A Review of Crowdsourcing Literature Related to the Manufacturing Industry

Richard D. Evans[1,*]
James X. Gao[1]
Sara Mahdikhah[2]
Mourad Messaadia[2]
David Baudry[2]

[1] Centre for Innovative Product Development and Manufacturing, Faculty of Engineering and Science, University of Greenwich, UK
[2] CESI/IRISE, Rouen, France

*Now works for Westminster Business School, University of Westminster, UK

This is a copy of the final published version of an article published in Journal of Advanced Management Science, Vol 4 (3), 2016, pp.234-241.

The published version is available at: doi: 10.12720/joams.4.3.224-231

A Review of Crowdsourcing Literature Related to the Manufacturing Industry

Richard D. Evans and James X. Gao
Centre for Innovative Product Development and Manufacturing
Faculty of Engineering and Science/ University of Greenwich, Chatham Maritime, United Kingdom
Email: {R.D.Evans, J.Gao}@greenwich.ac.uk

Sara Mahdikhah, Mourad Messaadia, and David Baudry
CESI/IRISE, Rouen, France
Email: {smahdikhah, mmessaadia, dbaudry}@cesi.fr

***Abstract*—In an increasingly competitive globalised manufacturing environment, the necessity to develop new products and introduce innovative enhancements to existing ranges has created a critical need for the increased utilisation and sharing of organisational and employee knowledge. The capture of this knowledge within industry is of paramount importance as organisations seek to survive and remain competitive. Crowdsourcing, as a collaborative idea generation and problem solving activity, allows employees to capture explicit knowledge from large groups of colleagues and teams, and offers the potential to extract previously unknown tacit knowledge in a less formal virtual environment. This paper provides a review of recently published literature relating to crowdsourcing in the manufacturing industry and offers suggestions for the future direction of crowdsourcing research in manufacturing and product development.**

***Index Terms*—crowdsourcing, manufacturing, peer production, product development**

I. Introduction to Crowdsourcing

In June 2006, Jeff Howe [1], a contributing editor to Wired.com, published an article in which he coined the term 'crowdsourcing', stating that it is "the act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in the form of an open call". Since then, other researchers [2], [3] have offered their own definitions of the term; Pedersen et al. [4] stated that "Crowdsourcing is a collaboration model enabled by people-centric web technologies to solve individual, organisational and societal problems using a dynamically formed crowd of people who respond to an open call for participation". Tarrell *et al.* [5] offered a more concise definition, concluding that it is the act of "using the collective intelligence of a large group of people to help solve problems". Since 2006, the term crowdsourcing has often been described using differing terms, with researchers [5] employing it interchangeably with 'Peer Production', 'User Generated Content', 'User Contributed Content', 'Smart Mobs' and, more frequently, 'Co-Creation'. For the purpose of this review, the terms 'user generated content' and 'user contributed content' are not considered specifically as they now tend to refer generically to much of the content uploaded by users to the World Wide Web (www) and not specifically to the activity of crowdsourcing, which focuses predominantly on enabling www users to solve problems and generate ideas through the act of collaboration online.

The concept of crowdsourcing has been a developing research topic in the field of Information Systems (IS) and Design Science (DS) since the turn of the Millennium [4], but has received little attention in published manufacturing literature. In 2013, Tarrell *et al.* [5] conducted a generalised review of available academic literature relating to crowdsourcing, concluding that the majority of crowdsource-related articles exist in IS publications, including the Journal of Information Systems Research, Journal of Management Information Systems, Management Information Systems Quarterly and in conference proceedings, such as the Hawaii International Conference on System Sciences, International Conference on Information Systems and ACM's annual Computer-Human Interaction Conference.

The activity of crowdsourcing is a relatively low cost and scalable process, which enables people to tap into knowledge bases via the www. In order to achieve this, different approaches may be taken, including the use of web 2.0 technologies, such as micro-blogging and social networking sites, which depend on user-contributed content. The end goal of a crowdsourcing project is to identify a solution to a recognised problem through the capturing of collective intelligence from employees dispersed around an organisation.

This paper aims to explore the current state of crowdsourcing literature and focuses on published material which is found within a manufacturing or product design/development context. Through critical analysis using Elsevier's academic database, Scopus, it has been possible to identify the current state of academic literature relating to crowdsourcing within the

Manuscript received November 1, 2014; revised January 21, 2015.

doi: 10.12720/joams.4.3.224-231

manufacturing environment. Future research pathways are identified in Section VIII following the review.

II. Challenges Facing Global Manufacturing

The last two decades have been characterised by major developments in enterprise globalisation and technological advancement, particularly highlighted by the birth of the www. This has resulted in many opportunities being created for businesses and individuals, but also many challenges.

In 2002, Gunasekaran *et al.* [6] stated that manufacturing organisations operating in the 21st century have to overcome challenges encountered on a number of fronts; these include: 1) Meeting the more complex requirements of customers who demand low-cost, but high quality solutions to address their own specific problems or opportunities; 2) Managing the explosion of data which has been facilitated by the increasing use of the www and technological advances, such as 3D design data capabilities; 3) Improving the lifecycle of products on a routine basis by focusing upon cost, quality, time and environmental impact; and 4) Establishing effective communication channels with employees and external partners anywhere in the world [7].

Manufacturing organisations, operating in this globally integrated business environment, are increasingly being required to develop flexible and responsive work processes to ensure their survival. Previous practices concentrating upon product cost, quality and time to market are no longer sufficient to maintain competitive advantage. The focus is progressively turning towards innovation with clearly differentiated product offerings being the anticipated outcome. Against this background, effective knowledge sharing is paramount and remains a significant challenge to both Small and Medium sized Enterprises (SMEs), large multi-national Original Equipment Manufacturers (OEMs) and within extended supply chains. The management and effective sharing of knowledge has been recognised [1] as crucial for the survival of global manufacturing enterprises. Research [2] suggests that, by sharing explicit employee and organisational knowledge already captured, companies are able to become more productive, enhance corporate performance and are more likely to survive than those that fail to discover hidden organisational knowledge.

III. The Success of Crowdsourcing

At present, the most widely-recognised application of crowdsourcing is within the recruitment industry, where sites such as Mechanical Turk (https://www.mturk.com/) and microWorkers (https://microworkers.com/) have allowed organisations around the world to crowd source ad-hoc members of staff to complete one-off tasks in return for financial reward; the generic business model is one of companies posting an advert detailing a specific task and potential 'employees' then bidding for the opportunity to perform it i.e. the organisation selects who to do the job, based on peer-reviews of prior work and the price quoted. For the organisation, it allows them to tap into a global knowledge-base and have the work completed for fees which are judged to be reasonable and competitive. Further industrial applications of crowdsourcing exist and these include, for instance in the field of astronomy, Galaxy Zoo (www.galaxyzoo.org), which aims to crowd source participants to help understand how galaxies are formed and how they may be classified by shape and, in the field of internet maps, OpenStreetMap (www.openstreetmap.org), which provides user-generated mapping applications that are maintained by www contributors from around the world.

In terms of the success of crowdsourcing, perhaps the most renowned is the web-based encyclopedia Wikipedia (www.wikipedia.org), which uses a wiki as a mechanism for crowdsourcing user-contributed information. By January 2015, the site had published over 4.77 million articles, all contributed by globally-dispersed internet users. In academia, multiple success stories may be reported. One was at the University of Washington, where researchers spent over a decade attempting to decipher protein data. Within three weeks of crowdsourcing user-contributed ideas, they had solved their specific problem, as a result of receiving over 57,000 contributions from members of the public [8].

Another instance of crowdsourcing being employed successfully was within the healthcare industry, where Chávez-Aragón, Lee and Vyas [9] proposed a crowdsourcing web-platform for gathering user-contributed information on how non-expert volunteers segment anatomical components from MR Images.

In the service industry, Vukovic *et al.* [10] developed a crowdsourcing methodology, based on electronic questionnaires, which were circulated to dispersed respondents to assist the researchers in solving service-related problems. Within the civil engineering field, Sonnleitner et al. [11] proposed a centralised web-based application to allow employees to contribute and access assessment records relating to buildings and structures.

Closely aligned to this paper, in the field of Product Development, Yu and Nickerson [12] proposed a sketch combination system which was tested by 1047 participants. Each member of the crowd submitted sketched designs of chairs for children whilst other crowd members evaluated the contributions; this allowed the problem owner to develop a new product entirely through iterative crowd design. Müller, Thoring and Oostinga [13] developed an online crowdsourcing game, which allowed designers to collect empirical data to understand what meanings users associate with certain shapes; they aimed to develop a crowdsourcing-based method to establish common meaning for shapes/forms.

Finally, within a more social context, O'Connor and Biewald [14] developed a crowdsourcing application called Facestat, which allowed photographers to determine how images of people are perceived by different members of a Crowd.

Increasing corporate usage of Web 2.0 technologies has driven the development of bespoke applications which employ crowdsourcing principles, although the use of such tools to crowd source is still in its infancy. In the

academic world, limited research has been conducted into the use of crowdsourcing within a manufacturing environment. This paper seeks to clarify the current position. Following previous exploratory studies [15, 16, 17], it has been confirmed that large organisations have now started to adopt crowdsourcing as a method for problem solving and idea generation, but current research still focuses primarily on the activity from the point of view of companies seeking input from external sources; in other words, using crowdsourcing as a mechanism to engage with potential customers or suppliers.

IV. Crowdsourcing Concerns

Academics and industrialists have expressed several concerns in relation to the activity of crowdsourcing. Both Pedersen *et al.* [4] and Sonnleitner *et al.* [11] commented on the question of intellectual property rights and copyright ownership of solutions submitted and stated that this could be a crucial barrier to impede the success of crowdsourcing within enterprises. Pedersen *et al.* [4] continued by stating that the success of a crowdsourcing campaign may depend on attracting and retaining knowledgeable participants. Further concerns relating to the activity of crowdsourcing, include:

- Trust: Between problem owners, solution providers and the crowds of participants;
- Quality of Ideas/Solutions: crowdsourcing systems in the future must be developed to facilitate the deciphering or user-evaluation of bad vs. good suggestions and allow problem owners to make informed decisions on submissions; and
- Loss of Control: By enabling crowdsourcing in the work place, manufacturing organisations risk the loss of corporate data and information which could potentially harm the business;

Researchers [13], [18] tend to agree that one of the most notable challenges facing crowdsourcing is how to maintain the motivation of solution providers. They divide the reasons for solution providers contributing to crowdsourcing projects into two distinct categories: extrinsic and intrinsic. Extrinsic motivation refers to tangible payoffs, whereas intrinsic refers to a solution provider achieving some form of personal fulfilment from contributing solutions. Müller *et al.* [13] seperated the reasons into four motivational categories: money, altruism, usefulness and fun. Other researchers [12], [19] suggest that by offering extrinsic motivation to solution providers, it may create social barriers in the workplace and discourage potential cooperation on the part of some. It is crucial that we understand better the motivational factors which can optimise participation in crowdsourcing activities.

Finally, some academics and industrialists question the need for crowdsourcing activities given quasi-ubiquitous internet search facilities, but, as Savage [8] stated, humans bring added benefits to crowd sourced problem solving, including their ability to notice unusual things and to pose questions which were not mentioned in the original problem identification. The World Wide Web per se is not able to highlight anomalies or suggest suitable changes, whereas motivated individuals forming part of a large crowdsourcing initiative are likely to suggest and develop novel and more innovative solutions.

V. Research Methodology

This paper presents a structured review of recently published literature relating to the topic of crowdsourcing in a manufacturing and/or product development context. It contributes to the fields of Manufacturing, Product Design and Product Development, but also extends into the research fields of IS and DS to offer an overview of research relating to crowdsourcing focused on the specialised field of manufacturing.

Elsevier's academic database, Scopus, was consulted to locate papers which include the keywords of 'Crowdsourcing' and 'Manufacturing' (or their alternatives). These keywords, shown in the left column of Table I, were then searched using Boolean search queries to identify and remove any duplicate papers which may use several keywords for the same meaning of crowdsourcing i.e. 'Co-Creation', 'Peer Production' and 'Smart Mobs'. The term manufacturing was also extended to include several key activities related to manufacturing, including 'Product Design' and 'Product Development'.

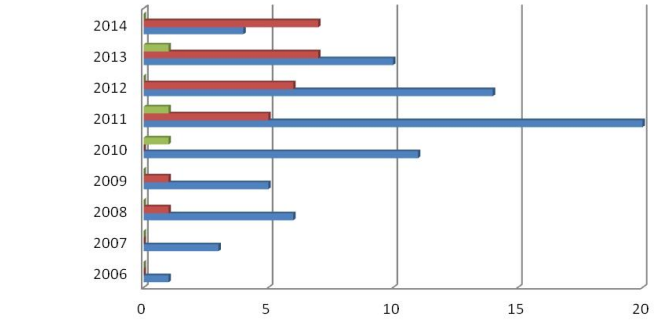
VI. Analysis of Related Work

TABLE I. Number of Papers Per Search Query

Search Term	No. of Papers	Publication Type (No. per type)
"Co Creation" / "Co-Creation" and "Product Development"	34	Conference Papers (20) Journal Articles (13) Book Chapters (1)
"Co Creation" / "Co-Creation" and "Product Design"	31	Conference Papers (25) Journal Articles (3) Review Papers (3)
"Co Creation" / "Co-Creation" and "Manufacturing"	19	Conference Papers (13) Journal Articles (5) Review Papers (1)
"Crowdsourcing" / "Crowd-sourcing" and "Product Development"	16	Journal Articles (6) Conference Papers (6) Review Papers (2) Research Notes (2)
"Crowdsourcing" / "Crowd-sourcing" and "Product Design"	11	Conference Papers (10) Journal Articles (1)
"Crowdsourcing" / "Crowd-sourcing" and "Manufacturing"	3	Journal Articles (2) Conference Papers (1)
"Peer Production" / "Peer-Production" and "Manufacturing"	3	Journal Articles (1) Conference Papers (1) Review Papers (1)
"Smart Mobs" / "Smart-Mobs" and "Manufacturing"	0	-
"Peer Production" / "Peer-Production" and "Product Development"	0	-
"Smart Mobs" / "Smart-Mobs" and "Product Development"	0	-
"Peer Production" / "Peer-Production" and "Product Design"	0	-
"Smart Mobs" / "Smart-Mobs" and "Product Design"	0	-

Research relating to the topic of crowdsourcing in manufacturing appears to be limited, as may be seen from the analysis of captured literature displayed in Table I. In total, 204 papers were found using the defined Boolean search queries. Of those, 100 unique papers were identified, the reduction from 204 to 100 being accounted for by 1) authors using two or three similar keywords for the same meaning of 'crowdsourcing' or 'manufacturing' and 2) spelling of keywords sometimes producing duplicate results e.g. the word 'crowdsourcing' when hyphenated displayed differing results.

Through further analysis of the terms by year of publication, it is interesting to note the trend in usage of the three key terms identified. As may be seen in Fig. 1, the term 'Co-Creation' was first used in 2006 at the time when 'Crowdsourcing' was identified by Howe [1]. 'Co-Creation' continued to grow in usage until 2011 when reference to it peaked, although it still remains in wide use today. Conversely, 'Crowdsourcing' was not immediately identified in the literature and was only first referenced in 2008; its usage started to increase from 2011 onwards and this coincides with its wider adoption outside academia as a result of the growth of social media. Finally, the term 'Peer Production' only appeared as a key term in 2010 but is used infrequently.



	2006	2007	2008	2009	2010	2011	2012	2013	2014
Peer Production	0	0	0	0	1	1	0	1	0
Crowdsourcing	0	0	1	1	0	5	6	7	7
Co-Creation	1	3	6	5	11	20	14	10	4

Figure 1. Number of publications by search query per year.

A. Publication Type and Name

From the identified 100 unique papers, 64 were published as conference papers, 27 as journal articles, 6 as review papers, 2 as research notes and 1 as a book chapter. Regarding where the papers were published, the most popular were: Journal of Product Innovation Management (3), Journal of Expert Systems with Applications (3), ACM's Lecture Notes in Computer Science (3), and the conference proceedings of ASME's Design Engineering Technical Conference (3).

B. Publications by Year

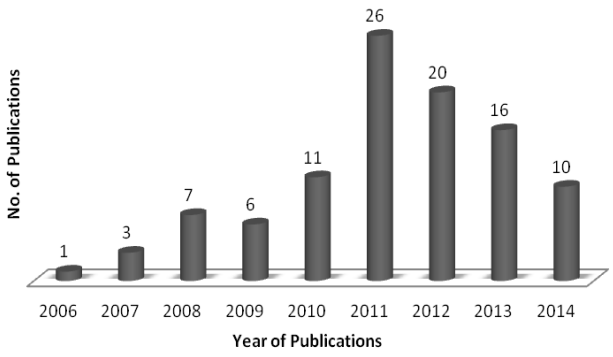


Figure 2. Number of publications per year.

By reference to Fig. 2, it is found that the majority of papers relating to crowdsourcing in manufacturing have been published since 2011 (72%). Only 1 paper [20] was published in 2006 when the term crowdsourcing was first used and, interestingly, the paper actually used 'co-creation' as its keyword, rather than 'crowdsourcing'. The highest number of publications in any one year was reached in 2011, when 26 papers were published (18 conference papers, 4 journal articles, 2 review papers, 1 book chapter and 1 research note). Prior to 2006, no published papers could be identified, even when the search parameters were expanded to include differing terminology for crowdsourcing.

C. Publications by Author and Affiliations

The most prolific author writing on the topic of crowdsourcing in manufacturing is Kurt Matzler from the University of Innsbruck in Austria, publishing a total of 5 papers, which have received a combined total of 436 citations, according to Google Scholar. Johann Fuller, also from the University of Innsbruck, has published 4 papers on the topic, whilst Thomas Kohler (Universitat Bremen) and Rajkumar Roy from Cranfield University have both published 3 papers on the topic. When affiliations are considered, the most notable is the University of Innsbruck, publishing a total of 6 papers, while the University of Tokyo follows with a record of 4 publications. Those with 3 publications include: Cranfield University, Tampereen Yliopisto, Universitat Kassel and the Technische Universitat Munchen.

D. Publications by Country

The greatest number of publications on Crowdsourcing emanate from the United States of America, where 21 papers (16%) in total have been published by researchers from American Universities, including: The IBM Almaden Research Centre (2), Stanford University (2), Carnegie Mellon University (2) and The George W. Woodruff School of Mechanical Engineering (2). As may be seen in Fig. 3, which incorporates multi-national collaborative articles, it may be seen that researchers from other countries worldwide make valuable contributions to the subject of Crowdsourcing; leading countries beyond the USA include Germany, United Kingdom, and Austria in Europe plus Japan.

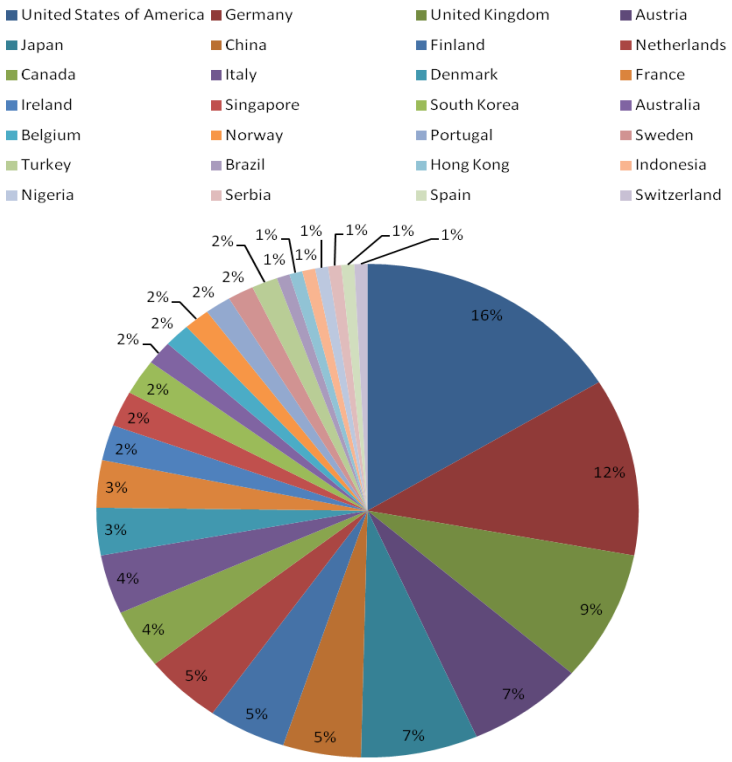


Figure 3. Number of publications by country.

E. Publications by Citations

The most widely cited paper on Crowdsourcing has been written by Kohler, Matzler and Fuller [21] of Universitat Bremen and HYVE AG in Munich, Germany; the trio published an article entitled "Avatar-Based Innovation: Using virtual worlds for Real-World Innovation"; this was published in Elsevier's Technovation journal and to date has received 159 citations, according to Scopus. Further mention should also be given to the works of [22], [23], [24], all of which have received 50+ citations.

F. Topics of Publications

In reviewing the content of each article individually, it was possible to categorise the focus of each paper. As may be seen in Table II, the majority of papers written on the subject of crowdsourcing in manufacturing relate to either 1) the integration of suppliers or customers into the manufacturing or design/development process (35%) or 2) using crowdsourcing to generate ideas for future designs and solve problems relating to manufacture (30%). In total, 7 papers explored the development of new tools or systems for improving the crowdsourcing process in manufacturing, while 9 papers explored the use of Web 2.0 technologies, such as social networking sites, blogs and virtual worlds, to crowdsource in manufacturing. It is worth noting that only 1 paper was identified which explored methods of crowdsourcing employees for manufacturing projects.

TABLE II. FOCUS OF IDENTIFIED PUBLICATIONS

Focus of Papers	No. of Papers
Integration of Suppliers *or* Customers into manufacturing and product design/ Development projects.	35
Using Crowdsourcing/Co-Creation as a method to generate ideas and solve problems in manufacturing and product design/development, including Models, Frameworks and Processes.	30
The Use of Web 2.0 Technologies (inc. Social Networking, Blogging, Virtual Worlds) to crowdsource/co-create in manufacturing and Product Development.	9
Review of the Advantages and/or Disadvantages of Crowdsourcing.	8
Development of new systems to enable crowdsourcing in manufacturing and product design/development.	7
Review of current / future literature relating to crowdsourcing in manufacturing.	7
Motivational Theory for Crowdsourcing (User *or* Business), including payment, rewards *inter alia*.	3
Crowdsourcing of new employees.	1

A total of 3 papers explored the topic of motivational factors relating to crowdsourcing, whilst numerous papers

referred to this matter more generally within their publications. Finally, 8 papers explored the advantages and/or disadvantages of using crowdsourcing in manufacturing.

VII. Conclusions

The review of published literature presented in this paper provides manufacturing organisations and academics with an overview of published literature and a starting point for future research into crowdsourcing in manufacturing.

The research methodology of employing differing keywords in combination, in Boolean search queries enabled the de-duplication of publications, which allowed for a summative view of current published research. However, this paper does not identify those publications which were submitted to publishers not indexed in the Scopus database and those publications which did not include 'crowdsourcing' and 'manufacturing' (or similar keywords) in the keywords section of their papers, even if the paper related to that topic.

Overall, Crowdsourcing is seen to offer individuals seeking solutions to specific problems the ability to elicit collective knowledge using an informal communication channel. It enables users to reach out to wider virtual communities and extract knowledge which previously remained hidden. The potential on offer in terms of outward facing contact with customers and suppliers has been recognised and pursued by academics (35 publications) and organisations, such as Lockheed Martin, Northrop Grumman and GE [25].

Crowdsourcing, as an idea generation and problem solving activity, offers those operating in manufacturing, the ability to capture diverse knowledge from network-connected contributors; this can be via the use of collaborative Web 2.0 technologies, such as blogging, micro-blogging and social networking sites *inter alia*.

This analysis has drawn three main conclusions relating to crowdsourcing in manufacturing research: The majority of research has been 1) published as conference papers (64%) as opposed to in journal articles (27%); 2) conducted into supplier or customer integration into crowdsourcing activities (35%) or how ideas are crowdsourced to solve design or other identified problems (30%); 3) into crowdsourcing in manufacturing focuses on the design stages of product development.

A final conclusion that may be drawn in relation to the activity of crowdsourcing is that its potential benefits to manufacturing processes are finally being recognised. The number of references to the word 'crowdsourcing' is on the increase and attention is now being paid to the activity of eliciting input from diverse users as opposed to the concept of how to co-create or collaborate more effectively to meet specific objectives. Crowdsourcing is being seen as opening up the market to potential suppliers of ideas and intellectual capital to contribute their expertise, knowledge and services to meet the needs of globally dispersed unknown partners.

The activity of crowdsourcing has a major role to play in the future successes of global manufacturing. Advancements in manufacturing systems will create a highly knowledge-intensive environment for its employees and, through the use of web 2.0-based tools, crowdsourcing will allow people to capture both tacit and explicit knowledge from dispersed colleagues far easier than experienced before; it should enable easier and better communication and collaboration between project teams, which in turn should increase efficiency and speed up innovation during product development. The manufacturing industry, in general, will require future collaboration with the ICT and Information Systems sectors to enable new business models to be created to incorporate crowdsourcing as a standard practice.

VIII. Future Work

Arising from this analysis of extant literature, it is possible to identify and suggest future research topics in relation to crowdsourcing and its use within the manufacturing industry. These include:

- Study in more depth the motivational factors which encourage participants to engage in crowdsourcing activities;
- Compare and contrast developed crowdsourcing tools / systems to establish the most suitable methods for specific manufacturing processes;
- How crowdsourcing may be used to capture problems experienced and ideas for improvements by end-users when finished products have entered into service;
- How crowd sourced ideas may be geo-tagged to determine the location of solution providers;
- How to use crowdsourcing to share ideas and capture problems relating to the ongoing servicing and repair of products;
- How to cleanse and measure the credibility and accuracy of crowd sourced suggestions;
- Compare and contrast the creativity of designs developed by the crowd compared with traditional product development processes;
- Identify the problems and barriers encountered in successful crowd collaboration; and
- Undertake a comparison of successful crowdsourcing in differing industries to establish whether crowdsourcing works more effectively in certain environments as opposed to others.

Acknowledgments

This paper is based on work funded by the European Program INTERREG IVA France-Channel-UK under the project "Building an Expertise Network for an Efficient Innovation and Training System (BENEFITS)".

References

[1] J. Howe. (2006). *The Rise of Crowdsourcing*. [Online]. Available from: http://archive.wired.com/wired/archive/14.06/crowds.html

[2] D. C. Brabham, "Crowd sourcing the public participation process for planning projects," *Journal of Planning Theory*, vol. 8, no. 3, pp. 242-262, 2009.

[3] J. Surowiecki, *The Wisdom of the Crowds*, USA: New York Anchor Books, 2004.

[4] J. Pedersen, D. Kocsis, A. Tripathi, A. Tarrell, A. Weerakoon, N. Tahmasbi, J. Xiong, W. Deng, O. Oh, and G. D. Vreede, *"Conceptual foundations of crowdsourcing: A review of IS research,"* in *Proc. Hawaii International Conference on System Sciences*, Wailea, Maui, HI: 579-588, 2013.
[5] A. Tarrell, N. Tahmasbi, D. Kocsis, J. Pedersen, A. Tripathi, J. Xiong, O. Oh, and G. D. Vreede, "*Crowdsourcing: A snapshot of published research,"* in *Proc. Americas Conference on Information Systems*, Chicago, USA, 15-17 August 2013, pp. 1-14.
[6] A. Gunasekaran,E. Tirtiroglu, and V. Wolstencroft, "An investigation into the application of agile manufacturing in an aerospace company," *Technovation*, vol. 22, no. 7, pp. 405-415, 2002.
[7] E. Shehab, M. Bouin-Portet, R. Hole, and C. Fowler, "Enhancing digital design data availability in the aerospace industry," *CIRP Journal of Manufacturing Science and Technology*, vol. 2, no. 4, pp. 240-246, 2009.
[8] N. Savage, "Gaining wisdom from crowds," *Communications of the ACM*, vol. 55, no. 3, pp. 13-15, 2012.
[9] A. Chávez-Aragón, W. Lee, and A. Vyas, "A crowdsourcing web platform-hip joint segmentation by non-expert contributors," in *Proc. IEEE International Symposium on Medical Measurements and Applications Proceedings*, Gatineau, QC, 4-5 May 2013, pp. 350-354.
[10] M. Vukovic, J. Laredo, Y. Ruan, M. Hernandez, and S. Rajagopal, "*Assessing service deployment readiness using enterprise crowdsourcing,"* in *Proc. IFIP/IEEE International Symposium on Integrated Network Management*, Ghent, Belgium, 27-31 May 2013, pp. 984-989.
[11] E. Sonnleitner, J. Kung, D. Schafer, and H. Wenzel, "A crowd-sourcing approach for area-wide on-line building assessment towards earthquake engineering," in *Proc. International Workshop on Database and Expert Systems Applications*, Los Alamitos, USA, 26-30 August 2013, pp. 3-8.
[12] L. L. Yu and J. V. Nickerson, "Generating creative ideas through crowds: An experimental study of combination," in *Proc. International Conference on Information Systems*, Shanghai, China, 4-7 December 2011, p. 21.
[13] R. M. Müller, K. Thoring, and R. Oostinga, "Crowdsourcing with semantic differentials: A game to investigate the meaning of form," in *Proc. Americas Conference on Information Systems*, Lima, Peru, 12-15 August 2010, p. 342.
[14] B. O'Connor and L. Biewald, *Superficial Data Analysis: Exploring Millions of Social Stereotypes*, Canada: O'Reilly, 2009.
[15] R, Evans, J. Gao, O. Owodunni, S. Shah, S. Mahdikhah, M. Messaadia, and D. Baudry, "A framework for improving the sharing of manufacturing knowledge through micro-blogging," in *Advances in Production Management Systems. Innovative and Knowledge-Based Production Management in a Global-Local World*, B. Grabot, et al., Ed. Springer Berlin Heidelberg, 2014, pp. 19-26.
[16] R. D. Evans, J. X. Gao, S. Woodhead, N. Martin, and C. Simmonds, "An investigation into collaboration and knowledge managementduring product development in the aerospace and defence industry," in *Proc. 4th INSTICC International Conference on Knowledge Management and Information Sharing*, Barcelona, Spain, 4–7 October 2012, pp. 113-118.
[17] R. D. Evans, J. X. Gao, N. Martin, and C. Simmonds, "An investigation into the potential use of social media technologies to improve the product development functions within the aerospace and defence industry," in *Proc. Tenth International Conference on Manufacturing Research*, Aston Business School, Birmingham, UK: 11-13 September 2012, pp. 718-723.
[18] N. Kaufmann, T. Schulze, and D. Veit, "More than fun and money. Worker motivation in crowdsourcing–A study on mechanical turk," in *Proc. Americas Conference on Information Systems*, Detroit, USA, 5-7 August 2011, pp. 1-11.
[19] R. Y. Arakji and K. R. Lang, "Digital consumer networks and producer-consumer collaboration: Innovation and product development in the video game industry," *Journal of Management Information Systems*, vol. 24, no. 2, pp. 195-219, 2007.
[20] C. H. Davis and E. Sun, "Business development capabilities in information technology SMEs in a regional economy: An exploratory study,". *Journal of Technology Transfer*, vol. 31, no. 1, pp. 145-161, 2006.
[21] T. Kohler, K. Matzler, and J. Füller, "Avatar-based innovation: Using virtual worlds for real-world innovation," *Technovation*, vol. 29, no. 6-7, pp. 395-407, 2009.
[22] M. K. Poetz and M. Schreier, "The value of crowdsourcing: Can users really compete with professionals in generating new product ideas?*" Journal of Product Innovation Management*, vol. 29, no. 2, pp. 245-256, 2012.
[23] S. Nambisan and R. A. Baron, "Virtual customer environments: Testing a model of voluntary participation in value co-creation activities," *Journal of Product Innovation Management*, vol. 26, no. 4, pp. 388-406, 2009.
[24] J. Füller, H. Mühlbacher, K. Matzler, and G. Jawecki, "Consumer empowerment through internet-based co-creation," *Journal of Management Information Systems*, vol. 26, no. 3, pp. 71-102, 2009.
[25] Aerospace Industries Association. (2010). *Disruptive Information Technologies-Special Report*. [Accessed on: 12 November 2014].

Richard D. Evans obtained his PhD from the University of Greenwich in 2013. He completed research into how Enterprise 2.0 Technologies could improve Collaboration and Knowledge Sharing in dispersed Product Development teams. He is currently a RESEARCH FELLOW within the Centre for Innovative Product Development and Manufacturing at the University of Greenwich, United Kingdom. Prior to starting his PhD, he held the position of ONLINE PRODUCT MANAGER at Dunelm Mill plc, a FTSE 250 company, in the UK. He is currently completing research in the field of "Knowledge Management in Collaborative Product Development" and is working on a European INTERREG-funded project in collaboration with CESi Association in Rouen, France and The University of Exeter. Dr. Evans is a professional member of the Institution of Engineering and Technology and the Chartered Institute of IT.

James X. Gao obtained his PhD from the University of Manchester in 1989. He is a world-class academic with an international reputation in manufacturing engineering, particularly in the application of information and communication technologies in the manufacturing industry. He has directed a large number of research projects sponsored by UK and European research councils and leading manufacturing companies. He has published over 190 papers in international journals and conferences. He is currently PROFESSOR OF MANUFACTURING ENGINEERING within the Centre for Innovative Product Development and Manufacturing at the University of Greenwich, United Kingdom.

Sara Mahdikhah was born in Tehran, Iran. She received her engineering diploma in Industrial Engineering from Mazandaran University of science and technology, Iran, in 2008 and then obtained her Master of Science degree in Industrial Engineering from the University of Tehran, Iran, in 2010. She moved to France and obtained a Masters in research in the domain of "Knowledge Integration in Mechanical Production Design and Manufacturing" from Ecole National Supérieur d'Art et Métier (ENSAM Paris tech) in 2011. She is now a PH.D. STUDENT in Industrial Engineering and Informatics at the University of Rouen, France. Sara works within the IRISE laboratory, located in the Graduate Engineering School at CESI in Rouen. Her research interests are: Product life cycle management (PLM), Small and medium enterprises (SME), Information modeling, process modeling and collaboration between OEM and supplier.

Mourad Messaadia was born in Constantine, Algeria. He received a diploma of engineering in 1997 from UBMA, Algeria. In 2003, he received his Masters degree in Automation and Production Processes at Polytechnic National Institute of Grenoble (INPG). In 2008, he held a PhD degree in Industrial Engineering at LAAS-CNRS laboratory, University of Toulouse. He worked in the Gas Industry as a MAINTENANCE ENGINEER and also as a WORKSHOP SUPERVISOR for three years. In 2013, he joined the Graduate Engineering School at CESI, Rouen, as a LECTURER and RESEARCHER. He participates in European projects (ActionPlanT, Suplight and BENEFITS) and different French projects. Dr. Messaadia was a reviewer of papers for IJPLM, IFAC, INCOM, and APMS and was member of research team at French System Engineering Association (Afis) and Eco-Design Systems for Sustainable Development (EcoSD). His current research interests are OEM-Supplier relationship, PLM approaches, system engineering and Eco-design.

David Baudry was born in Paris, France. He received an engineering diploma (equivalent to M.Sc.) from the Ecole Nationale Supérieure d'Ingénieur (ENSI) of Caen, France, in 1999 and a Ph.D in Electronics from the University of Rouen, France, in 2005. From 2000 to 2001 he joined SOPRA Group and was involved in software development. In 2001, he joined the Graduate Engineering School ESIGELEC at Rouen, France where he was lecturer and deputy head of the EMC Team of the ESIGELEC Research Institute (IRSEEM). He was also in charge of the "Mechatronic and electrical engineering" major in ESIGELEC. In 2010, he was entitled to supervise research. In 2011, he joined the Graduate Engineering School CESI at Rouen, France where he is currently lecturer and researcher. His research interests include near-field EMC in electronic and mechatronic systems, electromagnetic simulations and modeling. He is actually involved in the development of the axes "Modelling and optimizing industrial performance" and "Technological tools for innovative products" of the IRISE laboratory.