Malaysian Journal of Fundamental & Applied Sciences Vol.8, No.1 (2012) 44-48.

Malaysian Journal of Fundamental & Applied Sciences

available online at http://mjfas.ibnusina.utm.my

Worker's behaviour in manufacturing industry: An evidence from a minimum spanning tree

Shamshuritawati Sharif[1*] and Maman A. Djauhari[2]

[1]*College of Arts and Sciences, UUM, 06010 UUM Sintok, Kedah, Malaysia*
[2]*Department of Mathematics, Faculty of Science, UTM, 81310 UTM Skudai, Johor, Malaysia*

Received 19 December 2011, Revised 10 Janury 2012, Accepted 20 January 2012, Available online 28 January 2012

ABSTRACT

A manufacturing industry contributes around 10% Malaysian economic. It provides economic opportunities for related industries and business. However, the number of accidents in manufacturing sector, including fatal accidents, has been increased from time to time. We analyze worker's behaviour to understand the real situation. The method developed in econophysics has been used to transform the correlation structure into sub-dominant ultrametric structure. Its corresponding minimum spanning tree and the centrality measure are performed in order to identify the most influential variables.

| Adjacency matrix| Complex system| Distance matrix | Kruskal's algorithm| Network topology |

http://dx.doi.org/10.11113/mjfas.v8n1.373

1. INTRODUCTION

The manufacturing sector is one of the sexiest industrial sectors in Malaysian economic growth. It contributes around 13.3% [1]. In the last three years, Malaysia's manufacturing sector has been contributing the highest number of accidents which result in non-permanent disabilities (NPD), permanent disabilities (PD) and death (D). This sector becomes the second sector where accident occurrences causing death is placed on the top behind the construction sector as can be seen in Table 1.

Table 1.0 : The occupational accident by sector in 2008 – 2010

Sector	2008			2009			2010		
	NPD	PD	D	NPD	PD	D	NPD	PD	D
Manufacturing	1565	134	76	1186	79	53	1367	154	57
Agriculture, Forestry, Logging & Fishing	365	7	42	363	8	40	433	17	29
Utility	82	12	19	85	3	18	34	3	11
Construction	55	2	72	34	6	62	46	4	63
Transport, Storage & Communication	18	1	8	18	0	8	13	1	11
Hotel & Restaurant	13	1	1	18	0	0	20	0	0
Public Services & Statutory Bodies	3	1	2	0	0	1	36	2	3
Mining & Quarrying	4	0	6	2	1	2	2	1	0
Wholesale & Retail Trade	2	0	0	0	0	0	0	0	0
Financial, Insurance, Real Estate & Business Services	2	1	4	0	0	1	26	1	1

Source : DOSH (2010)

From Table 1 we learn that the current practices are differs considerably from DOSH policy.

**Corresponding author at:*
E-mail addresses: shamshurita@yahoo.com (Shamshuritawati Sharif)

Department of Occupational Safety and Health (DOSH), Government of Malaysia, conducted three major responsibilities, namely, standard setting, enforcement, and promotion. All the activities are conducted periodically from time to time in order to guarantee employers and employees in the country pay more attention to safety and health at work [2].

The DOSH policy comprises:

(i) To prepare and preserve a workplace with a safe and healthy working system;
(ii) To ensure that all staff are provided with the relevant information, instruction, training and supervision regarding methods to carry out their duties in a safe manner and without causing any risk to health;
(iii) To investigate all accidents, diseases, poisonous and/or dangerous occurrences, and to have action taken to ensure that these occurrences will not be repeated;
(iv) To provide basic welfare facilities to all workers; to revise and improve on this policy whenever necessary; and
(v) To comply with all the requirements of legislations related to safety and health as stated in the Occupational Safety and Health Act 1994 (Act 514), as well as regulations and codes of practice which have been approved.

More specifically, that table shows that the workplace is neither safety nor healthy as required in the first policy of DOSH. Therefore, to respond the third policy (investigates all accidents, diseases, etc.), in what follows we investigate all accident occurrences and then recommend the action that has to be taken to ensure that those occurrences will be reduced.

The remainder of the paper is designed as follows. In the next section, we discuss on the research design and its implementation followed by data analysis methodology. Later, in Section 3 we discuss the research results. A conclusion will be delivered in the last section.

2. RESEARCH METHODOLOGY

Worker's behaviour will be considered as a complex system consisting of 25 variables as nodes connected by (25-1)*25/2 = 300 links each of which is related to the correlation coefficient between the two nodes adjacent to it. The nodes and links will be considered as a network or, more specifically, a weighted undirected graph [3].

2.1 Data preparation

There are 136 workers that have been participated in this survey. Our focus is on the front line workers only, i.e., operators and technicians because they are the main target of DOSH policy. The worker's behaviour characteristics are classified into seven factors. See Appendix I for the list of variables and their factors, and [4] for the details of the questionnaire.

2.2 Network analysis

Network analysis was originally developed in computer science. However, nowadays, it has been used in various fields of study. See, for example, [5] in sociology, [6] and [7] in finance, and [8] in transportation. In practice, network analysis starts with a correlation matrix. Then, we transform it into a distance matrix [9]. From this matrix we construct the corresponding sub-dominant ultrametric (SDU) distance matrix based on minimum spanning tree (MST).

For this purpose we use Kruskal algorithm as suggested in [2] and [9]. MST will then be used to simplify the original network and summarize the most important information. To visualize the MST we use the open source called 'Pajek' [10]; and [11]. See, [12] for the open source.

Furthermore, to interpret the MST we use dot plot matrix, and centrality measures such as degree, betweenness, closeness, and eigenvector centralities.

To make the MST more attractively and efficiently useful, we use the Kamada Kawai procedure provided in Pajek [13].

2.3 Centrality Measure

From network analysis view point, the role or degree of importance of each particular node can be analyzed by using its centrality measures such as degree, betweenness, and closeness centralities. These will help us to find the most important nodes in the network structure [14], [15] and [16].

Degree centrality indicates the connectivity of nodes. It provides information on how many other nodes are connected with a particular node.

On the other hand, betweenness centrality is reflects the extent to which a node lies in relative position with respect to the others [17]. This measure indicates the potentiality of node to influence the others.

Closeness centrality measures how close a node is to all other nodes in terms of correlations. Closeness can also be regarded as a measure of how long the information is to spread from a given node to other reachable nodes.

Those measures are computed based on the MST as follows [8], [18], and [19]:

(i) Degree centrality of node i is $d_i = \sum_{j=1}^{n} a_{ij}$ where $a_{ij} = 1$ if the i-th and j-th nodes are linked and 0 otherwise.

(ii) Betweenness centrality of node i, b_i, is the ratio of the number of path passing through i between two different nodes and the number of all possible paths from j to k for all j and k where $j \neq i$ and $k \neq i$.

(iii) Closeness centrality of node i, c_i, is the ratio of the number of links in the MST, which is equal to (n-1), and the number of links in the path from i to j for all $j \neq i$.

Degree centrality is the simplest of the node centrality measures by using the local structure around nodes only. In order to identify the role of importance, degree centrality is no longer appropriate to be the best measure. The higher the degree centrality does not reflect to the strength of each particular node.

Due to that limitation of degree centrality, in this subsection we introduce "average of weights" as another measure. It is the average of weights of all links adjacent to each node. This measure reflects the strength of influence of a particular node to the others. The node that has larger scores in all measures is considered to be more central in terms of it influence to the others.

3. RESEARCH RESULT

In Figure 1.0 shows the correlation structure of 25 worker's behaviour culture variables. The degree and direction of their inter-relationship is representing by the colour of the figure. In this case, instead of analyzing 25*25=625 correlation elements, here, we can filter the information into 300 correlation elements by using MST.

Figure 2.0 we present the dot plot matrix of the adjacency matrix A that corresponds to the MST of distance matrix D given by Kruskal's algorithm [20]. The element of A is a_{ij} = 1 if the i-th and j-th nodes are linked and 0 otherwise. This matrix is a symmetric matrix and all diagonal elements are 0. In Figure 2.0, empty cell represents 0 and colour cell 1. This figure shows the worker's behaviour characteristics are more dispersed around diagonal. This indicates that managing worker's behaviour is a bit complicated.

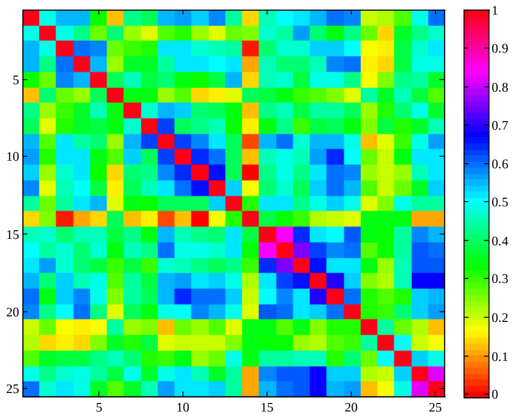

Fig. 1 Correlation Matrix

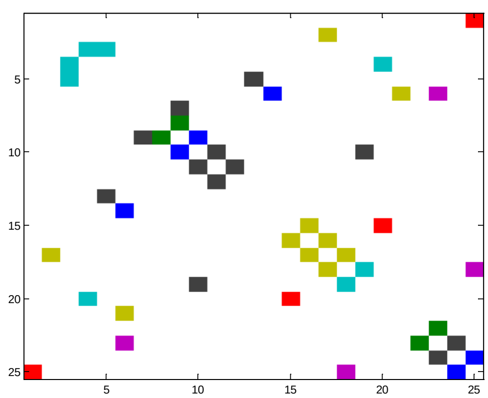

Fig. 2 Dot Plot Matrix

To elaborate the above findings more clearly, based on the MST issued from Matlab version 7.8.0 (R2009a), we use Pajek software to represent the centrality measure in Figure 3.0: (a)-(d). From this figure we see the interconnectivity among all characteristics. The size and colour of the node represent the score of centrality measure and the rank of importance for degree centrality, betwenness centrality, closeness centrality and eigenvector centrality.

See Figure 3.0, in Appendix II we present the centrality measure discussed previously. From that figure, we learn that:

(i) Based on degree centrality, see Figure 3.0 (a), There are seven points; CA6, CB3, CB4, CD3, CD4, CF3, and CG2 (red points) have the highest number of links (3) in the network. CA3, CA4, CA5, CB5, CD1, CD2, CE1, CE2, CG1 (green points) is 2 links. The rests (yellow points) are of 1 link only. The higher the number of links, the higher the influence of that particular characteristic.

(ii) In terms of betweenness, see Figure 3.0 (b), CD4 (red point) has an excellent position compared to the others where the information flow in the network can easily reach others. This node is the closest node to the others. The second (third, and fourth, respectively) closest node to the others are CD3 (green point) (CG2 (yellow point), and CD2 and CE1 (blue points), respectively).

(iii) According to the closeness centrality, see Figure 3.0 (c), the most important nodes CD4 (red point). It plays the most important role in the network followed by, in order of importance: CD3 (green point or the second most important), CE1 and CG2 (yellow points or the third most important), CD1 and CG1 (blue points or the fourth most important) and CA1, CA2, CB4, and CD1 (black points or the fifth most important. The rest (purple points) are the sixth most important. This means that those currencies strongly influence the others.

(iv) Average of weight centrality can be used to indicate the average correlations between a particular node and the other nodes adjacent to it. In terms of degree, CA6, CB3, CB4, CD3, CD4, CF3, and CG2 are the most influential variables while in terms of sum of weights the most influential is CC2 (red point), followed by CA6 CF1, (green points), and CF2 and CF3 (yellow points). See Figure 3.0 (d).

4. CONCLUSION

Dot plot matrix analysis shows that there is high correlation among characteristics within and also between factors in worker's behaviour. According to the centrality measures together, after using the Pareto analysis, the following variables are the vital few in managing the worker's behaviour of manufacturing industry; CA2, CA3, CA5, CA6, CB4, CD1, CD3, CD4, CF3, and CG2. These variables represent the following factors; 'Reacting Behaviour', 'Personal Protective Equipment', Tools and Equipment', 'Ergonomics' and 'Communication'. These variables should be paid more attention by DOSH as well as Malaysian industrial management in reducing the number of fatality.

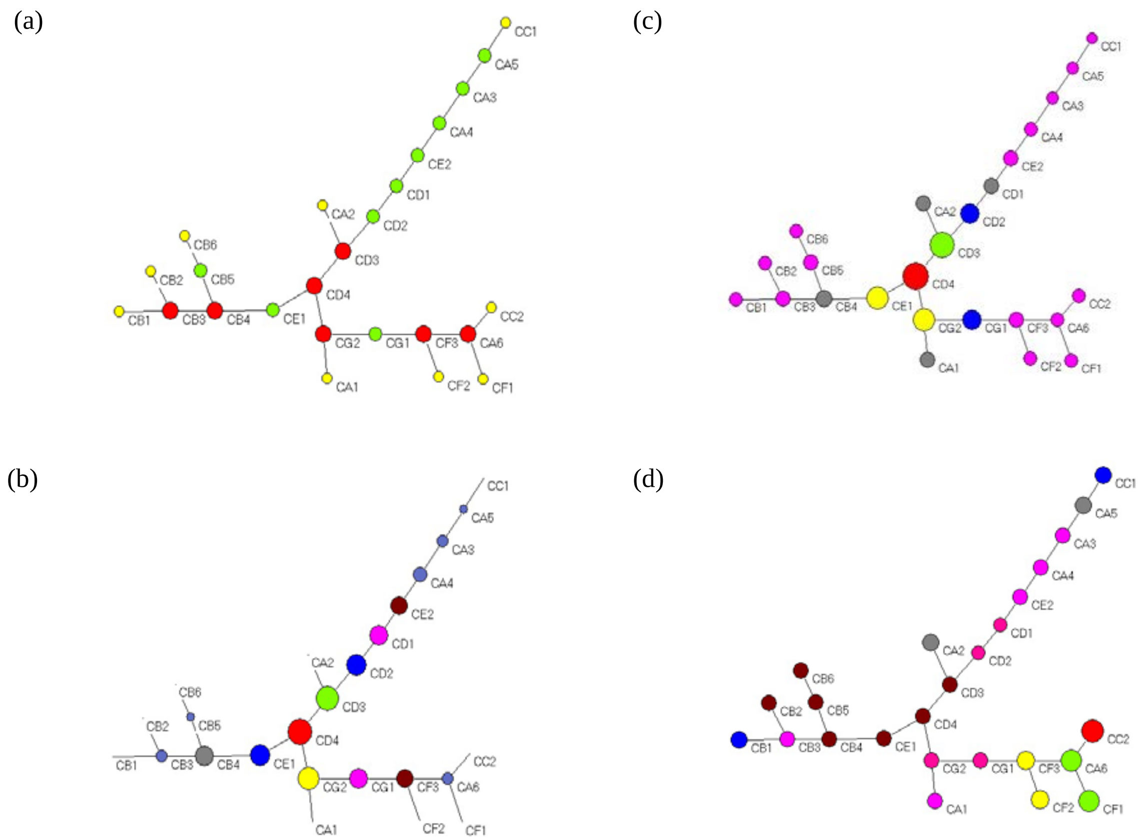

Fig. 3 A correlation network analysis of worker's behaviour and its centrality measure (a) degree centrality (b) betweenness centrality (c) closeness centrality (d) average sum of weight centrality

ACKNOWLEDGMENT

This research is sponsored by the Ministry of Higher Education of Malaysia under the FRGS vote numbers 4F013 and RUG vote number Q.J130000.7126.02H18. The authors gratefully acknowledge those sponsorships, Goverment of Malaysia, Universiti Teknologi Malaysia and Universiti Utara Malaysia.

REFERENCES

[1] Ministry of Finance Malaysia. (2011, Jun 17). Malaysia Economic Report 2010/2011 [Online]. Available : http://www.treasury.gov.my.

[2] Department of Occupational Safety and Health Malaysia (2011, January 20). Statistics [Online]. Available: http://ww.dosh.gov.my.

[3] P. Jayawant, and K. Glavin, Involve a journal of mathematics, 2(4) (2009), 439–450.

[4] H. Djauhari, Safety Culture at a manufacturing Industry in Johor Malaysia. M.S. Thesis, Universiti Teknologi Malaysia, Malaysia, (2010).

[5] T. Krichel, and N. Bakkalbasi, "A Social Network Analysis of Research Collaboration in the Economics Community," presented at the International Workshop on Webometrics, Informetrics and Scientometrics & Seventh COLLNET Meeting, France, (2006).

[6] R. N. Mantegna, European Physical Journal B, 11 (1999), 193-197.

[7] S. Miccichè, G. Bonanno, F.Lillo, and R.N. Mantegna, Physica A, 324 (2003), 66–73.

[8] K. Park, and A. Yilmaz, "A Social Network Analysis Approach to Analyze Road Networks," presented at the ASPRS Annual Conference. San Diego, CA, (2010).

[9] R. N. Mantegna, and H. E. Stanley, An Introduction to Econophysics: Correlations and Complexity in Finance. Cambridge University Press, Cambridge UK, (2000).

[10] V. Batagelj, and A. Mrvar, "A Density based approaches to network analysis: Analysis of Reuters terror news network," presented at the Ninth Annual ACM SIGKDD, Washington, D.C, (2003).

[11] M. De Nooy, A. Mvrar, and V. Batagelj, Exploratory Social Network Analysis with Pajek. Cambridge: Cambridge University Press, London, (2004).

[12] V. Batagelj, and A. Mrvar, (2011, January 6). PAJEK: Program for Analysis and Visualization of Large Networks, version 2.02. [Online]. Available : http://pajek.imfm.si/doku.php?id=download.

[13] T. Kamada, and S. Kawai, Information Processing Letters, 31 (1) (1989), 7–15.

[14] Y. Xu, J. Ma, Y. Sun, J. Hao, Y. Sun, and Y. Zhao, "Using Social Network Analysis As A Strategy For E-Commerce Recommendation," presented at the Pacific Asia Conference on Information Systems (PACIS), India , (2009).

[15] A. Abbasi, and J. Altmann, "On the Correlation between Research Performance and Social Network Analysis Measures Applied to Research Collaboration Networks," TEMEP Discussion Paper, No.2010, Seoul National University, Korea, (2010).

[16] J. Monárrez-Espino, and J. R. Caballero-Hoyos, Estudios sobre las Culturas Contemporaneas. 16(32) (2010), 155-171.

[17] L. Freeman, Sociometry, 40 (1977), 35–41

[18] S.P. Borgatti, Connections, 18(1) (1995), 112-114.

[19] P. Sieczka, and J.A. Holyst, Physica *A*, 388 (2009), 1621-1630.

[20] J.B. Kruskal, Proceedings of the American Mathematical Society, 7(1) (1956), 48-50.

APPENDIX I:
WORKER'S BEHAVIOUR COMPONENTS AND THEIR CORRESPONDING VARIABLES

Reacting behaviour	1 CA1 I always adjust my personal protective equipment before doing my job so that I can work safely 2 CA2 I never do shortcut in my job 3 CA3 I always change my position carefully when doing my job 4 CA4 I always stop my work first before attaching safety guards 5 CA5 I always do my job in order so that I can work safely 6 CA6 I never do horseplay during my job
Personal Protective Equipment	7 CB1 I always use head gear 8 CB2 I always use eye protection and face shielding 9 CB3 I always use hearing protection 10 CB4 I always use respiratory protection 11 CB5 I always use arm and hand covering 12 CB6 I always use foot and leg protection
Specific Job Risk	13 CC1 I always follow safety policy and procedure 14 CC2 I never experience accidents due to my job
Tools and equipments	15 CD1 I always use right tools and equipments for my job 16 CD2 I always use tools and equipments for my job correctly 17 CD3 Tools and equipment I use for my job are always be maintained well 18 CD4 I always participate to keep my workplace in a good housekeeping
Safe Work Practice	19 CE1 I understand how work safely in my job 20 CE2 I always work safely
Ergonomics	21 CF1 I never do many repetition in my job 22 CF2 I never do my work in long duration without rest 23 CF3 I never have awkward posture in my work
Communication	24 CG1 I always inform my friend if they act unsafely 25 CG2 I always remind my friend to work safely

APPENDIX II:
CENTRALITY MEASURE

Node	Code	Degree	Betweenness	Closeness	Average Of Weights
1	CA1	1	0	0.162	0.838
2	CA2	1	0	0.159	0.832
3	CA3	2	0.344	0.209	0.934
4	CA4	2	0.301	0.207	0.930
5	CA5	2	0.290	0.205	0.906
6	CA6	3	0.692	0.282	1.105
7	CB1	1	0	0.159	0.820
8	CB2	1	0	0.157	0.814
9	CB3	3	0.489	0.261	1.066
10	CB4	3	0.453	0.255	1.056
11	CB5	2	0.228	0.197	0.901
12	CB6	1	0	0.146	0.803
13	CC1	1	0	0.146	0.786
14	CC2	1	0	0.144	0.766
15	CD1	2	0.163	0.188	0.897
16	CD2	2	0.163	0.185	0.892
17	CD3	3	0.391	0.250	0.998
18	CD4	3	0.391	0.233	0.991
19	CE1	2	0.159	0.183	0.891
20	CE2	2	0.083	0.170	0.864
21	CF1	1	0	0.128	0.729
22	CF2	1	0	0.114	0.638
23	CF3	3	0.366	0.224	0.953
24	CG1	2	0.083	0.166	0.848
25	CG2	3	0.344	0.220	0.950