | *J Occup Health* |
| *Journal of Occupational Health Psychology* | *J Occup Health Psychol* |
| *Journal of Organizational Behavior* | *J Organ Behav* |
| *Journal of Personality and Social Psychology* | *J Pers Soc Psychol* |
| *Journal of Risk Research* | *J Risk Res* |
| *Journal of Safety Research* | *J Safety Res (JSR)* |
| *Journal of China Coal Society* | *J China Coal Soc* |
| K | |
| *Kgk-kautschuk Gummi Kunststoffe* | *Kgk-kaut Gummi Kunst* |
| M | |
| Man Made Disasters ★ | *Man Made Disasters* |
| Managing the risks of organizational accidents (Reason, 1997) ★ | *Managing Risks Org A* |
| *Mathematical Problems In Engineering* | *Math Probl Eng* |
| N | |
| Normal Accidents: Living with High Risk Technologies (Perrow, 1984) ★ | *Normal Accidents Liv* |
| O | |
| *Occupational and Environmental Medicine* | *Occup Environ Med* |
| *Occupational Medicine* | *Occup Med-Oxford* |
| P | |
| *Personnel Psychology* | *Pers Psychol* |
| *Physica A* | *Physica A* |
| *Procedia Social and Behavioural Sciences* | *Procd Soc Behv* |
| *Professional Safety* | *Prof Saf* |
| *Psychological Bulletin* | *Psychol Bull* |
| *Psychological Review* | *Psychol Rev* |
| R | |
| *Reliability Engineering & System Safety* | *Reliab Eng Syst Safe (RESS)* |
| Resilience Engineering: Concepts and Precepts (Hollnagel et al., 2006) ★ | *Resilience Eng Conce* |
| *Risk Analysis* | *Risk Anal (RA)* |
| S | |
| *Safety Science* | *Safety Sci (SS)* |
| *Scandinavian Journal of Work, Environment & Health* | *Scand J Work Env Hea* |
| *Science* | *Science* |
| *Social Science & medicine* | *Soc Sci Med* |
| T | |
| *Traffic Injury Prevention* | *Traffic Inj Prev* |
| *Transportation Research Part F: Traffic Psychology and Behaviour* | *Transport Res F-Traf* |
| *Transportation Research Record* | *Transport Res Rec* |
| W | |
| *Work* | *Work* |
| *Work and Stress* | *Work Stress* |

## Appendix B. Additional materials

1. How to download Web of Science data for Bibliometrics Research https://docs.google.com/presentation/d/1WjXu3MRMNgfyLddicBa1lbqnWIUc1342JEWV4B-Mrqw/edit?usp=sharing.
2. How to Create a journal Overlay Map of Science Using the Web of Science: Extracting the Journal information from a reference unit. https://docs.google.com/presentation/d/16j4RYLb9DH32THYDDufHKTjs7xQOxpotpUO2ZxVTC0k/edit?usp=sharing.
3. How to Get journal citation data from ISI-JCR. https://docs.google.com/presentation/d/1kx6XQqJu0eDBEbRGiy01O86g_4gTCq_GqUykhNBoLTs/edit?usp=sharing.
4. Additional materials on Journals metrics information. https://docs.google.com/document/d/1RMb14K2c5L47GKaqHsceEc6CrZPUdyZGIFW2DqFfCwo/edit?usp=sharing.

## References


Garfield, E., 1965. Can citation indexing be automated. In: Paper Presented at the Statistical Association Methods for Mechanized Documentation, Symposium Proceedings.

Garfield, E., 1999. Journal impact factor: a brief review. Can. Med. Assoc. J. 161 (8), 979–980.

Gmür, M., 2003. Co-citation analysis and the search for invisible colleges: a methodological evaluation. Scientometrics 57 (1), 27–57.

Hale, A., 2006. Method in Your Madness: System in Your Safety. Valedictory Lecture. Delft University of Technology, Safety Science Group, Delft, Netherlands.

Hale, A.R., Hovden, J., 1998. Management and culture: the third age of safety. A review of approaches to organizational aspects of safety, health and environment. Occup. Injury Risk Prevent. Interv., 129–165.

Heinrich, H.W., Petersen, D., Roos, N., 1950. Industrial Accident Prevention. McGraw-Hill, New York.

Hollnagel, E., Woods, D.D., Leveson, N., 2006. Resilience Engineering: Concepts and Precepts. Ashgate Publishing Ltd..

Kostoff, R.N., 1998. The use and misuse of citation analysis in research evaluation. Scientometrics 43 (1), 27–43.

Leydesdorff, L., Rafols, I., Chen, C., 2013. Interactive overlays of journals and the measurement of interdisciplinarity on the basis of aggregated journal–journal citations. J. Am. Soc. Inform. Sci. Technol. 64 (12), 2573–2586.

Li, J., 2014. Fundamentals of Information Retrieval in Safety Science and Technology. Capital University of Economics and Business Press, Beijing.

MacRoberts, M.H., MacRoberts, B.R., 2010. Problems of citation analysis: a study of uncited and seldom-cited influences. J. Am. Soc. Inform. Sci. Technol. 61 (1), 1–12.

Perrow, C., 1984. Normal Accidents: Living with High Risk Technologies. Princeton University Press.

Pudovkin, A.I., Garfield, E., 2002. Algorithmic procedure for finding semantically related journals. J. Am. Soc. Inform. Sci. Technol. 53 (13), 1113–1119.

Reason, J., 1990. Human Error. Cambridge University Press.

Reason, J.T., 1997. Managing the Risks of Organizational Accidents, vol. 6. Ashgate, Aldershot.

Reniers, G., Anthone, Y., 2012. A ranking of safety journals using different measurement methods. Saf. Sci. 50 (7), 1445–1451.

Tsay, M.-Y., Xu, H., Wu, C.-W., 2003a. Author co-citation analysis of semiconductor literature. Scientometrics 58 (3), 529–545.

Tsay, M.-Y., Xu, H., Wu, C.-W., 2003b. Journal co-citation analysis of semiconductor literature. Scientometrics 57 (1), 7–25.

Turner, B.A., Pidgeon, N.F., 1978. Man-made Disasters. Wykeham Publications, (London).

Van Eck, N.J., Waltman, L., 2010. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics 84 (2), 523–538.

Waltman, L., van Eck, N.J., Noyons, E., 2010. A unified approach to mapping and clustering of bibliometric networks. J. Informetrics 4 (4), 629–635.