This item is the archived peer-reviewed author-version of:

A bibliometric analysis of peer-reviewed publications on domino effects in the process industry

Reference:

Li Jie, Reniers Genserik, Cozzani Valerio, Khan Faisal.- A bibliometric analysis of peer-reviewed publications on domino effects in the process industry
Journal of loss prevention in the process industries - ISSN 0950-4230 - 49:A(2017), p. 103-110
Full text (Publisher's DOI): <https://doi.org/10.1016/J.JLP.2016.06.003>
To cite this reference: <http://hdl.handle.net/10067/1444710151162165141>

A bibliometric analysis of domino effects in the chemical industry

Jie Li ¹, Genserik Reniers ^{2,3}, Valerio Cozzani ⁴, Faisal Khan ⁵

1. Capital University of Economics and Business, Beijing, China

2. Safety and Security Science, Delft University of Technology, Delft, The Netherlands

3. Antwerp Research Group on Safety and Security (ARGoSS), Faculty of Applied Economics, Universiteit Antwerpen, Antwerp, Belgium.

4. Dipartimento di Ingegneria Chimica, Mineraria e delle Tecnologie Industriali, Alma Mater Studiorum, Università di Bologna, Bologna, Italy.

5. Safety and Risk Engineering Group, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, Canada.

Abstract:

The topic of domino effects in chemical industry has started to gain more attention in risk analysis and safety assessment researches over the past two decades. The popularity of the topic is partly due to the occurrence of catastrophic domino effects, e.g., LPG-induced domino effects in Mexico City in 1984, and partly due to legislations, Seveso Directives, mandating the owners and managers of chemical plants to take the likelihood of domino effects into account when contemplating the prevention/mitigation of major accidents in their plants. The present study aims to take advantage of the-state-of-the-art bibliometric analysis tools to investigate the trend, and the geographical and authorial distributions of scientific papers, mostly published in peer-reviewed journals and excluding books and technical reports, around the globe. The result of this study can be used by researchers in the identification of the most influential research institutes and authors contributing to the domain of domino effects in chemical industry.

Keywords: Bibliometric study; Domino effects; Chemical industry.

1. Introduction

The term domino effects in chemical industry refers to a chain of accidents in which a primary accident, fire or explosion, escalates, triggering secondary and tertiary accidents and so on. In comparison with other major accidents, the risk analysis and safety management of domino effects in the chemical

industry is a new one, mainly gaining attention since the notorious LPG disaster in Mexico City in 1984, where an LPG leakage resulted in an initial vapor cloud explosion followed by several secondary explosions and fires (Arturson, 1987). Many smaller accidents involving domino effects have taken place since (Reniers, 2010; Darbra et al., 2010; Abdolhamidzadeh et al., 2011; Reniers and Cozzani, 2013). The latest catastrophic accident involving domino effects occurred in Tianjin, China, in August 2015, in which two initial explosions triggered fires burning for days and leading to about eight other explosions (Huang and Zhang, 2015).

The increase of attention given to the risk analysis of domino effects in chemical plants over the past decades has been driven by the high impact of domino effects on society on one hand and law enforcements and regulations such as European Seveso Directives (Article 8 of Seveso II and Article 10 of Seveso III) on the other hand. However, due to both the data scarcity arising from the low frequency of domino effects and the complexity and interdependencies involved in such accidents, the modeling and incorporation of domino effects in quantitative risk analyses have been challenging. The need for the identification of primary accident scenarios, escalation mechanisms, escalation and damage probabilities, identification of secondary accident scenarios, and also modeling the safety measures in place are some of the main challenges in this regard.

Nevertheless, recent work dedicated to the determination of escalation probabilities (Cozzani and Salzano, 2004; Cozzani et al., 2005, 2006; Landucci et al., 2009) along with the development of advanced mathematical and probabilistic methods such as Monte Carlo simulation (Abdolhamidzadeh et al., 2010), Bayesian network (Khakzad et al., 2013; Khakzad, 2015; Khakzad and Reniers, 2015a), graph theory (Khakzad and Reniers, 2015b), and event sequence diagram (Zhou et al., 2016) has made promising improvements in risk assessment and safety management of domino effects.

Due to the importance of domino effects from either a safety or security perspective, the present work aims to conduct a bibliometric analysis of attempts devoted to the modeling and risk analysis of domino effects in the chemical industry over the past decades.

2. Data and data mining techniques

The data used in the present study has been retrieved from the Web of Science Core Collection on November 23, 2015 (the database was last updated on November 20, 2015), including Science Citation Index Expanded (1900 – present), Social Sciences Citation Index (1956 – present), Arts & Humanities Citation Index (1975 – present), Conference Proceedings Citation Index-Science (1994 – present) and Conference Proceedings Citation Index-Social Science & Humanities (1994 – present). Using "domino effect" and “chemical” as the search topics, a total of 112 records were found in the database, excluding books chapters, e.g., Reniers and Pavlova (2013).

Bibliometric analysis of domino effects in chemical industry was performed using methods such as outputs analysis, co-citations analysis (Marshakova, 1973; Small, 1973), and network visualization were used in the present work. For example, in the method of co-citation analysis, the more two papers are cited together the higher their co-citation score. The results obtained from the above-mentioned analyses can be categorized based on (i) the temporal trend of publications, (ii) their geographical distribution, and (iii) their authorial distribution. Accordingly, the bibliometric data was visualized using freely available mapping tools such as VOSviewer (van Eck and Waltman, 2009), CiteSpace (Chen, 2006), and Gephi (Bastian et al., 2009).

3. Results

3.1 Temporal distribution

The cumulative trend of the publications over time can be used as an index of the popularity and the importance of domino effects in the chemical industry. According to Figure 1, the publications in the domain of domino effects in the chemical industry can be divided into two distinguishable periods, that is, before 1996 and after 1996. Although some of the worst domino effects took place before 1996, e.g., LPG-induced fires and explosions in Mexico City in 1984, there is only one publication in the first period (Bagster and Pitblado, 1991). However, with the emerge of Seveso II (Directive 96/82/EC), the Article 8 of which mandates the EU members to consider domino effects in risk analysis studies, in December 1996 the topic started to gain attention among the European risk and safety community. The trend has been almost constant with a notable increase between 2004 and 2008. However, the most

increase in the number of publications can be noted between 2013 and 2014, most likely due to the amendment of Seveso II which resulted in Seveso III (Directive 2012/18/EC) in July 2012. Article 10 of Seveso III explicitly requires the EU member states to account for the likelihood of domino effects in hazardous industries.

Figure 1. Annual distribution of publications on domino effects in the chemical industry.

3.2. Geographical distribution

To the best of the authors' knowledge, there is no obliging legislation on domino effects available outside of Europe. As a result, the assumption of the strong correlation between the increasing trend of the publication in Figure 1 and Seveso Directives should normally be implicated from the geographical distribution of the publications. To this end, cooperation networks were analyzed to investigate affiliated countries, affiliated institutes, and authors. In the networks, a node is allocated to each co-author of a publication; the size and the color of a node reflect the number of publications and the cluster to which the node belongs, respectively. It should be noted that for the sake of better clarity only the largest sub-networks have been kept in the analysis.

3.2.1. Countries of affiliation

Figure 2 depicts the countries with the highest contribution to the topic of domino effects in the chemical industry. Being in line with the hypothesis of Seveso-induced domino effect studies in Europe, as can be seen from Figure 2, European countries Italy, Belgium, and The Netherlands are mainly affiliated with the research, followed by India and Canada. The connections between the nodes represent respective collaboration, with the highest collaborations between Belgium and The Netherlands (e.g., Janssens et al., 2015), Italy and Canada (e.g., Khakzad et al., 2013), and India and Iran (e.g., Abdolhamidzadeh et al., 2010).

Figure 2. The countries with the highest contribution/cooperation in the domain of domino effects in chemical industry.

Figure 3 displays the number of publications per country along with the number of co-authorships. A remarkable observation from Figure 3 is that China with 20 publications seems to be disconnected from the cooperation network due to the lack of collaboration with other countries (zero number of co-authorship in Figure 3), thus not being visible in Figure 2. This also holds true for the USA. However, it can be expected that owing to the recent catastrophic domino effects in China, e.g., the one in Tianjin in August 2015, and the increasing importance of security risks in the chemical industry, which seems to be an urgent concern especially in the context of domino effects, there will be more collaboration among research centers in the future.

Figure 3. Number of publications and co-authorships per country in the domain of domino effects in the chemical industry.

3.2.2. Institutes of affiliation

To have a better look at the geographical distribution of the publications, the distributions per affiliated institutions have been presented in the cooperation network in Figure 4, mainly consisting of European institutions. The main institutions are University of Bologna, Italy, Universities of Antwerp and KULeuven, Belgium, Delft University of Technology, The Netherlands, along with non-European universities such as Pondicherry University, India, Memorial University of Newfoundland, Canada, and Sharif University of Technology, Iran.

The authors cooperation network includes, as main researchers, V. Cozzani (University of Bologna, Italy), G. Reniers (University of Antwerp, Belgium), F. Khan (Memorial University of Newfoundland, Canada), and S.A. Abbasi (Pondicherry University, India).

Figure 5. Cooperation network of authors in the domain of domino effects in the chemical industry

3.3. Co-Citation Analysis

3.3.1. Co-citation network analysis

The co-citation network is a network of references that has been co-cited by a set of publications; the more cited together, the more similar the articles become in the network. In the present study, CiteSpace (Chen, 2006) is used to create the co-citation network of the publications in the domain of domino effects in the chemical industry. Compared to other bibliographic tools, CiteSpace can analyze the co-citation network by a single year, and then integrate the time series of co-citation networks.

In the co-citation network analysis, we divided the time line 1996-2015 into 10 time intervals (2 years in each interval); the top 50 most cited publications were then extracted from each interval based on the time of citation. Finally, 2177 references were obtained from the 112 relevant articles, the co-citation network of which is depicted in Figure 6. The network consists of 379 nodes and 5266 edges; small isolated groups are not shown in Figure 6. The size of each node represents the number of citations of a certain document, indicating the work of Khan (1998), Cozzani et al. (2004, 2005), and Lees (1996) as the most cited publications. In this regard, Khan F and Cozzani V are the authors most referred to in the domain of domino effects in chemical industry (see also Table 1).

Figure 6. The largest set of connected co-citation network of DEC research and the landmark nodes were shown in the network.

Furthermore, we marked the publications of the top 4 productive authors (see Section 3.2.3) in the co-citation network in Figure 7. The results show 31 papers of Khan F from 1992 to 2005, mainly published in Journal of Loss Prevention in the Process Industries (6 papers) and Process Safety Progress (5 papers). Likewise, the publications made by Cozzani V from 2001 to 2009 (11 papers) have been mainly published in Journal of Hazardous Materials (5 papers), while those of Reniers G from 2005 to 2013 (9 papers) have been published in Safety Science (2 papers), Journal of Loss Prevention in the Process Industries (2 papers), and Journal of Hazardous Materials (2 papers). Nine papers of Abbasi S.A. from 1994 to 2007 have been published in different journals. Among these four authors, Khan F is the most widely cited scholar in the field of domino effect accidents in the chemical industry, followed by Abbasi, Reniers, and Cozzani.

Figure 9 RENIERS, G's publications in co-citation network

Figure 10 ABBASI, SA's publications within the co-citation network

Table 1 Detailed information of the landmark nodes (only publications with more than 15 citations are mentioned)

Author	Title	Year	Document type	Cited Frequencies
KHAN FI	Models for domino effect analysis in chemical process industries	1998	PROCESS SAF PROG	34
COZZANI V	The assessment of risk caused by domino effect in quantitative area risk analysis	2005	J HAZARD MATER	28
COZZANI V	The quantitative assessment of domino effects caused by overpressure: Part I. Probit models	2004	J HAZARD MATER	27
LEES FP	Loss Prevention in the Process Industries	1996	BOOK	27
COZZANI V	Escalation thresholds in the assessment of domino accidental events	2006	J HAZARD MATER	26
KHAN FI	An assessment of the likelihood of occurrence, and the damage potential of domino effect (chain of accidents) in a typical cluster of industries	2001	J LOSS PREVENT PROC	19
KHAN FI	DOMIFFECT (DOMIno eFFECT): user-friendly software for domino effect analysis	1998	ENVIRON MODELL SOFTW	19
GUBINELLI G	A simplified model for the assessment of the impact probability of fragments	2004	J HAZARD MATER	19
CENTER FOR CHEMICAL PROCESS SAFETY (CCPS)		2000	GUID CHEM PROC QUANT	16

3.3.2. Co-citation Cluster analysis

The co-citation network can be clustered using modularity method, and named using TF*IDF (Salton et al., 1975) and log-likelihood ratio (Chen et al., 2010, Dunning, 1993) techniques. There are 8 large clusters identified within the documents co-citations network, and marked with the log-likelihood ratio

results. The detail information of the clusters are listed in Table 2. ID is the rank of the clusters based on the size of the cluster, and the size is number of cited publications in a certain cluster. Mean (cited year) is the average year of the cited publications in the cluster. In CiteSpace, Silhouettes is used to measure the homogeneity or consistency of the cluster (Rousseeuw, 1987).

The largest cluster, Cluster #0, is *domino effect*, with 121 references and an average year of publication as 2001. The majority of the most-cited documents are gathered in this cluster, implying that these publications can be considered as the main stream research in the field. Cluster #7 is *chemical cluster*, with an average year of publications as 2001, and including 11 publications. Cluster #1 is *new software package maxcred-ii*, cluster #2 is *domino effect analysis*, and cluster #3 is *overpressure*. Cited publications from these clusters are from 1986-1989. The average year of cited publications from #4 *fertilizer industry* is 1993.

The color of the links shows the first co-cited year of the members in a certain cluster. The blue links describing two publications were co-cited in 1996 while the most recent co-citation links are shown in yellow or orange. The current results demonstrate that the focus of research on domino effects in the chemical industry has changed from cluster #1 *new software package maxcred-ii* toward the more recent clusters #0, #3 and #7. The more recent papers citing the members in cluster #0, #3 and #7 were listed in Table 3, 4, and 5.

Figure 11 Co-citation clusters of DEC research, name of the clusters were extracted from title of the citing articles by using LLR algorithm

Table 2 Eight Largest clusters of co-cited references among the 20 clusters

ID	Size	Silhouette	mean(Cited Year)	Label by TF*IDF	Label by log-likelihood ratio
0	121	0.72	2001	(14.06) accident sequence; (14.06) main feature; (13.85) research; (13.85) method; (13.75) application	domino effect (276.53, 1.0E-4); art (176.04, 1.0E-4); state (176.04, 1.0E-4);
1	43	0.916	1989	(17.23) software package; (15.56) new software package maxcred-ii; (15.56) rapid quantitative risk analysis; (13.75) controlling environmental risk; (11.14) chemical process industries	new software package maxcred-ii (255.53, 1.0E-4); rapid quantitative risk analysis (255.53, 1.0E-4); tool (161.28, 1.0E-4);
2	41	0.865	1989	(17.49) domino effect analysis; (15.12) domiffect; (11.63) chemical process industries; (9.37) analysis; (9.15) software	domino effect analysis (360.05, 1.0E-4); domiffect (197.26, 1.0E-4); software (172.1, 1.0E-4);

3	36	0.913	1986	(15.56) use; (15.56) probit function; (13.61) overpressure; (13.36) domino accident; (12.61) quantitative risk assessment	overpressure (305.04, 1.0E-4); domino accident (269.27, 1.0E-4); use (235.15, 1.0E-4);
4	34	0.844	1993	(11.62) domino chemical accident; (11.62) statistical analysis; (10.32) rapid risk assessment; (10.32) computer-automated tool torap; (9.76) fertilizer industry	fertilizer industry (155.93, 1.0E-4); rapid risk assessment (127.36, 1.0E-4); computer-automated tool torap (127.36, 1.0E-4);
5	27	1	1988	(16.94) high proton affinity; (16.94) aromatic domino effect; (16.94) poly-2; (5.16) domino effect; (5.16) domino	high proton affinity (410.3, 1.0E-4); aromatic domino effect (410.3, 1.0E-4); poly-2 (410.3, 1.0E-4);
6	19	1	1995	(18.29) helix sense; (15.56) noncovalent chiral effect; (15.56) peptide helix sense; (15.56) temperature tuning; (15.56) noncovalent chiral domino effect	control (503.5, 1.0E-4); noncovalent chiral effect (250.95, 1.0E-4); peptide helix sense (250.95, 1.0E-4);
7	11	0.984	2001	(10.22) chemical cluster; (9.85) security; (9.41) man-made domino effect disaster; (8.28) managing domino; (8.28) industrial area	chemical cluster (88.05, 1.0E-4); need (67.76, 1.0E-4); man-made domino effect disaster (67.76, 1.0E-4);

Table 3 Articles that cite >=10 members of Cluster # 0.

Author	Year	Title	References included in Cluster # 0
Abdolhamidzadeh, B	2010	a new method for assessing domino effect in chemical process industry	20
Reniers, G	2010	an external domino effects investment approach to improve cross-plant safety within chemical clusters	15
Darbra, RM	2010	domino effect in chemical accidents: main features and accident sequences	13
Cozzani, V	2014	quantitative assessment of domino and natech scenarios in complex industrial areas	10

Table 4 Totally 7 articles that cite the members of Cluster # 7.

Author	Year	Title	References included in Cluster # 7
Reniers, GLL	2008	Managing domino effect-related security of industrial areas	6
Genserik, R	2009	Man-made Domino Effect Disasters in the Chemical Industry: The Need for Integrating, Safety and Security in Chemical Clusters	1
Reniers, G	2009	Domino effects within a chemical cluster: A game-theoretical modeling approach by using Nash-equilibrium	1
Reniers, GLL	2007	DomPrevPlanning (c): User-friendly software for planning domino effects prevention	1
Reniers, G	2010	An external domino effects investment approach to improve cross-plant safety within chemical clusters	1
Reniers, GLL	2008	Knock-on accident prevention in a chemical cluster	2
Pavlova, Y	2011	A sequential-move game for enhancing safety and security cooperation within chemical clusters	1

Table 5 Totally 8 articles that cite the members of Cluster # 3.

Author	Year	Title	References included in Cluster # 7
Salzano, E	2003	The use of probit functions in the quantitative risk assessment of domino accidents caused by overpressure	18
Cozzani, V	2004	The quantitative assessment of domino effects caused by overpressure - Part I. Probit models	10
Salzano, E	2005	The analysis of domino accidents triggered by vapor cloud explosions	2
Abdolhamidzadeh, B	2010	A new method for assessing domino effect in chemical process industry	2
Cozzani, V	2014	Quantitative assessment of domino and NaTech scenarios in complex industrial areas	1
Khan, FI	2001	Risk analysis of a petrochemical industry using ORA (Optimal Risk Analysis) procedure	1

Chen, YT	2012	Investigation and analysis of historical Domino effects statistic	1
Alileche, N	2015	Thresholds for domino effects and safety distances in the process industry: A review of approaches and regulations	1

4. Conclusions

In the present study, we performed a bibliometric analysis of available publications in the field of domino effects in the chemical industry. Investigating the countries, institutions, and researchers, it was demonstrated that the increasing trend in the topic has mainly been incentivized by European legislations especially Seveso Directives II and III. As a result, the European countries Italy, Belgium, and The Netherlands have made the most contributions in this regard although researchers from non-European countries such as India, Canada, and Iran have also conducted extensive researches both in the past and in the present. Accordingly, the universities such as University of Bologna, Italy, University of Antwerp, Belgium, Delft University of Technology, The Netherlands, Memorial University of Newfoundland, Canada, Pondicherry University, India, and Sharif University of Technology, Iran, along with the researchers such as Cozzani V, Khan F, Reniers G, and Abbasi SA have played a key role in advancing the knowledge in this field.

References

- Abdolhamidzadeh B, Abbasi T, Rashtchian D, Abbasi SA. A new method for assessing domino effect in chemical process industry. *Journal of Hazardous Materials*, 2010; 182 (1-3): 416-426.
- Abdolhamidzadeh B, Abbasi T, Rashtchian D, Abbasi SA. Domino effect in process industry accidents – An inventory of past events and identification of some patterns. *Journal of Loss Prevention in the Process Industries*, 2011; 24: 575–593.
- Arturson G. The tragedy of San Juanico-the most severe LPG disaster in history. *Burns*, 1987; 13(2): 87-102.
- Bagster DF, Pitblado RM. The estimation of domino incident frequencies – An approach. *Process Safety and Environmental Protection*, 1991; 69: 195–199.
- Bastian M, Heymann S, and Jacomy M. 2009. Gephi: An Open Source Software for Exploring and Manipulating Networks. *International Conference on Weblogs and Social Media*.

- Chen C. CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. *Journal of the Association for Information Science and Technology*, 2006; 57, 359-377.
- Chen, C., Dubin, R. & Kim, M. 2014. Emerging trends and new developments in regenerative medicine: a scientometric update (2000 – 2014). *Expert Opinion on Biological Therapy*, 14, 1295.
- Chen, C., Ibekwesanyuan, F. & Hou, J. 2010. The structure and dynamics of cocitation clusters: A multiple-perspective cocitation analysis. *Journal of the Association for Information Science and Technology*, 61, 1386-1409.
- Cozzani V, Salzano E. The quantitative assessment of domino effects caused by overpressure part I. probit models. *Journal of Hazardous Materials*, 2004; A107: 67–80.
- Cozzani V, Gubinelli G, Antonioni G, Spadoni G, Zanelli S. The assessment of risk caused by domino effect in quantitative area risk analysis. *Journal of Hazardous Materials*, 2005; A127: 14–30.
- Cozzani V, Gubinelli G, Salzano E. Escalation thresholds in the assessment of domino accidental events. *Journal of Hazardous Materials*, 2006; 129: 1–21.
- Council Directive 96/82/EC (Seveso II) of 9 December 1996 on the control of major-accident hazards involving dangerous substances. *Official Journal of the European Communities*, L 10/13, Brussels, January 14, 1997, 0013–0033.
- Dunning, T. 1993. Accurate methods for the statistics of surprise and coincidence. *Computational Linguistics*.
- Landucci G, Gubinelli G, Antonioni G, Cozzani V. The assessment of the damage probability of storage tanks in domino events. *Accident Analysis and Prevention*, 2009; 41:1206–1215.
- Darbra, RM, Palacios A, Casal J. Domino effect in chemical accidents: Main features and accident sequences. *Journal of Hazardous Materials*, 2010; 183: 565–573.
- Huang P, Zhang J. Facts related to August 12, 2015 explosion accident in Tianjin, China. *Process Safety Progress*, 2015; 34(4): 313-314.
- Janssens J, Talarico L, Reniers G, Sörensen K. A decision model to allocate protective safety barriers and mitigate domino effects. *Reliability Engineering and System Safety*, 2015; 143: 44-52.
- Khakzad N, Khan F, Amyotte P, Cozzani V. Domino effect analysis using Bayesian networks. *Risk Analysis*, 2013; 33 (2): 292-306.
- Khakzad N. Application of dynamic Bayesian network to risk analysis of domino effects in chemical infrastructures. *Reliability Engineering & System Safety*, 2015; 138: 263-272.
- Khakzad N, Reniers G. Risk-based design of process plants with regard to domino effects and land use planning. *Journal of Hazardous Materials*, 2015a; 299: 289–297.

- Khakzad N, Reniers G. Using graph theory to analyze the vulnerability of process plants in the context of cascading effects. *Reliability Engineering & System Safety*, 2015b; 143: 63-73.
- Marshakova IV. System of document connections based on references. *Nauchno-Tekhnicheskaya Informatsiya Seriya 2-Informatsionnye Protsessy I Sistemy*, 1973; 3-8.
- Reniers G, Pavola Y. 2013. Using Game theory to improve safety within chemical industrial parks, Springer.
- Rousseeuw, P. 1987. Silhouettes: a graphical aid to the interpretation and validation of cluster analysis. *Journal of Computational and Applied Mathematics*, 20, 53-65.
- Salton, G., Wong, A. & Yang, C. 1975. A vector space model for information retrieval. *Communications of The ACM*.
- Small H. Co-citation in the scientific literature: A new measure of the relationship between two documents. *Journal of The American Society for Information Science*, 1973; 24, 265-269.
- Zhou J, Reniers G, Khakzad N. Application of event sequence diagram to evaluate emergency response actions during fire-induced domino effects. *Reliability Engineering & System Safety*, 2016; doi:10.1016/j.ress.2016.02.005.
- Van Eck N, Waltman L. 2009. Software survey: VOSviewer, a computer program for bibliometric mapping.