Shabad Dyal et al. International Journal of Recent Research Aspects ISSN: 2349-7688, Vol. 5, Issue 1, March 2018, pp. 488-493

An investigation on the impact of technological advancements in the field of Geology

Shabad Dyal, Saurabh Dhiman

Disaster Management Department of Geography, Panjab University Chandigarh

***Abstract:* The development of affordable digital technologies that allow the collection and analysis of georeferenced field data represents one of the most significant changes in field-based geoscientific study since the invention of the geological map. Digital methods make it easier to re-use pre-existing data (e.g. previous field data, geophysical survey, satellite images) during renewed phases of fieldwork. Increased spatial accuracy from satellite and laser positioning systems provides access to geostatistical and geospatial analyses that can inform hypothesis testing during fieldwork. High-resolution geomatic surveys, including laser scanning methods, allow 3D photorealistic outcrop images to be captured and interpreted using novel visualization and analysis methods. In addition, better data management on projects is possible using geospatially referenced databases that match agreed international data standards. Collectively, the new techniques allow 3D models of geological architectures to be constructed directly from field data in ways that are more robust compared with the abstract models constructed traditionally by geoscientists. This development will permit explicit information on uncertainty to be carried forward from field data to the final product. Current work is focused upon the development and implementation of a more streamlined digital workflow from the initial data acquisition stage to the final project output.**

***Keywords:* Technological advancement, Geology, IT, Implications.**

I. INTRODUCTION

Geology is the study of the Earth's structure and history. It underpins the provision of resources to the UK's population and industry, delivers a wide range of essential services, and helps us understand how we can live more sustainably on our planet, thanks to our strong skills base, education and research. Necessity (human needs and wants) is the mother of invention (technology). The Earth is made up of chemical elements, all of which exist in fixed amounts. However, it is not the elements themselves that are the object of human affection, but rather it is the properties that these elements possess (either alone or in partnership with other elements) that humans seek. In this context, resources are anything that provide these useful properties. To this point, humanity has not yet exhausted any of these resources, yet concerns have been voiced about the prospect of running out of such resources. . Technology represents ways that humans apply human ingenuity, knowledge, and experience to organize capital, energy, and materials to get what they want and need. It is the means to make things useful, to acquire things that are already useful, or to transform things that are not useful into things that are. If human action with respect to nonfuel mineral resources is characterized by simply changing the form of resources through separation and re-arrangement to maximize their utility, then it should be clear that the total available resource should consist of both in-situ (not yet extracted) materials and of in-use materials (manufactured stocks-in-use, emissions, or disposable wastes). It is likely that future needs can be met by continually rearranging resources in all these forms, such that resources are not permanently destroyed.

Geology is the multi-disciplinary science that studies the earth and its history. We live on a dynamic planet that is constantly changing. Our ability to survive as a civilization and as a species is intricately linked to the geologic processes that shape our earth, form its natural resources and allow it to recover from the abuse that our society heaps upon it. Geology is important because virtually all the natural materials our society needs such as oil, gas, metals, building materials, and so forth are found by geologists. Geologic engineers evaluate roads, buildings and dams for geologic stability and hazard potential. Environmental protection and remediation are important geologic issues faced by contemporary society.

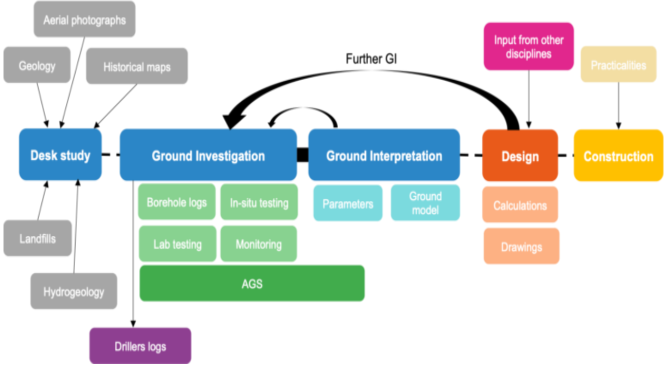


Figure 1: Overview of the Engineering Geology Life Cycle & data collected throughout

Geology is an exciting profession that typically combines indoor and outdoor work. Students of geology encounter science in its broadest sense because geology incorporates those aspects of astronomy, biology, chemistry, engineering, mathematics and physics that are important to understanding the Earth and its interactions with the atmosphere, the biosphere, and the hydrosphere.

Geology requires problem solving, good 3D visualization and the ability to collect and process data accurately. Geologists are like detectives. Data that allow geologists to solve problems seldom arrive in a linear fashion. Geologists must be able to collect fragments of information and develop interpretations based on those data. They must be able to separate important and trivial data and be able to adjust their interpretations as new data are collected. Developing models, either in their mind or on their computer, is essential. Once geologists have completed their work, they must be able to effectively communicate their results to others. Strong verbal and written communication skills are essential in geology. Most geologists work on practical problems that involve people.

Those individuals, whether an individual landowner, an elected official, or the CEO of a Fortune 500 company, want answers communicated in a way they can understand. Geologists work on every continent from the tropics to the poles and on and under the surface of the oceans. They work on foot or from ropes in high mountains, in submersibles and on ships, in mobile laboratories in trucks or aircraft, and in offices and labs in universities, research parks, urban offices, and high-rise offices buildings. In these various settings, geologists use a wide range of equipment. The field geologist may use only a hammer, compass/pocket transit, notebook, pencil, and map or GPS unit.

II. INFORMATION TECHNOLOGY APPLIED TO ENGINEERING GEOLOGY

Geologists work on every continent from the tropics to the poles and on and under the surface of the oceans. They work on foot or from ropes in high mountains, in submersibles and on ships, in mobile laboratories in trucks or aircraft, and in offices and labs in universities, research parks, urban offices, and high-rise offices buildings. In these various settings, geologists use a wide range of equipment. The field geologist may use only a hammer, compass/pocket transit, notebook, pencil, and map or GPS and bore-hole shear devices (to measure the strength of materials).

As discussed earlier, geology is a broad multi-disciplinary science. The digital handling of engineering geological data leads to the great advantage that vast amounts of such data can be combined and analysed, as well as imported into and exported from databases and/or large (virtual) spatial models in fractions of seconds. In the pre-digital era this was not possible at all due to the time consuming character of such operations [17].

The biggest potential of IT is the possibility to process and analyse large amounts of primary data, such as in geophysical surveying, remote sensing and in cone penetration testing. Processes such as anti-aliasing, improvement of signal to noise ratios and, generally, processing of large data sets would not have been possible without the data handling capacity of IT.

Digital data handling, however, forces us also to adopt strict rules on the uniformity of data formats and to an appropriate choice of parameters to be described. The uniformity of the data formats is essential for the "interoperability" of data on different parameters and from different data sources. However, the use of large databases and the importation of datasets into programs for numerical analysis also require uniformity in the way to structure the description of the engineering geological parameters [16].

IT offers opportunities for efficient handling of engineering geological information. The two most significant aspects of IT for technical geosciences are (Loudon, 2000): The obvious ability of computers to calculate, thus opening up possibilities of more rigorous analysis with quantitative and statistical methods, and more vivid graphical presentation with visualization techniques.

Figure 2. Automated field data acquisition

The manipulation and management of information; this ranges from the ability to move elements of a picture in a graphics system to the ability to capture data, store vast quantities of information in a database management system, and retrieve specific items on demand. IT influences the way in which engineering geologists investigate the real world, how they communicate, what they know and how they think. This can lead to better science, cost savings, increased speed and flexibility in data collection, storage, retrieval, analysis, communication, and presentation [18].

Since the spectacular increase of calculation power in the 1960's and 1970's through the development of computers, engineering geologists and geotechnical engineers started the development of digital methodologies to support the effective and efficient execution of their work. Initially this development focused on the application of the enhanced data handling capacity and calculation velocity to introduce more detail in conventional methods of slope stability calculation, the calculation of the behaviour of soil and rock around tunnel openings and in foundations and earthworks to obtain more refined results [19].

There exists a strong tendency for specialists, even within one organization, to work independently with newly emerging technologies as IT, selecting their own computing tools and their own structure and format for storing data. If there is no effort for standardisation then this may lead to users spending more time on transforming data than on solving geotechnical problems. Sharing data between organizations will add further complexity.

It is important that any new technology has a clear tangible benefit. This might be increasing the accuracy of analysis, providing new data, improving efficiency of a task, facilitating better communication between the supply chain or improving safety. By identifying this 'added value' at the start of the project and reviewing it throughout ensures that technology is not used just for the sake of using it – something that potentially risks undermining the technology that will assist.

Technologies that are already showing 'added value' include:

Drones – Benefits include surveying large areas quickly, accessing places that are too dangerous for humans to access and ability to generate 'intelligent' 3D models of sites that open the door to 'unlimited' site visits;

3D Ground Modelling – Allows better visualisation of ground related risks to help ground engineers make more informed decisions. It also acts as a powerful communication tool to communicate ground risks to clients and other stakeholders; and

Smart Infrastructure – Enables real-time asset data to be obtained that can assist design verification, early identification of potential problems and a predictive maintenance approach.

Artificial intelligence (AI) also has huge potential to assist the ground engineering industry. Yes, the ground is notoriously unpredictable making it difficult for AI to make reliable predictions on ground conditions or parameters. But based on historic data, AI could produce generative models that ground engineers could test and revise following targeted ground investigations.

III. CHALLENGES

We should not shy away from the fact that embracing technology will bring its own challenges.

Four of the key challenges are:

- Upskilling of the industry;
- Validation of new software;
- Industry standards; and
- Industry culture.

Firstly, we must ensure that people are adequately trained in any new software tools and processes that are available (e.g. borehole logging using tablets). This is no easy task and ignites the debate as to whether the training responsibility lies with the industry or university. What is for sure though is that without the necessary skills to use and interpret the results from new technology we won't be able to achieve nearly as much as we could. Geologists must also not forget their core skills of critical thinking and interpreting the subsurface.

Secondly, we must ensure new technology is robust and can be trusted. It is very easy to produce an all singing and dancing 3D model, but it must also make geological sense. Professor Fookes hinted at this in the First Glossop Lecture where he stated, "Technical innovation must stand the test of time in order to prove its worth". We must also ensure that new processes and technology are also incorporated into existing industry standards or if required new standards developed [20].

The most difficult challenge of all, is the cultural transformation of the industry. Currently the value of data is not well enough understood, particularly among clients. As it is the clients who hold the purse strings, it is them who can lead the transformation. But it is equally the job of designers and contractors to share success stories and highlight the benefits that technology and effective information management can bring. This is particularly important if benefits are not realised until further down the asset life cycle. It is also crucial that the whole supply chain is singing off the same hymn sheet.

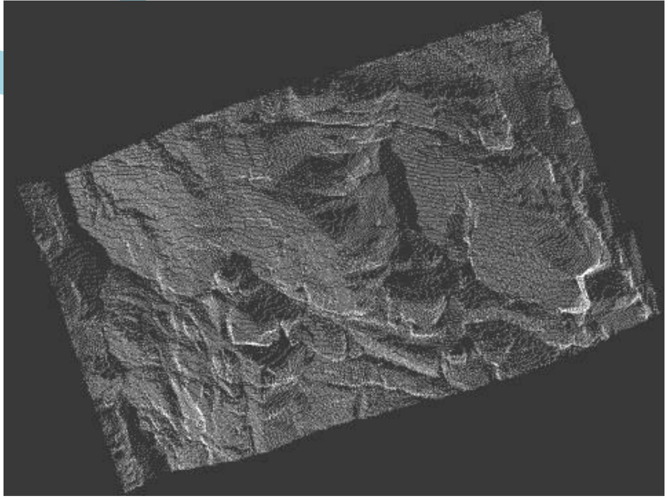


Figure 3. Point cloud data set of a rock surface, generated with a laser scanner

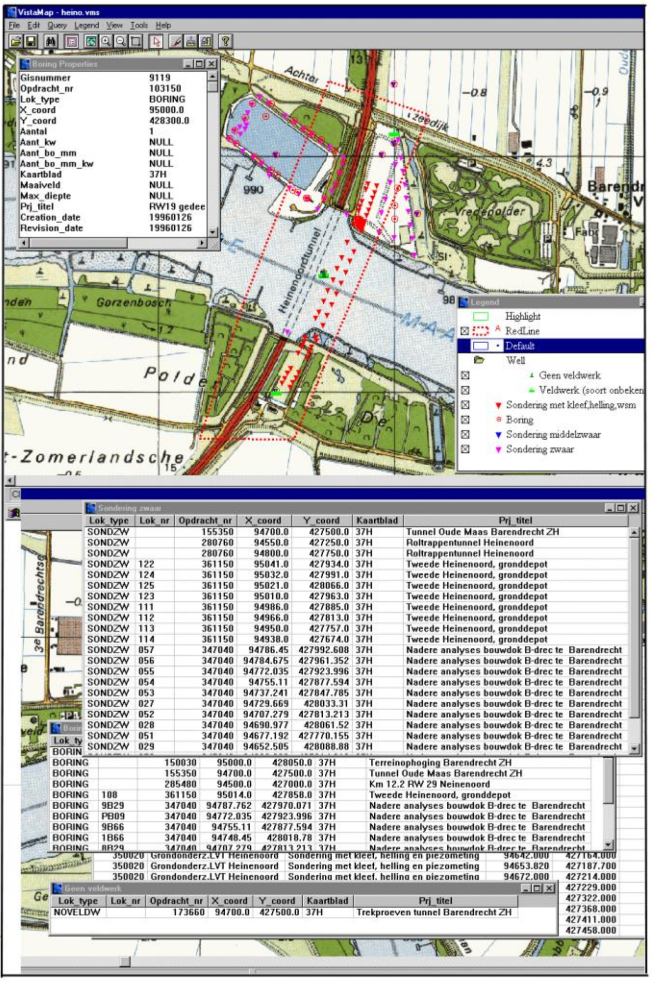
Where do we go from here?

Whether it is providing additional tools to better equip the ground engineer or creating cost savings for the client, the benefits of embracing new technologies and effective information management are clear. What we must do is to be better at sharing these benefits and success stories, particularly with clients.

Yes, there will be challenges along the way, particularly winning the hearts and minds of everyone in the industry but these are worth overcoming. We must remember that new technologies should make the life of an engineering geologist easier, not harder and allow us to focus on what we do best – critical thinking and interpreting the ground. It is important that these core skills are not sacrificed as these are things that technology cannot replace.

IV. IMPLICATIONS OF THE NEW PARADIGM

There is strategic value in looking at technology from the 'outside' as an emerging geological phenomenon. The problem of coping with the consequences of technology and technological change offers different answers, depending on whether we think of technology primarily as a human-generated and controlled phenomenon, or whether we look at it as a quasi-autonomous phenomenon that in effect operates according to its own dynamics.



Gisnummer	9119
Opdracht_nr	103150
Lok_type	BORING
X_coord	95000.0
Y_coord	428300.0
Aantal	1
Aant_kw	NULL
Aant_bo_mm	NULL
Aant_bo_mm_kw	NULL
Kaartblad	37H
Maaiveld	NULL
Max_diepte	NULL
Prj_titel	RW19 gedee
Creation_date	19960126
Revision_date	19960126

Lok_type	Lok_nr	Opdracht_nr	X_coord	Y_coord	Kaartblad	Prj_titel
SONDZW		155350	94700.0	427500.0	37H	Tunnel Oude Maas Barendrecht ZH
SONDZW		280760	94550.0	427250.0	37H	Roltrappentunnel Heinenoord
SONDZW		280760	94800.0	427750.0	37H	Roltrappentunnel Heinenoord
SONDZW	122	361150	95041.0	427934.0	37H	Tweede Heinenoord, gronddepot
SONDZW	124	361150	95032.0	427991.0	37H	Tweede Heinenoord, gronddepot
SONDZW	125	361150	95021.0	428066.0	37H	Tweede Heinenoord, gronddepot
SONDZW	123	361150	95010.0	427963.0	37H	Tweede Heinenoord, gronddepot
SONDZW	111	361150	94986.0	427885.0	37H	Tweede Heinenoord, gronddepot
SONDZW	112	361150	94966.0	427813.0	37H	Tweede Heinenoord, gronddepot
SONDZW	113	361150	94950.0	427757.0	37H	Tweede Heinenoord, gronddepot
SONDZW	114	361150	94938.0	427674.0	37H	Tweede Heinenoord, gronddepot
SONDZW	057	347040	94786.45	427992.608	37H	Nadere analyses bouwdok B-drec te Barendrecht
SONDZW	056	347040	94784.675	427961.352	37H	Nadere analyses bouwdok B-drec te Barendrecht
SONDZW	055	347040	94772.035	427923.996	37H	Nadere analyses bouwdok B-drec te Barendrecht
SONDZW	054	347040	94755.11	427877.594	37H	Nadere analyses bouwdok B-drec te Barendrecht
SONDZW	053	347040	94737.241	427847.785	37H	Nadere analyses bouwdok B-drec te Barendrecht
SONDZW	027	347040	94729.669	428033.31	37H	Nadere analyses bouwdok B-drec te Barendrecht
SONDZW	052	347040	94707.279	427813.213	37H	Nadere analyses bouwdok B-drec te Barendrecht
SONDZW	028	347040	94690.977	428061.52	37H	Nadere analyses bouwdok B-drec te Barendrecht
SONDZW	051	347040	94677.192	427770.155	37H	Nadere analyses bouwdok B-drec te Barendrecht
SONDZW	029	347040	94652.505	428088.88	37H	Nadere analyses bouwdok B-drec te Barendrecht

Lok_ty						
BORIN						
BORING		150030	95000.0	428050.0	37H	Terreinophoging Barendrecht ZH
BORING		155350	94700.0	427500.0	37H	Tunnel Oude Maas Barendrecht ZH
BORING		285480	94500.0	427000.0	37H	Km 12.2 RW 29 Neinenoord
BORING	108	361150	95014.0	427858.0	37H	Tweede Heinenoord, gronddepot
BORING	9B29	347040	94787.762	427970.071	37H	Nadere analyses bouwdok B-drec te Barendrecht
BORING	PB09	347040	94772.035	427923.996	37H	Nadere analyses bouwdok B-drec te Barendrecht
BORING	9B66	347040	94755.11	427877.594	37H	Nadere analyses bouwdok B-drec te Barendrecht
BORING	1B66	347040	94748.45	428018.78	37H	Nadere analyses bouwdok B-drec te Barendrecht
BORING	8B29	347040	94707.279	427813.213	37H	Nadere analyses bouwdok B-drec te Barendrecht

350020	Grondonderz.LVT Heinenoord	Sondering met kleef, helling en piezometing	94642.000	427164.000
350020	Grondonderz.LVT Heinenoord	Sondering met kleef, helling en piezometing	94653.820	427187.700
350020	Grondonderz.LVT Heinenoord	Sondering met kleef, helling en piezometing	94672.000	427214.000
				427229.000
				427322.000
				427368.000
				427411.000
				427458.000

Lok_type	Lok_nr	Opdracht_nr	X_coord	Y_coord	Kaartblad	Prj_titel
NOVELDW		173660	94700.0	427500.0	37H	Trekproeven tunnel Barendrecht ZH

Figure 4. Example of GeoGis database for geotechnical data

Looking at technology from the inside, we tend to formulate solutions to the problem of natural capital degradation that draw a straight line from the seemingly excessive use of resources like energy to policies that might restrict such use.

However, prescriptions such as constricting the resource stream on which the function of technology depends, for example by taxing carbon, tend to encounter resistance. Technology is not passive but has evolved mechanisms for its own defence – a requirement of any dynamic system whose longevity is measured in a large number of internal clock cycles, such as the time between cell phone bills or elections. The most important of these defenses is preemptive in nature and takes advantage of fundamental properties of its human parts, especially the property of acquisitiveness. Technology defends its mode of operation primarily by offering incentives such as abundant food, medicines, instant communication channels and other desiderata that bind, or even addict, humans to the system that produces them, as well as by less subtle mechanisms expressed via legal, judicial, political, military and other elements of the technological armory. The upshot is that attempts to ratchet back the rate of energy use and of consumption of the other resources on which this cornucopia depends, or to interfere with the continuing diversification and penetration of technology as it seeks out new sources of energy and material resources, are automatically resisted by the feedback loops on which technological metabolism is based. This is the nature of a positive feedback loop – it has intrinsic stability against disruption – the twist here being that humans, as sentient components of such a loop, may feel surprise or dismay upon realizing their enforced participation in a dynamics they thought they controlled. Policies that are based only on a consideration of future human wellbeing and do not take into account the needs of technology, especially the need to continue metabolizing at a high rate – which is the source of the constraints and incentives that channel human behaviour towards technology-friendly activities and is thus the sine qua non of technology – are likely to fail or be slow to implement because they consider the implicit two-way compact between system and parts only from the viewpoint of the parts.

With respect to human well-being, a high rate of technological energy consumption is, by itself, not the central problem. Global warming is not a necessary consequence of a high rate of energy use, but of the lack of adequate recycling mechanisms. The hydrosphere consumes energy more than a thousand times faster than the technosphere, but it recycles its own waste (fallen rainwater).

The technosphere, in burning fossil fuels, operates without any provision to recycle a major waste product, carbon. From the point of view of an autonomous technosphere, climate change is not a problem to be solved by using less energy, but by using more energy. As seen from the dynamics of the Carnot engine, whatever useful work is done by a system, additional energy is required to power a recycling mechanism.

Efforts to ramp up 'renewable' energy sources such as those based on wind or photovoltaics offer new ways to use energy to do work without the principal drawback of fossil-fuel combustion, that is, without the need to recycle carbon.

However, renewables technology is still technology. Trying to fix the climate problem by turning to renewables may therefore not lead where it seems. This will be the case if opportunities offered by renewables appear different to the technosphere than to humans. The emergence of new technological subsystems that can capture abundant but previously unavailable or little-used renewable resources like that provided by sunlight may just as likely be an opening move in the expansion of the technosphere towards massive increases in the use of these new resources than simply a way to substitute new cleaner energy sources for older sources that degrade the environment. For example, with regard to solar energy, there is no reason to expect that the technosphere will limit itself to extracting energy from just the fraction of the solar radiation flux that happens to be incident on the planetary disk. Technology is already extending itself into space and it may not be indifferent to the large fluxes of solar energy available there. Geoengineering proposals to counteract global warming by deploying a cloud of refractive 'flyers' in space to deflect incident solar energy away from the Earth are already on the books (Angel 2006). However, deflecting sunlight is throwing away usable energy. It is a short step to see how this idea might be retuned to do just the opposite – to capture the energy of photons in space that would have missed the Earth and then transmit the energy down to the Earth's surface (e.g. in the form of microwaves; Glaser 1968). This is not a prediction, but illustrates how looking at the technosphere from the outside provides its own perspective on possible Earth futures.

V. CONCLUSION

The model aims to provide new ideas on the management of geological risks in the construction and infrastructure processes, so that as a proposition is introduced into the investment process is carried out in different countries, from its legal body, in a manner that establish a requirement for active and passive actors in this process, this would be in the author's opinion, the best way to establish a way to ensure sustainability of building development in the medium and long term. This also would avoid the large outlay of money and resources that the states have to pay or release each year, after the frequent occurrence of natural and technological disasters. It is relevant to mention that as a model of technological innovation, this model is dynamic, allowing for interaction between actors and resource persons. Its main limitations depend on how deep or not be covered by the interdisciplinarity participation, to what extent would be apply or not the different management tools, as well as aspects related to the introduction of technology transfer and / or innovations in the process.

Reference

[1]. Angel, R. 2006. Feasibility of cooling the Earth with a cloud of small spacecraft near the inner Lagrange point (L1). Proceedings of the National Academy of Science of the USA, 103, 17 184–17 189. http://dx.doi.org/10.1073/pnas.0608163103

[2]. Barnosky, A. D.,Matzke, N.etal. 2011. Has the arth's sixth mass extinction already arrived? Nature, 471, 51–57. http://dx.doi.org/10.1038/nature09678

[3]. Crutzen, P. J. 2002. Geology of mankind. Nature, 415, 23.

[4]. Crutzen, P. J. & Stoermer, E. F. 2000. The Anthropocene. Global Change Newsletter, 41, 17–18.

[5]. Daily, G. C. (ed.) 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press,

[6]. Covelo. Ehrlich, P. R. & Ehrlich, A. H. 2013. Can a collapse of global civilization be avoided? Proceedings of the Royal Society B, 280, 20122845. http://dx.doi.org/10.1098/rspb.2012.2845

[7]. EIA 2012. Annual Energy Review 2011. US Energy Information Agency, DOE/EIA-0384(2011). http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf

[8]. FAO 2011. FAOSTAT. Food and Agricultural Organization of the United Nations. http://faostat.fao.org/site/377/DesktopDefault.aspx?PageID=377#ancor

[9]. Glaser, P. E. 1968. Power from the Sun: its future. Science, 162, 857–861.

[10]. Goldstein, E. 2012. Possible dynamics of technological metals in the Anthropocene. 2012 Fall Meeting of the American Geophysical Union. Abstract GC53C-1292. http://fallmeeting.agu.org/2012/eposters/eposter/gc53c-1292/

[11]. Haff, P. K. 2010. Hillslopes, rivers, plows, and trucks: mass transport on Earth's surface by natural and technological processes. Earth Surface Processes and Landforms, 35, 1157–1166. http://dx.doi.org/10.1002/esp.1902

[12]. Haff, P. K. 2012. Technology and human purpose: the problem of solids transport on the Earth's surface. Earth System Dynamics, 3, 417–431. http://dx.doi.org/10.5194/esd-3-149-2012

[13]. Haff, P. K. 2013. Maximum entropy production by technology. Accepted for publication. In: Dewar, R. C., Lineweaver, C., Niven, R. & Regenauer-Lieb, K. (eds) Beyond the Second Law: Entropy Production and Non-Equilibrium Systems. Springer, Berlin, in press Hermann, W. A. 2006. Quantifying global exergy resources. Energy, 31, 1685–1702.

[14]. IEA 2012. Key World Energy Statistics. International Energy Agency. http://www.iea.org/publications/freepublications/publication/kwes.pdf

[15]. IPCC 2007. IPCC Fourth Assessment Report: Climate Change 2007. Intergovernmental Panel on Climate Change.

http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml#1

[16]. S. Dalal & P. Chahar, Deadlock Resolution Techniques: An Overview in International Journal of Scientific and Research Publications (IJSRP), ISSN 2250-3153, Volume 3, Issue 7, July 2013, pp. 1-6.

[17]. A. Saini, S. Dalal and Dr. Kamal Sharma, A Survey on Outlier Detection in WSN, International Journal of Research Aspects of Engineering and Management ISSN: 2348-6627, Vol. 1, Issue 2, June 2014, pp. 69-72

[18]. U. Rani, S. Dalal, and J. Kumar, “Optimizing performance of fuzzy decision support system with multiple parameter dependency for cloud provider evaluation,” Int. J. Eng. Technol., vol. 7, no. 1.2, pp. 61–65, 2018

[19]. Mittal, A and Sharma, KK and Dalal, S, Applying clustering algorithm in case retrieval phase of the case-based reasoning, International Journal of Research Aspects of Engineering and Management, vol. 1, no. 2, pp. 14-16, 2014.

[20]. S. Dalal, G. Tanwar, N. Alhawat, "Designing CBR-BDI agent for implementing supply chain system", System, vol. 3, no. 1, pp. 1288-1292, 2013.

[21]. Paltridge, G. W. 1975. Global dynamics and climate – a system of minimum entropy exchange. Quarterly Journal of the Royal Meteorological Society, 101, 475–484.

[22]. Rauch, J. N. & Pacyna, J. M. 2009. Earth’s global Ag, Al, Cr, Cu, Fe, Ni, Pb, and Zn cycles. Global Biogeochemical Cycles, 23, GB2001. http://dx.doi.org/10.1029/2008GB003376

[23]. Sassoon, R. E., Hermann, W. A., Hsiao, I-C., Miljkovic, L., Simon, A. J. & Benson, S. M. 2009. Quantifying the flow of exergy and carbon through the natural and human systems. In: Collins, R. T. (ed.) Materials for Renewable Energy at the Society, and Technology Nexus. Materials Research Society Symposium Proceedings 1170E, 1170-R01-03.

[24]. Schneider, S. H., Semenov, S. et al. 2007. Assessing key vulnerabilities and the risk from climate change. In: Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J. & Hanson, C. E. (eds) Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, 779–810.

[25]. Scott, J. C. 2010. The Art of Not Being Governed. Yale University Press, New Haven.

[26]. Sessions, A. L., Doughty, D. M., Welander, P. V., Summons, R. E.& Newman, D. K. 2009. The continuing puzzle of the great oxidation event. Current Biology, 19, R567–R574. http://dx.doi.org/10.1016/j.cub.2009.05.054

.