ISSN:0975-3583,0976-2833 VOL7,ISSUE04, 2016

AHuman-CenteredRiskModelfortheConstructionSafety

Ajith kumar[1], Arul C[2], B.Manoharan[3] and M. Jeganathan[4]
[1,2]Assistant Professor, Department of Civil Engineering
Nehru Institute of Technology
[3]Professor (Tenure), PMIST, Vallam, Thanjavur.
[4]Associate Professor,Designed Environment and Research Institute (DEAR Institute) Trichy- 621 213.
erarul@gmail.com, jegann1978@gmail.com

ABSTRACT

The paper aims at quantifying the human errors in the construction work and analysing theirpotential impact on the construction accident. It proposes to analysis the risks in the construction safetywith the human reliability analysis (HRA) method. The paper adopted a fuzzy Bayesian network (BNN)approach to incorporate the cognitive reliability and error analysis method (CREAM), which is one of therepresentative HRA method, into the construction safety analysis. This fuzzy BNN was developed into ahuman-centered risk model. The model used the intuitionistic fuzzy sets (IFS) to represent the expert'sjudgment and generated the probability distribution by the mass assignment theory. A case study on thefireaccidentintheconstructionofXiamenMetroLine2inChinawasprovided.Themodelhasprovedto be able to analysis the construction accident from the human factor perspective and elicit meaningfulquantificationresults.

Key wordsCognitivescience,construction,humanfactor,safetymanagement.

INTRODUCTION

Theconstructionindustryisconsideredasoneofthemost significant contributors to the Gross Domestic Prod-uct(GDP)formostindustrializedanddevelopingcoun-tries [1]. In China, the GDP from building construction was6180.8billionRMBin2018,whichaccountedfor6.87%ofthetotalGDPofthewholeyear[2].Inthefirsthalfof the 2018, there were 85933 Chinese construction enter-prises taking construction activities. The number of Chineseconstruction industry employees was up to 4.4 million overthe same period. However, the large demand of new hous-ing construction comes up with the increasing risks to theconstruction safety. The construction worker may take riskybehaviour in the practical operations and these behaviourscaneventuallyleadtothecatastrophicaccidents[3].

Aseriesapproacheshavebeentakentoassessandmanage the risks in the construction safety. For example,Tam *et al.* [4] identify the weaknesses in the safety manage-ment for the construction project. These weaknesses includebut not limited to the poor safety awareness, the lack oftrainingandsoon.ZouandWang[5]takeabroadviewonthe risks in construction projects and emphasizes on the riskmanagement strategies. The work of Shao *et al.* [6] revealsthe accident pattern for the building construction and coversaspects such as the timing and the geographic condition forthe accident. To manage the potential risks in the safetyconstruction,moreadvancedapproachessuchasthebuildinginformation modelling(BIM) [7], [8], unmanned aerial vehi-cle(UAV)[9],[10],etc.,havebeenproposedandappliedin practice. The general trends in the construction safetyanalysis that revealed in these studies includes the accessand analysis of the huge data [7], [11], the collaborationsand interaction between human and machine [9], [12] thecomprehensive evaluation over both spatial and temporalinformation [7] and so on. All these studies have deepened theunderstandingofrisksassociatedwiththeconstructionwork.Nevertheless, it remains certain critical issues for analysingrisksinconstructionprojectthatneedtobeanswered.(Vasanthy and Jeganathan 2007, Vasanthy et.al., 2008, Raajasubramanian et.al., 2011, Jeganathan et.al., 2012, 2014, Sridhar et.al., 2012, Gunaselvi et.al., 2014, Premalatha et.al., 2015, Seshadri et.al., 2015, Shakila et.al., 2015, Ashok et.al., 2016, Satheesh Kumar et.al., 2016).

A. POSSIBILITY-PROBABILITYTRANSFORMATION

As described in the last subsection, there is a structural dif-ferencebetweentheprobabilityandthepossibilitymeasures.The probability has fully taken advantage of the algebraicstructure of the unit interval. The uncertainty described by theprobability is additivity. For example, in a system constitutingof identical independent components, the probability for anevent as one component being failure and its complementmust add up to one. Also, the failure probability of the systemincreases with the number of components in it. By contrast,thepossibilitymeasuresusetheunitintervalasatotalorder-ing. Still taking the system and its components as an example,the possibility of the system failure is equal to the failurepossibilityofonecomponent.To fuse the uncertain information from the two differentresources, it is necessary to adopt an automated reasoningprocedure. In this study, the mass assignment theory has beentakentotransformthepossibilitytotheprobability[17].The crucial idea in the mass assignment theory is offering anormalised fuzzy subset *A* of theand generating a family ofprobability distribution o In this distribution family, eachdistributioncorrespondstosomeredistributionofthemassesassociatedwithsetstoelementsofthosesets.

B.AWARENESSANDBEHAVIOROFWORKER

Another major risk influencing factor concerned in the con-struction safety study is the safety awareness and safetybehavioroftheconstructionworker[3],[4],[31].Thework-ers'awarenessandbehaviorcanbeaffectedbyvariousfactorssuchasthecompanysize[35],themanagementmeth od [36], the safety program [37], the supervision [38]andsoon.Nevertheless,anapparentlimitinthesestudiesis the lack of exploration on the cognitive process of theworker [39]. By contrast, there have been numerous HRAstudies on the cognitive model of operator's safety percep-tionandbehavior[16].IntheCREAM,thehumanerrorisanalyzedbasedonthefourmajorcognitiveprocessesas observation/identification, interpretation, planning/choiceand action/execution. The cognitive analysis in the CREAMhelpstorevealthemechanismoftheoperator'sbehaviorandoffersaninsighttothehappeningoftheaccid ent.Asaresult,the use of the CREAM BNN in construction safety wouldmuch deepen the understanding of the worker's perceptionandbehavior.

CASESTUDY

To infer the probability distribution for the construction acci-dent,itneedstheexperttooffertheCPTvalues.Toeasethe difficulties in offering the large amount of probabilities,the noisy-MAX model [41] is adopted here to help expertsmake their own judgements. The noisy-MAX model is thegeneralization of the noisy-or gate [42], which assumes thatall the causes in the net are independent to each other andeach of these causes can lead to the effect independently.Thenoisy-MAXextendsthisassumptiontotheparentnodeswith multi-valued (non-Boolean) domains. **CASESTUDY**

In this section, a numerical example is presented using theproposed fuzzy BNN CREAM approach. This example refersto the construction accident happened in the tunnelling pro-cessoftheXiamenMetroLine2(XML2)inXiamen,Fujian,Chinain2017.

ISSN:0975-3583,0976-2833 VOL7,ISSUE04, 2016

I. CONCLUSIONANDFUTUREWORK

Inthisstudy,ahuman-centeredriskmodelwasdevelopedforquantifying the HEP and the probability of the accident inthe construction work. The approach is based on the a fuzzyBNN version of the CREAM that models the PSFs' effectson the human error and the construction accident. To buildthemodel,itstartswithcollectingtheexpert'sopinions.Theexperts have to offer their own judgements of the PSFs'effects.Thesejudgementsarerepresentedasthemembershipdegree for different fuzzy sets in each PSF. In this process,with introducing the concept as IFS, the uncertainties in theexpert's judgement are considered from both the objectiveand the subjective perspective. The expert's judgements areadjusted with combining the uncertainty into the membershipdegree. The adjusted results, which are the possibility distri-butions to the fuzzy sets, are firstly convert to the MA andthen to the probability distributions. These prior probabilitydistributionsofPSFsareinputintotheBNNforinferences.(Manikandan et.al., 2016, Sethuraman et.al., 2016, Senthil Thambi et.al., 2016).

In the risk model, the structure of the BNN follows thedefinitions in the CREAM, which determines the humanerror with nine PSFs. Also, each reasoning process in theCREAMistransferredintoalocalBNN.Eventually,aBNNmodelling the PSFs' probabilistic influence on the humanerror can be achieved. To adapt the BNN to analysis thescenarios in the construction accident, two modificationshavebeenmade.Firstly,thePSFastheworkingconditionisgivenamuchbroaderdefinition.Inthisdefinition,allthe mechanical, physical and environmental factors havingdirecteffectsontheconstructionsafetyareconsideredastheworking condition. Secondly, beside the unintentional humanerror,theviolationisconsideredasanothertypeoftheunsafeact of the construction worker. In the model, the violation isdefined as the deliberate deviations from the safe operation inthe construction and should be evaluated separately.However,therearealsocertainlimitationsinthisstudyandfutureworkshouldbeperformed:

REFERENCES

[1] H. Lingard and S. M. Rowlinson, *Occupational Health and Safety inConstructionProjectManagement*.London,U.K.:SponPress,2005.

[2] NationalBureauofStatisticsofChina.(2018).*StatisticalBulletinofNational Economic and Social Development in 2018*. [Online]. Available:http://www.stats.gov.cn/tjsj/zxfb/201902/t20190228_1651265.html

[3] S. S. Man, A. H. S. Chan, and H. M. Wong, ''Risk-taking behaviors ofHong Kong construction workers—A thematic study,'' *Saf. Sci.*, vol. 98,pp. 25–36,Oct.2017,doi:10.1016/j.ssci.2017.05.004.

[4] C.M.Tam,S.X.Zeng,andZ.M.Deng,''Identifyingelementsofpoor construction safety management in China,'' *Saf. Sci.*, vol. 42, no. 7,pp.569–586,Aug.2004,doi:10.1016/j.ssci.2003.09.001.

[5] P. X. W. Zou, G. Zhang, and J. Wang, ''Understanding the key risks inconstructionprojectsinChina,''*Int.J.ProjectManage.*,vol.25,no.6,pp.601–614,Aug.2007,doi:10.1016/j.ijproman.2007.03.001.

[6] B. Shao, Z. Hu, Q. Liu, S. Chen, and W. He, ''Fatal accident patterns ofbuildingconstructionactivitiesinChina,''*Saf.Sci.*,vol.111,pp.253–263,Jan. 2019,doi: 10.1016/j.ssci.2018.07.019.

[7] E. A. Pärn, D. J. Edwards, and M. C. P. Sing, ''The building informationmodelling trajectory in facilities management: A review,'' *Autom. Con-struct.*,vol.75,pp.45–55,Mar.2017,doi:10.1016/j.autcon.2016.12.003.

[8] R.Edirisinghe,K.A.London,P.Kalutara,andG.Aranda-Mena,‘‘Buildinginformation modelling for facility management: Are we there yet?’’ *Eng.,Construct.Archit.Manage.*,vol.24,no.6,pp.1119–1154,Nov.2017,doi:10.1108/ECAM-06-2016-0139.

[9] S. Siebert and J. Teizer, ‘‘Mobile 3D mapping for surveying earthworkprojectsusinganunmannedaerialvehicle(UAV)system,’’*Autom.Constr.*,vol.41,pp.1–14,May2014,doi:10.1016/j.autcon.2014.01.004.

[10] M.GheisariandB.Esmaeili,‘‘Applicationsandrequirementsofunmannedaerialsystems(UASs)forconstructionsafety,’’*Saf.Sci.*,vol.118,pp.230–240,Oct.2019,doi:10.1016/j.ssci.2019.05.015.

[11] S.Bruno,M.DeFino,andF.Fatiguso,‘‘Historicbuildinginforma-tion modelling: Performance assessment for diagnosis-aided informationmodelling and management,’’ *Autom. Construct.*, vol. 86, pp. 256–276,Feb. 2018, doi:10.1016/j.autcon.2017.11.009.

[12] T. Rakha and A. Gorodetsky, ‘‘Review of unmanned aerial system (UAS)applicationsinthebuiltenvironment:Towardsautomatedbuildinginspec-tion procedures using drones,’’ *Automat. Construct.*, vol. 93, pp. 252–264,Sep. 2018,doi: 10.1016/j.autcon.2018.05.00.

[13] X. Pan and Z. Wu, ‘‘Performance shaping factors in the human errorprobabilitymodificationofhumanreliabilityanalysis,’’*Int.J.Occu-pationalSaf.Ergonom.*,vol.26,no.3,pp. 538–550,Jul.2020,doi:10.1080/10803548.2018.1498655.

[14] P. Baraldi, L. Podofillini, L. Mkrtchyan, E. Zio, and V. N. Dang, ‘‘Com-paring the treatment of uncertainty in Bayesian networks and fuzzy expertsystems used for a human reliability analysis application,’’ *Rel. Eng. Syst.Saf.*,vol.138,pp.176–193,Jun.2015,doi:10.1016/j.ress.2015.01.016.

[15] L.Mkrtchyan,L.Podofillini,andV.N.Dang,‘‘Bayesianbeliefnetworksforhumanreliabilityanalysis:A reviewofapplicationsandgaps,’’*Rel.Eng.Syst.Saf.*,vol.139,pp. 1–16,Jul.2015,doi:10.1016/j.ress.2015.02.006.

[16] E. Hollnagel, Ed., ‘‘CREAM—A second generation HRA method,’’ in*Cognitive Reliability and Error Analysis Method*. Oxford, U.K.: Elsevier,1998, ch. 6, pp. 151–190.

[17] J.F.Baldwin,J.Lawry,andT.P.Martin,‘‘Amassassignmenttheoryoftheprobability of fuzzy events,’’ *Fuzzy Sets Syst.*, vol. 83, no. 3, pp. 353–367,Nov.1996.

[18] F.Xiao,‘‘Adistancemeasureforintuitionisticfuzzysetsanditsapplicationtopatternclassificationproblems,’’*IEEETrans.Syst.,Man,Cybern.Syst.*,earlyaccess,Dec.27,2019,doi:10.1109/tsmc.2019.2958635.

[19] F.Xiao,‘‘EFMCDM:Evidentialfuzzymulticriteriadecisionmakingbasedonbeliefentropy,’’*IEEETrans.FuzzySyst.*,vol.28,no.7,pp. 1477–1491,Jul. 2020,doi: 10.1109/tfuzz.2019.2936368.

[20] F. Xiao, Z. Zhang, and J. Abawajy, ‘‘Workflow scheduling in distributedsystems under fuzzy environment,’’ *J. Intell. Fuzzy Syst.*, vol. 37, no. 4,pp. 5323–5333,Oct.2019,doi:10.3233/JIFS-190483.

[21] S. Parsons, ‘‘Probabilistic graphical models: Principles and techniques byDaphne Koller and Nir Friedman, MIT Press, 1231 pp., $95.00, ISBN 0-262-01319-3,’’ *Knowl. Eng. Rev.*, vol. 26, no. 2, pp. 237–238, 2011, doi:10.1017/S0269888910000275.

[22] L.A.Zadeh,‘‘Probabilitymeasuresoffuzzyevents,’’*J.Math.Anal.Appl.*,vol.23,no.2,pp.421–427,1968,doi:10.1016/0022-247X(68)90078-4.

[23] L. A. Zadeh, ‘‘The concept of a linguistic variable and its application toapproximatereasoning—I,’’*Inf.Sci.*,vol.8,no.3,pp.199–249,1975,doi:10.1016/0020-0255(75)90036-5.

[24] A. M. Whaley, S. Hendrickson, R. Boring, J. Joe, K. Blanc, and J. Xing,‘‘Bridging human reliability analysis and psychology, part 1: The psy-chological literature review for the IDHEAS method,’’ in *Proc. PSAM11ESREL12*, Helsinki, Finland,Jun. 2012.

[25] R. L. Boring, ‘‘Fifty years of THERP and human reliability analysis,’’

in*Proc.ProbabilisticSaf.AssessmentManage.(PSAM11)*,Helsinki,Finland,Jun. 2012.

[26] Erik, *Cognitive Reliability and Error Analysis Method: CREAM*, 1st ed.Amsterdam, The Netherlands:Elsevier, 1998.

[27] Z.L.Yang,S.Bonsall,A.Wall,J.Wang,andM.Usman,‘‘Amod-ifiedCREAMtohumanreliabilityquantificationinmarineengineer-ing,’’*OceanEng.*,vol.58,pp. 293–303,Jan.2013,doi:10.1016/j.oceaneng.2012.11.003.

[28] M. C. Kim, P. H. Seong, and E. Hollnagel, ‘‘A probabilistic approach fordetermining the control mode in CREAM,’’ *Rel. Eng. Syst. Saf.*, vol. 91,no.2,pp.191–199,Feb.2006,doi:10.1016/j.ress.2004.12.003.

[29] E. W. L. Cheng, H. Li, D. P. Fang, and F. Xie, ‘‘Construction safetymanagement:AnexploratorystudyfromChina,’’*Construct.Innov.*,vol.4,no.4,pp.229–241,Dec.2004,doi:10.1108/14714170410815114.

[30] L. Zhang, X. Wu, M. J. Skibniewski, J. Zhong, and Y. Lu, ‘‘Bayesian-network-basedsafetyriskanalysisinconstructionprojects,’’*Rel.Eng.Syst.Saf.*,vol.131,pp.29–39,Nov.2014,doi:10.1016/j.ress.2014.06.006.

[31] Y.Chen,B.McCabe,andD.Hyatt,‘‘Aresiliencesafetyclimatemodelpre-dictingconstructionsafetyperformance,’’*Saf.Sci.*,vol.109,pp.434–445,Nov. 2018, doi: 10.1016/j.ssci.2018.07.003.

[32] O. Abudayyeh, T. K. Fredericks, S. E. Butt, and A. Shaar, ‘‘An inves-tigationofmanagement’scommitmenttoconstructionsafety,’’*Int. J.ProjectManage.*,vol.24,no.2,pp. 167–174,Feb.2006,doi:10.1016/j.ijproman.2005.07.005.

[33] C.QianandJ.Ruoyu,‘‘Safety4Sitecommitmenttoenhancejobsitesafetymanagementandperformance,’’*J.Construct.Eng.Manage.*,vol. 138, no. 4, pp. 509–519, Apr. 2012, doi: 10.1061/(ASCE)CO.1943-7862.0000453.

[34] H.Z.A.Khan,A.Chan,W.Utama,R.Gao,andS.Memon,‘‘Determinantsofsafetyclimateforbuildingprojects:SEM-basedcross-validationstudy,’’ *J. Construct. Eng. Manage.*, vol. 143, Feb. 2017, Art. no. 5017005, doi:10.1061/(ASCE)CO.1943-7862.0001298.

[35] B.H.W.Guo,T.W.Yiu,andV.A.González,‘‘Doescompanysizematter?Validationofanintegrativemodelofsafetybehavioracrosssmallandlargeconstruction companies,’’ *J. Saf. Res.*, vol. 64, pp. 73–81, Feb. 2018, doi:10.1016/j.jsr.2017.12.003.

[36] H. Guo, Y. Yu, Q. Ding, and M. Skitmore, ‘‘Image-and-skeleton-basedparameterized approach to real-time identification of construction work-ers’ unsafe behaviors,’’ *J. Construct. Eng. Manage.*, vol. 144, Jun. 2018,Art.no.04018042,doi:10.1061/(ASCE)CO.1943-7862.0001497.

[37] P. L. Bigelow, D. P. Gilkey, S. Greenstein, and M. P. Kirsch, ‘‘Evaluationof HomeSafe: An injury and illness prevention program in residentialconstruction,’’ *Work*, vol. 11, no. 1, pp. 21–33, 1998, doi: 10.3233/WOR-1998-11104.

[38] S. Winge, E. Albrechtsen, and B. A. Mostue, ‘‘Causal factors and con-nectionsinconstructionaccidents,’’*Saf.Sci.*,vol.112,pp. 130–141,Feb. 2019, doi:10.1016/j.ssci.2018.10.015.

[39] R.Jin,P.X.W.Zou,P.Piroozfar,H.Wood,Y.Yang,L.Yan,andY.Han,‘‘Asciencemappingapproachbasedreviewofconstructionsafetyresearch,’’*Saf.Sci.*,vol.113,pp. 285–297,Mar.2019,doi:10.1016/j.ssci.2018.12.006.

[40] J.Reason,‘‘Humanerror:Modelsandmanagement,’’*West.J.Med.*,vol.172,no.6,pp.393–

396,Jun.2000,doi:10.1136/ewjm.172.6.393.

[41] F.J.DíezandS.F.Galán,‘‘EfficientcomputationforthenoisyMAX,’’ *Int. J. Intell. Syst.*, vol. 18, no. 2, pp. 165–177, Feb. 2003, doi:10.1002/int.10080.

[42] F. J. Díez, ‘‘Parameter adjustment in Bayes networks. The generalizednoisyOR–gate,’’in*Proc.9thInt.Conf.UncertaintyArtif.Intell.*,Jul.1993,pp.99–105,doi:10.1016/b978-1-4832-1451-1.50016-0.

[43] M.Konstandinidou,Z.Nivolianitou,C.Kiranoudis,andN.Markatos,‘‘A fuzzy modeling application of CREAM methodology for human relia-bilityanalysis,’’*Rel.Eng.Syst.Saf.*,vol.91,no.6,pp. 706–716,Jun.2006,doi: 10.1016/j.ress.2005.06.002.

[44] J. Chen, D. Zhou, C. Lyu, and X. Zhu, ‘‘A method of human reliabilityanalysisandquantificationforspacemissionsbasedonaBayesiannetworkand the cognitive reliability and error analysis method,’’ *Qual. Rel. Eng.Int.*, vol.34,pp.1–16,Jul. 2018,doi:10.1002/qre.2300.

[45] Vasanthy M and M. Jeganathan. 2007. Ambient air quality in terms of NOx in and around Ariyalur, Perambalur DT, Tamil Nadu. Jr. of Industrial pollution Control., 23(1):141-144.

[46] Vasanthy. M ,A.Geetha, M. Jeganathan,and A.Anitha. 2007. A study on drinking water quality in Ariyalur area. J.Nature Environment and Pollution Technology. 8(1):253-256.

[47] Ramanathan R ,M. Jeganathan, and T. Jeyakavitha. 2006. Impact of cement dust on azadirachtain dicaleaves – ameasure of air pollution in and Around Ariyalur. J. Industrial Pollution Control. 22 (2): 273-276.

[48] Vasanthy M and M. Jeganathan. 2007. Ambient air quality in terms of NOx in and around Ariyalur, Perambalur DT, Tamil Nadu. Pollution Research., 27(1):165-167.

[49] Vasanthy M and M. Jeganathan. 2008.Monitoring of air quality in terms of respirable particulate matter – A case study. Jr. of Industrial pollution Control.,24(1):53 - 55.

[50] Vasanthy M, A.Geetha, M. Jeganathan, and M. Buvaneswari. 2008. Phytoremediation of aqueous dye solution using blue devil (Eichhornia crassipes). J. Current Science. 9 (2): 903-906.

[51] Raajasubramanian D, P. Sundaramoorthy, L. Baskaran, K. Sankar Ganesh, AL.A. Chidambaram and M. Jeganathan. 2011. Effect of cement dust pollution on germination and growth of groundnut (Arachis hypogaea L.). IRMJ-Ecology. International Multidisciplinary Research Journal 2011, 1/1:25-30 : ISSN: 2231-6302: Available Online: http://irjs.info/.

[52] Raajasubramanian D, P. Sundaramoorthy, L. Baskaran, K. Sankar Ganesh, AL.A. Chidambaram and M. Jeganathan. 2011. Cement dust pollution on growth and yield attributes of groundnut. (Arachis hypogaea L.). IRMJ-Ecology. International Multidisciplinary Research Journal 2011, 1/1:31-36.ISSN: 2231-6302. Available Online: http://irjs.info/

[53] Jeganathan M, K. Sridhar and J.Abbas Mohaideen. 2012. Analysis of meterological conditions of Ariyalur and construction of wind roses for the period of 5 years from January 2002. J.Ecotoxicol.Environ.Monit., 22(4): 375-384.

[54] Sridhar K, J.Abbas Mohaideen M. Jeganathan and P Jayakumar. 2012. Monitoring of air quality in terms of respirable particulate matter at Ariyalur, Tamilnadu. J.Ecotoxicol.Environ.Monit., 22(5): 401-406.

[55] Jeganathan M, K Maharajan C Sivasubramaniyan and A Manisekar. 2014. Impact of cement dust pollution on floral morphology and chlorophyll of healianthus annus plant – a case study. J.Ecotoxicol.Environ.Monit., 24(1): 29-34.

[56] Jeganathan M, C Sivasubramaniyan A Manisekar and M Vasanthy. 2014. Determination of

cement kiln exhaust on air quality of ariyalur in terms of suspended particulate matter – a case study. IJPBA. 5(3): 1235-1243. ISSN:0976-3333.

[57] Jeganathan M, S Gunaselvi K C Pazhani and M Vasanthy. 2014. Impact of cement dust pollution on floral morphology and chlorophyll of healianthus annus.plant a case study. IJPBA. 5(3): 1231-1234. ISSN:0976-3333.

[58] Gunaselvi S, K C Pazhani and M. Jeganathan. 2014. Energy conservation and environmental management on uncertainty reduction in pollution by combustion of swirl burners. J. Ecotoxicol. Environ.Monit., 24(1): 1-11.

[59] Jeganathan M, G Nageswari and M Vasanthy. 2014. A Survey of traditional medicinal plant of Ariyalur District in Tamilnadu. IJPBA. 5(3): 1244-1248. ISSN:0976-3333.

[60] Premalatha P, C. Sivasubramanian, P Satheeshkumar, M. Jeganathan and M. Balakumari.2015. Effect of cement dust pollution on certain physical and biochemical parameters of castor plant (ricinus communis). IAJMR.1(2): 181-185.ISSN: 2454-1370.

[61] Premalatha P, C. Sivasubramanian, P Satheeshkumar, M. Jeganathan and M. Balakumari.2015. Estimation of physico-chemical parameters on silver beach marine water of cuddalore district. Life Science Archives. 1(2): 196-199.ISSN: 2454-1354.

[62] Seshadri V, C. Sivasubramanian P. Satheeshkumar M. Jeganathan and Balakumari.2015. Comparative macronutrient, micronutrient and biochemical constituents analysis of arachis hypogaea. IAJMR.1(2): 186-190.ISSN: 2454-1370.

[63] Seshadri V, C. Sivasubramanian P. Satheeshkumar M. Jeganathan and Balakumari.2015. A detailed study on the effect of air pollution on certain physical and bio chemical parameters of mangifera indica plant.Life Science Archives. 1(2): 200-203.ISSN: 2454-1354.

[64] Shakila N, C. Sivasubramanian, P. Satheeshkumar, M. Jeganathan and Balakumari.2015. Effect of municipal sewage water on soil chemical composition- A executive summary. IAJMR.1(2): 191-195.ISSN: 2454-1370.

[65] Shakila N, C. Sivasubramanian, P. Satheeshkumar, M. Jeganathan and Balakumari.2015. Bacterial enumeration in surface and bottom waters of two different fresh water aquatic eco systems in Ariyalur, Tamillnadu. Life Science Archives. 1(2): 204-207.ISSN: 2454-1354.

[66] Ashok J, S. Senthamil kumar, P. Satheesh kumar and M. Jeganathan. 2016. Analysis of meteorological conditions of ariyalur district. Life Science Archives. 2(3): 579-585.ISSN: 2454-1354. DOI: 10.21276/lsa.2016.2.3.9.

[67] Ashok J, S. Senthamil Kumar, P. Satheesh Kumar and M. Jeganathan. 2016. Analysis of meteorological conditions of cuddalore district. IAJMR.2 (3): 603-608.ISSN: 2454-1370. DOI: 10.21276/iajmr.2016.2.3.3.

[68] Satheesh Kumar P, C. Sivasubramanian, M. Jeganathan and J. Ashok. 2016. South Indian vernacular architecture -A executive summary. IAJMR.2 (4): 655-661.ISSN: 2454-1370. DOI: 10.21276/iajmr.2016.2.3.3.

[69] Satheesh Kumar P, C. Sivasubramanian, M. Jeganathan and J. Ashok. 2016. Green buildings - A review. Life Science Archives. 2(3): 586-590.ISSN: 2454-1354. DOI: 10.21276/lsa.2016.2.3.9.

[70] Satheesh Kumar P, C. Sivasubramanian, M. Jeganathan and J. Ashok. 2016. Indoor outdoor green plantation in buildings - A case study. IAJMR.2 (3): 649-654.ISSN: 2454-1370. DOI: 10.21276/iajmr.2016.2.3.3.

[71] Manikandan R, M. Jeganathan, P. Satheesh Kumar and J. Ashok. 2016. Assessment of ground water quality in Cuddalore district, Tamilnadu, India. Life Science Archives. 2(4): 628-636.ISSN:

ISSN:0975-3583,0976-2833 VOL13,ISSUE03, 2022

2454-1354. DOI: 10.21276/lsa.2016.2.3.9.

[72] Manikandan R, M. Jeganathan, P. Satheesh Kumar and J. Ashok. 2016. A study on water quality assessment of Ariyalur district, Tamilnadu, India. IAJMR.2 (4): 687-692.ISSN: 2454-1370. DOI: 10.21276/iajmr.2016.2.3.3.

[73] Sethuraman G, M. Jeganathan, P. Satheesh Kumar and J. Ashok. 2016. Assessment of air quality in Ariyalur, Tamilnadu, India. Life Science Archives. 2(4): 637-640.ISSN: 2454-1354. DOI: 10.21276/lsa.2016.2.3.9.

[74] Sethuraman G, M. Jeganathan, P. Satheesh Kumar and J. Ashok. 2016. A study on air quality assessment of Neyveli, Tamilnadu, India. IAJMR.2 (4): 693-697.ISSN: 2454-1370. DOI: 10.21276/iajmr.2016.2.3.3.

[75] Malarvannan J, C. Sivasubramanian, R. Sivasankar, M. Jeganathan and M. Balakumari. 2016. Shading of building as a preventive measure for passive cooling and energy conservation – A case study. Indo – Asian Journal of Multidisciplinary Research (IAJMR): ISSN: 2454-1370. Volume – 2; Issue - 6; Year – 2016; Page: 906 – 910. DOI: 10.21276.iajmr.2016.2.6.10.

[76] Malarvannan J, C. Sivasubramanian, R. Sivasankar, M. Jeganathan and M. Balakumari. 2016. Assessment of water resource consumption in building construction in tamilnadu, India. Life Science Archives (LSA) ISSN: 2454-1354 Volume – 2; Issue - 6; Year – 2016; Page: 827 – 831 DOI: 10.21276/lsa.2016.2.6.7.

[77] Sivasankar R, C. Sivasubramanian, J. Malarvannan, M. Jeganathan and M. Balakumari. 2016. A Study on water conservation aspects of green buildings. Life Science Archives (LSA),ISSN: 2454-1354. Volume – 2; Issue - 6; Year – 2016; Page: 832 – 836, DOI: 10.21276/lsa.2016.2.6.8.

[78] Ashok J , S. Senthamil Kumar , P. Satheesh Kumar and M. Jeganathan. 2016. Analysis and design of heat resistant in building structures. Life Science Archives (LSA), ISSN: 2454-1354. Volume – 2; Issue - 6; Year – 2016; Page: 842 – 847. DOI: 10.21276/lsa.2016.2.6.10.