"Enhancement of Safety By Incorporating 'Changing Environmental Geography' As A Factor in Hazard Identification and Risk Analysis (HIRA) Study"

Jayesh Narayan Idate[a], Dutta Baishakhi[b]

[a]Assistant Manager, Trans Thane Creek Waste Management Association, Navi Mumbai, PhD Scholar in Geography, University of Mumbai, India

[b]Associate Professor in Geography, R. J. College of Arts, Science & Commerce, Ghatkopar, Mumbai. University of Mumbai, India.

Abstract

Industries are essential components engaged in manufacture, process, purify list of products by which our day-to-day requirements are fulfilled. But incidents like Bhopal gas tragedy concerns about industrial operations. "Industrial Safety" concept gripped after Bhopal Gas tragedy to safe guard industrial workers, accidental impacts, surrounding residents and ultimately environment. These concerns resulted in assessment of man and machine through in-depth studies.

Concept like Hazard Identification and Risk Assessment (HIRA) is one of the popular methodology, comprises of hazard occurrence and computation of risk threshold. Increasing competition in market, advancement of technologies and micro management skills made uncontrolled development and industrial set ups. Ultimately, these resulted in local climate change, change in land use pattern and absolute or less buffer zone between industries.

Incorporating "Changing Environmental Geography" as a factor in HIRA matrix will address priorities in assessment of hazards. It will also list out processes, which impacted through changing geographical scenarios over period of time. These tools can aware governmental and non-governmental organization well in advance for making strategic actions in planning stage.

This paper is attempted to bring out attention towards changing geographical land use patterns and their consequences over period of time. It ponders upon the possibility of accidents due to surrounding environment and brings requirements of preventive measures. Records of such studies will also be useful for geographer to understand pattern of development and associated hazards.

Keywords: HIRA, Industrial Safety, Accidents, Environmental Geography, Local climate change.

Introduction:

Industrial revolution in India started in the 19^{th} century. It comprises of extraction of raw material through mining, primary processing, material production, secondary processing, manufacturing, production and fabrication. According to Environmental Impact Assessment (EIA) notification under sub-rule (3) of Rule 5 of the Environmental

(Protection) Rules, 1986; any new industrial project or activities, any expansion or modernization of existing project and activities based on potential environmental impact; shall be approved through process of Environmental Clearance from designated authorities.

EIA study is process in which risk exposure on human health & environment due to industrial project is assessed to impose certain restrictions and prohibition. This study addresses activities, its associated raw material & processes, their impact on environment & human health, risks of accidents and consequential factors which could lead to environmental effects. Hazard Identification and Risk Assessment (HIRA) is one of the widely used tool in computation of risk factors in such studies.

IS-15656:2006 is one of the Indian standard published by Bureau of Indian Standard (BIS) in 2006. This Code of practice is intended for safety professionals and engineers in the areas of chemical plant safety to upgrade safety performance of the plants and covers the methods of identifying, assessing and reducing hazards including evaluation and selection of methods for particular applications.

But basically, it has own limitations. User can compute risk factor within certain scope of work based on competency level in the study subject. Dynamic variable like changing climatic conditions and their impacts will never be addressed in study scope. Basic root cause of this limitation is non-availability of secondary data or trusted source of information. Rather, many natural hazards like flood, earthquake and forest fire cannot be predicted well in advance, due to limited set of records. Man made hazards like explosions, fire and release of toxic gases also unpredicted due to data confidentiality of neighboring industrial activity. Man made flood in recent years is best example for it. Due to competitive business models in every sector, land use patterns are changed drastically. Geological contour level got manipulated specially in urban areas and this resulted in narrowing surface runoff channels, ultimately resulting ‘Urban flood’ scenarios.

Following is the best example from Dombivali city situated in Thane District, Maharashtra, India.

Image(a): Google Earth image, Year 2004, Dombivali MIDC, Maharashtra, India (Source: Google Earth)

Image(b): Google Earth image, Year 2022, Dombivali MIDC, Maharashtra, India (Source: Google Earth)

City comprises of 12,46,381populations as per 2011 census and having around 606 industries. Average rainfall in this area is approximately 1250mm annually. From above facts and figures, it can be predicted that “Industrial Safety” can impacted due to surrounding geographical levels.

In process of HIRA study, user may consider hazards associated to work place. But, due to unavailability of city planning projection, data resources and extend of development; it is difficult to evaluate risk. Incorporating such details in Safety planning will help to minimize impact of accidents, reduce exposure on human health and suppress the extent of environmental degradation.

HIRA procedure is based on 'Matrix' mechanisms. The main elements of matrix are 'Occurrence' of Hazardous event and their 'Consequences'. Incorporating 3rd element as "Changing Environmental Geography" will scale up priority of issues. It will also help to elaborate rate of changing surrounding conditions over period of time, by frequently studying same scope of work. These records will not only help as base line data for "Environmental Clearance" but also assist government and non-government organizations for their planning.

In this paper, attempt is made to check viability of integrated matrix method.

Hazard Identification and Risk Assessment (HIRA) as per IS 15656:2006-

The overall methodology presented in this code allows systematic identification of hazards as well as quantification of risks associated. This code can use in improving plant safety performance reduce human and property loss.

Risk analysis process comprises of:

a. Hazard identification
b. Consequences assessment (Zone of impact and scale of damages)
c. Accident frequency assessment.
d. Risk estimation (Combining accident consequences and frequency)

The quantitative risk analysis (QRA) is most applicable and provide meaningful results when a plant is build, operated and maintained as per design intent and good engineering practices. According to this code, external events are defined as 'an event caused by natural hazard (earthquake, flood) etc or man induced events (aircraft crash, sabotage etc).

Process of risk analysis is as per follows:

[Figure-I: HIRA Process (Source: IS- 15656:2006)]

Risk calculation:

According to clause 7.1 of this code, Risk can be defined as a measure of economic loss, human injury or environmental damages both in terms of likelihood and magnitude of loss, injury or damage.

Mathematical expression of risk:

R=FC, where, R= risk (loss or injury per year), F= Frequency (event per year) and C= consequences (loss or injury per event)

According to clause 7.2 of this code, in many cases the hazard cannot be completely eliminated through the probability of occurrence can be reduced with addition of safety measures and at a financial cost.

General practices in HIRA study:

HIRA study is widely used in Chemical, Petrochemical, Textile, Construction, automobile processes. There are few research papers published on correlation between human errors and accidents, in which HIRA is main tool to diagnose root cause of accidental event.

HIRA process starts from following steps:

1. Identification of Hazard and its probability.
2. Evaluation of potential consequences leading to accidental events.
3. Computation of Risk based on Probability of occurrence and its consequences.
4. Use of Matrix for setting priorities to implement effective preventive or corrective actions.
5. Re-computation after preventive control and testing hypothesis.

HIRA Matrix:

[Figure: II- Risk Matrix Chart]

In general, HIRA matrix has 2 components, viz: Probability of occurrence and Impact severity. Based on brain storming, past empirical data and process flow studies; they rank from 1 to 5, depending on their credentialed. Lowest number shows least probability of occurrence or impact severity. While highest number show potential dangerous situation.

Risk is calculated by multiplying these two components, where highest severity condition having limited chances of occurrence, results in least priority. These results to have systematic choice for user in prioritizing efforts on risk control.

The root causes of hazards are based on natural as well as manmade activities. This HIRA exercise based on hypothetical assumptions of expected events.

Case Study:

Case Study 1 of Common Hazardous Waste Treatment Storage and Disposal Facility (CHWTSDF).

CHWTSDF is common facility engaged in hazardous waste management. Trans Thane Creek Waste Management Association (TTCWMA) is one of the oldest facility situated at Mahape, Navi Mumbai in Maharashtra state of India. Facility started in January 2004, for which Environmental Impact Assessment (EIA) study was conducted in 1998, as per the notification made under the Environmental Protection Act 1986 and rules there under. TTCWMA is having only landfill facility where hazardous waste is disposed through landfill operation in scientifically secured landfill.

Few Essential criteria for setting up of hazardous waste landfill:

a. Landfill base shall be 5meter above from flood level.
b. No surface water shall be allowed to enter in hazardous waste.

c. Proper channelizing surface run-off so that it will not be mixed with hazardous waste or leachate.

Image(c): Google Earth image, Year 2003, TTCWMA, Maharashtra, India (Source: Google Earth)

As per the HIRA study conducted in 1998, the probability of flood is almost negligible. This is due to ground level at 15meters from surrounded flood level. Although looking to photo (3), it seems that there is sufficient lower-level area surrounded to CHWTSDF. This makes easy surface runoff without disturbing activity of waste disposal activity. So, Let us consider probability of Occurrence is ranked as 1.

Any water contamination in hazardous waste will result in dangerous situation. It will generate large amount of leachate and get impacted to nearby water body and subsequent environment. The potential of its impact will be more concentrated to people working nearby vicinity. Many dissolved chemicals can absorb through skins resulting ill-health and medical emergency. Thus, Severity considered as 5.

Considering above facts, the risk valuation is calculated as: 5.

Summary of test method: Although there is less probability of flood like situation, its impact is not permanently omitted. Hence landfill bund shall be constructed at least5-meter height as a design parameter.

Case: 2

TTCWMA is situated in TTC Industrial area, which is nearby Navi Mumbai city. Due to integrated town management planning and greatest connectivity, Navi Mumbai city becomes favorable investment area. This attracted rapid development scenarios with increasing competitive market.

Many investors invest in TTC Industrial area looking to easy and quickest facility available for Common Effluent Treatment Plant (CETP-for waste water disposal) and CHWTSDF (for hazardous waste disposal). Increasing land value and accommodation of large facility, development was progressed with minimum buffer zone. Area surrounded by CHWTSDF is not under control of CHWTSDF. Ultimately, in course of land development of surrounded area, basic level of land is hiked to certain level.

Image(d): Google Earth image, Year 2022, TTCWMA, Maharashtra, India (Source: Google Earth)

These made challenges in easy runoff flow and can be expected local flood situation in rainy season, when large rainfall occurs in small amount of time. Thus, the probability of flood like hazard will be more, ranking to 5. Since the consequences will be high at all time, ranked to 5.

Ultimate risk valuation will be 25, which is extremely dangerous situation and need prime attention to safe guard process plant. Since, large quantum of waste is disposed in landfills starting from 2004, it will be difficult to excavate old waste, raise the height and refill with waste. Rather it will be highly costly affair and impractical.

To overcome such issue, operator of TTCWMA has increased height of buffer zone through construction debris and re-channelize own surface runoff. Due to this activity, TTCWMA has restricted its development near the vicinity of buffer zone.

Imposition of "Changing Environmental Geography" Factor:

Development is unavoidable tasks in present days due to economic attractions and demand ratios by population. Hence integrated approach is important in every government and non-government agencies. Now days, we are surrounded by lots of legal restrictions with different acts, rules, protocols and SOPs. But being citizens, we are unaware many of new changes. Rather its information is not on single platform, where we can understand and react equally.

As earlier said, Environmental Clearance is prior application need to submit to government agencies before starting of any project and HIRA is one of the exercises to judge the associated hazard.

If government sets "Changing Environmental Geography" as a statistical factor for certain pockets of regions and make available on public platform, then user can integrate this new factor in HIRA study and overcome with practical and longtime solution.

Concept of 3 element-based Risk matrix:

[Table:1- Three element based Risk Matrix]

Valuation of factor can be decided roughly from following elements:

[Table:2- Base to deciding Valuation Factor]

Case 3:

Construction of new landfill on north east side.

Image(e): Concept on Proposed Landfill Construction, Google Earth image, Year 2022, TTCWMA, Maharashtra, India (Source: Google Earth)

Since, base height is much lower from flood level, probability of flood will rank as 5, with consequences to 5. The potential of surrounding development is variable. As this open land can be used by market competitive business application, its pattern of use is dynamic. Hence, due to highest variable in land use pattern it will ranked as 5.

[Table:3- Scale selection for Changing Environmental Geography]

Ultimate risk evaluation will be 125, which is extremely dangerous. The decision of project occupier is not sufficient and also requires involvement from governmental agencies.

Such extreme value will result in following possibilities:

a. Either restrict the new project or its expansion (if any).
b. Restrict development to nearby vicinity by freezing entire land as “No Development Zone.”
c. Sharing uniform responsibility of human health, environmental impactand development projection by government, non-government agencies.
d. Make in-depth evaluation of fact about project over its importance and selection over acceptable environmental degradation.

Benefits by incorporating Factor:

1. Reconciliation of activities or project planning with changing geographical conditions.
2. Integrated approach and involvement of all governmental and non-governmental agencies will benefit in prevention of certain projects.
3. Extend project life with due planning process.
4. Address areas of concern.
5. List out areas where immediate approach is required.
6. Data sharing and awareness on single platform will help in pre-investment planning.
7. Prepares secondary data which can be helpful to other industrial projects.
8. Restriction to project planning where environmental risk is more and having least control efficiency.
9. Help in buffer zone allocation, reservation and its management.

Limitations of this concept:

1. This integrated factor is based on a factor which will correlate “Changing environmental geography”. Policy and statistical facts are two basic elements in designing of factor. Thus, in-depth research and subsequent SOP need to be design.
2. A digital factor for every set or pocket of geo-location need to be static. So all governmental and non-governmental agencies involvement is must. This will result in long time exercise initially.
3. Personal conflict of interest in designing a factor in certain pockets cannot be neglected.
4. Knowledge, interest, ethics and ultimately competency are main barriers during designing and publishing such factors.
5. Review and update of this factor is required after certain period of time. SOP/ Protocols/ Regulations are need to be set.
6. Uncertainty due to natural hazards for which data is still unavailable.

Requirements for integrated approach to overcome limitations:

1. In-depth policy decision and formulating it in regulation can address its requirement.
2. Allocation of tasks and making accountable for activity will minimize errors or uncertainty.
3. Designing micro-level management and involvement of every planning sector with respect to certain geographical pockets will reduce efforts.
4. Single window knowledge sharing platform through digital mode.
5. Training and awareness with due research will aware industries.

Summary:

Due to set of pollution levels, accidental hazards and competition in land acquisition; we cannot oppose industrial set ups. Rather they are essential elements in our survivals. In due course of development, geological conditions get change over period of time. By this, unexpected climatic changes result in improper functioning of environmental cycles. Human errors also contribute to manmade hazards, whose potential cannot be predicted due to limited available data sources.

Addressing extent of geological changes through single factor will highlight progress of developing scenarios to developed conditions. This will help in designing new processes, projects or activities. This will also restrict or oppose development with due “Risk evaluation”.

HIRA is the principle methodology used by industries in safeguarding man and machine. This study mainly restricted within internal boundaries of study scope. Due to limited projection on surrounding changes, controlling this associated hazard becomes difficult. This can result in drastic disaster and can impact ‘Safest Plant’.

To overcome this limitation by enhancing better preventive control; it becomes necessary to address surrounding environment and its geographical changes.

“Changing Environmental Geography” as a additional factor in HIRA study will elaborate “Risk” in set of statistics. This will help in implementation of corrective or preventive action. Publishing outcome of such exercises will useful to governmental agencies in town planning. This will also useful to industries in setting up their plants as per surrounding risks and potential of future risk.

Conclusion:

HIRA is the effective planning tool before commissioning of project. It is based on Probability of occurrence and its relative risk severity of hazardous event. This study comprises of designated scope, which ideally conducted within limited boundaries of industry.

Formulation of a new factor namely “Changing Environmental Geography,” and its integration in HIRA study will help to minimize the accident potential. Such activity will address accidents due to natural hazards which are borne by changing geographical patterns. This will also highlight manmade hazards associated by neighboring activities.

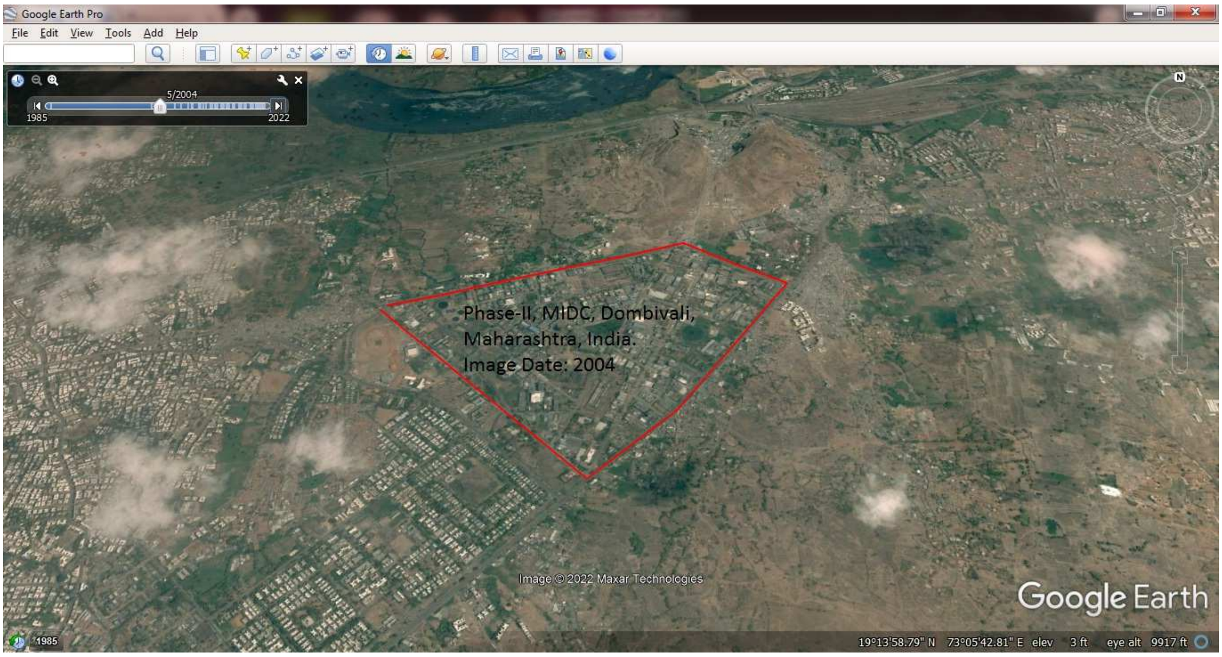
Formulation of this factor needs in-depth study followed by participation of governing authority. Availability of these values on public portal will inform stake holders during investment, planning, commissioning of unit and post operation expansion. This attempt by different organizations and its public record will give secondary data to researchers and policy makers to address critical issues like Climate change, Environmental degradation, Geographical manipulation and requirement of amendment in regulations.

Selected References:

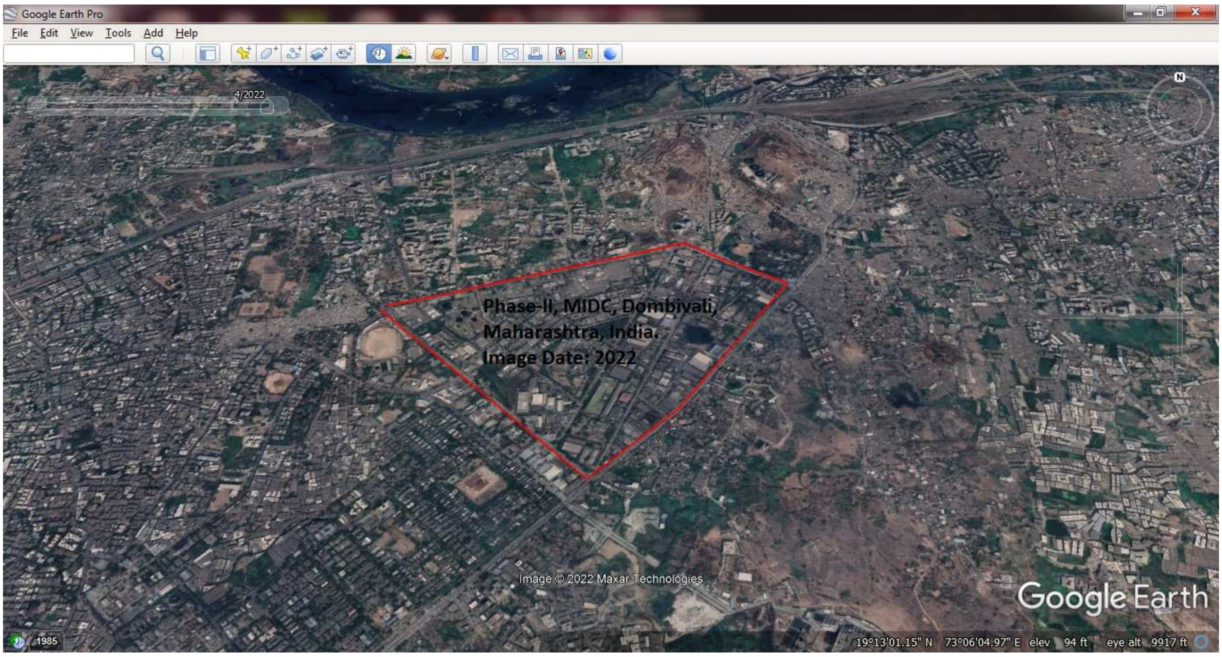
1. P. Eraiayanbu, M. Anbalagan, R. Prabhu, I Sirajudeen, P. Satheeshkumar (17-18th March 2017), 'Hazard Identification and Risk Assessment with Human Error Analysis Method in Automotive Industry,' published in International Journal of Innovative Research in Science, Engineering and Technology, Volume 6, Special issue 8, May 2017, Page No. 133-135.
2. Fajrul Falakh, OnnySetiani, 'Hazard Identification and Risk Assessment in Water Treatment Plant considering Environmental Health and Safety Practice', presented in The International Conference on Energy, Environment, Epidemiology and Information System (ICENIS), E3S Web of conferences 31, 06011 (2018), page no. 4-5.
3. A. Vantarakis, S. Paparrodopoulos, P. Kokkinos, G. Vantarakis, K. Fragou, and I. Detorakis, (15th March 2016), 'Impact on the Quality of Life When Living Close to a Municipal Wastewater Treatment Plant', published in Journal of Environmental and Public Health, Volume 2016, Article ID 8467023, page no. 2-3.
4. Ashokkumar T C, Dr. Muthukumar K, Manojkumar R M, (March 2020) 'Hazard identification and Risk assessment (HIRA) in Textile Industry', published in International Research Journal of Engineering and Technology (IRJET), Vol. 7, issue-3, Page No. 2150-2155.
5. Revised Action Plan for Industrial Cluster in Severely Polluted Areas, Dombivali, July-2020, published by Maharashtra Pollution Control Board, Page No. 8-11.
6. IS: 15656-2006, Hazard Identification and risk analysis- code of practice [CHD8: Occupational Safety, Health and Chemical Hazards], (May 2006), published by Bureau of Indian Standard (BIS), Page No. 1-, 5 and 7.

List of Images:

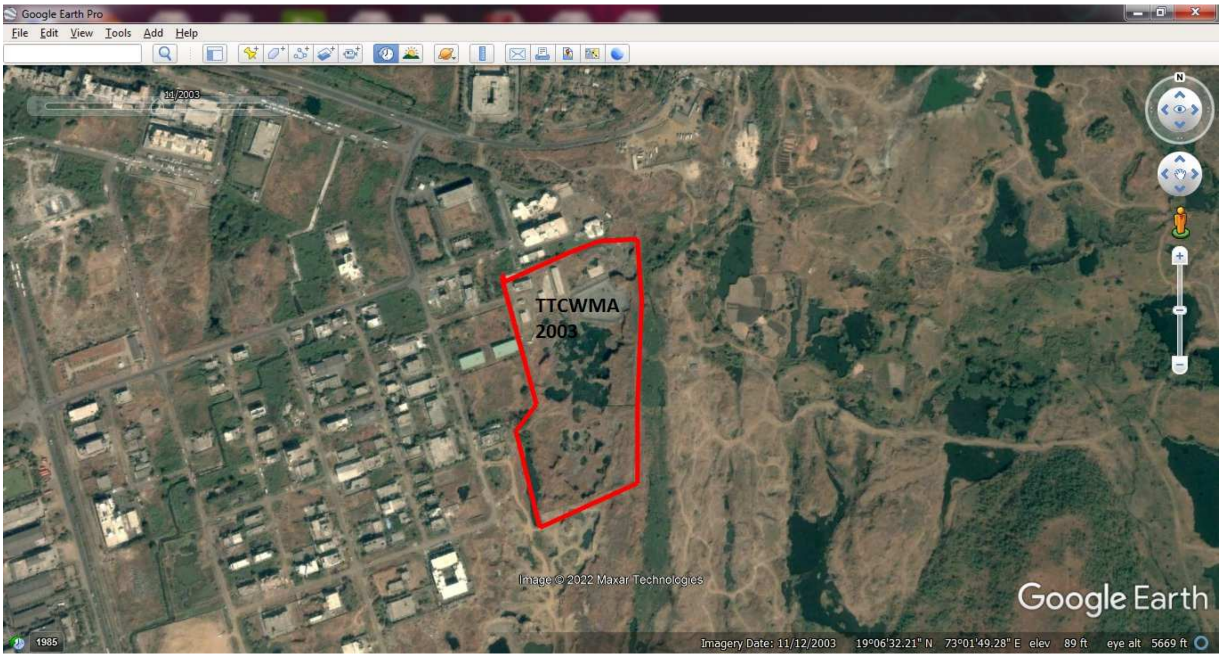
Image(a): Google Earth image, Year 2004, Dombivali MIDC, Maharashtra, India (Source: Google Earth)



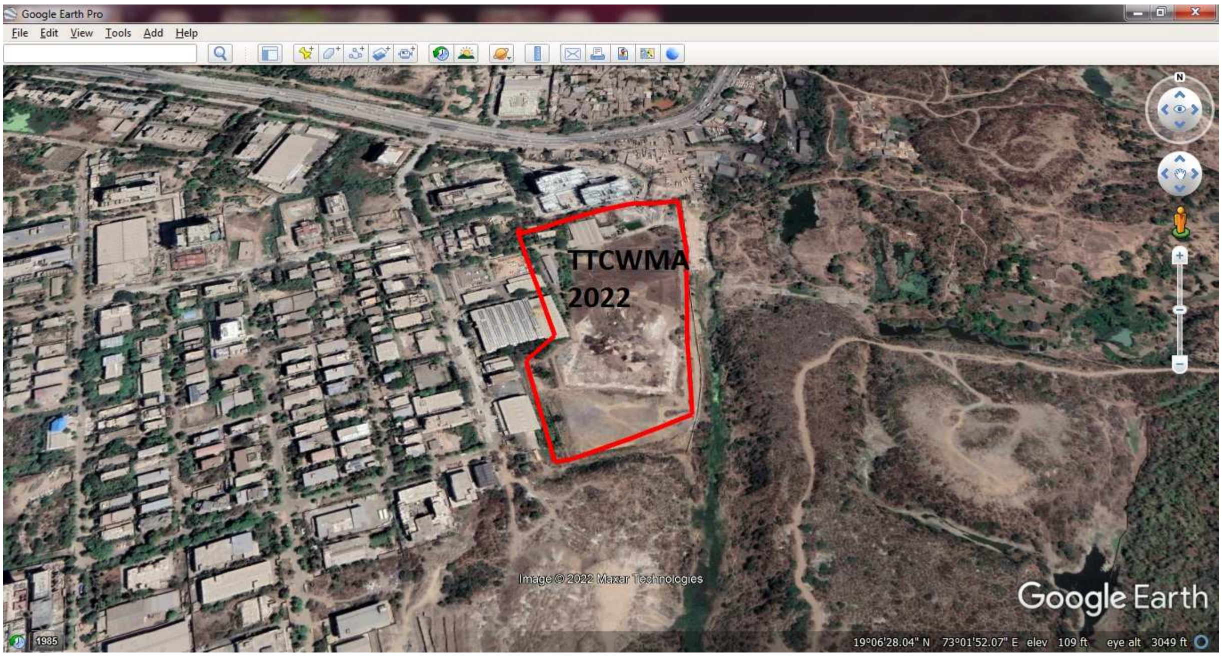
Image(b): Google Earth image, Year 2022, Dombivali MIDC, Maharashtra, India (Source: Google Earth)



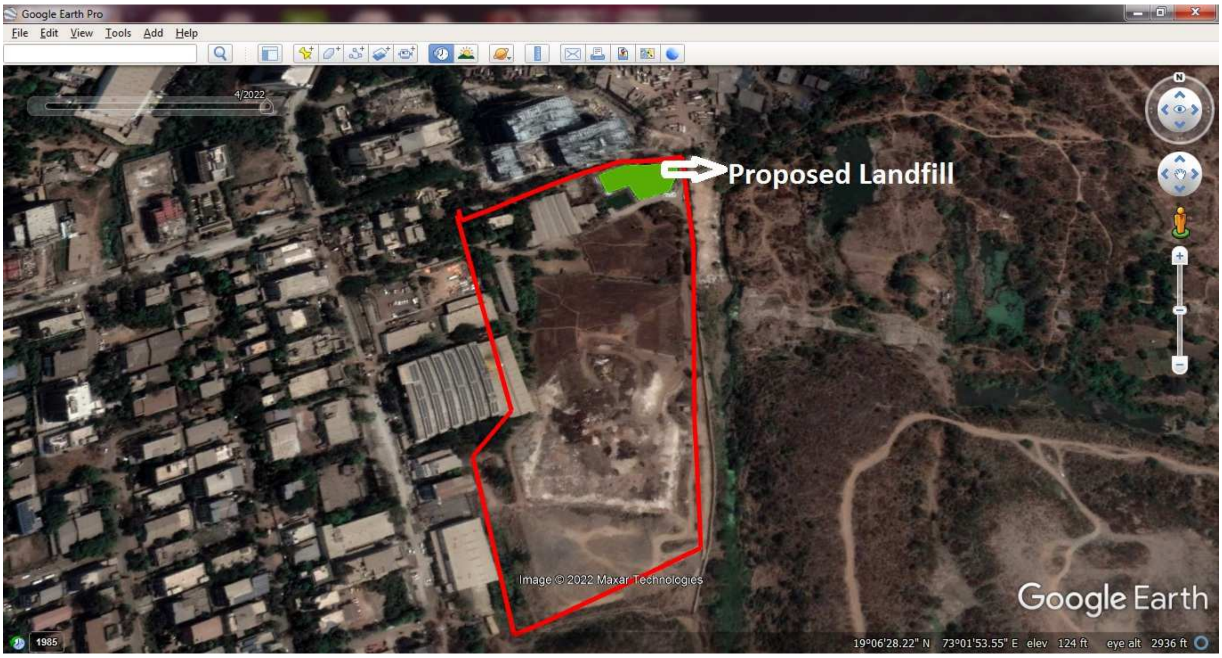
Image(c): Google Earth image, Year 2003, TTCWMA, Maharashtra, India (Source: Google Earth)



Image(d): Google Earth image, Year 2022, TTCWMA, Maharashtra, India (Source: Google Earth)

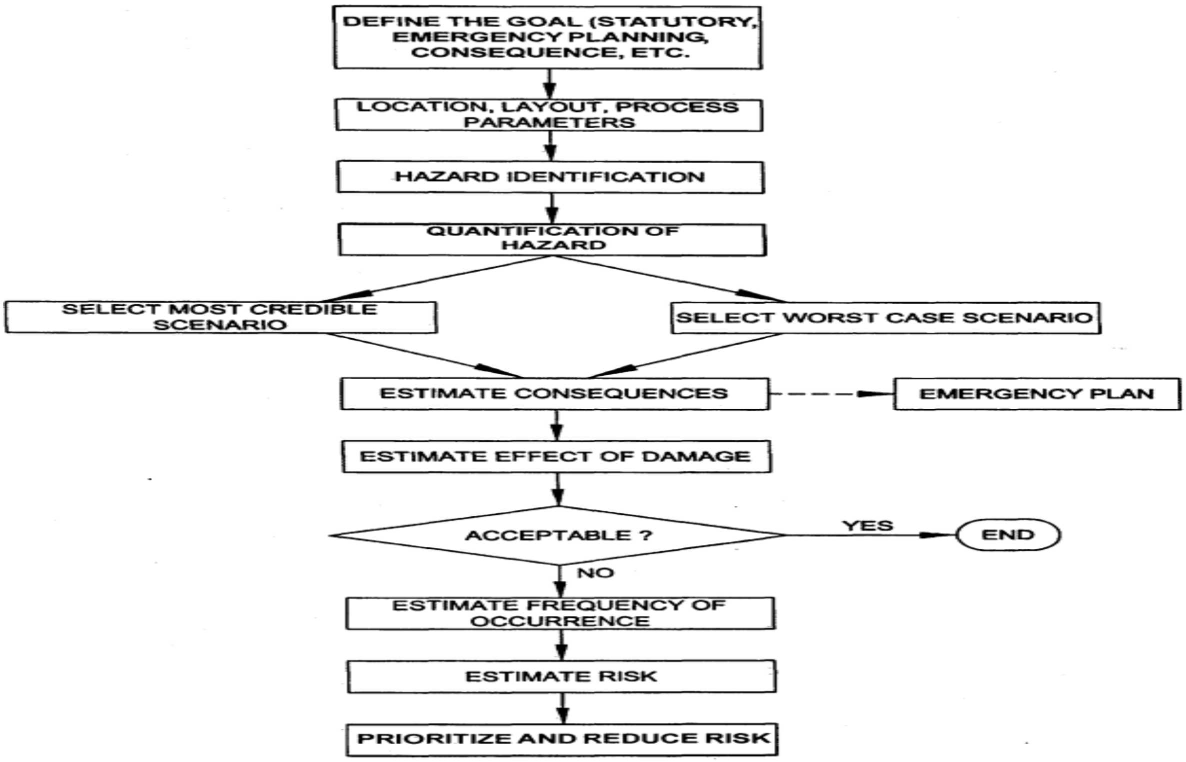


Image(e): Concept on Proposed Landfill Construction, Google Earth image, Year 2022, TTCWMA, Maharashtra, India (Source: Google Earth)



List of Figures:

[Figure-I: HIRA Process (IS- 15656:2006)]



[Figure: II- Risk Matrix Chart]

RISK MATRIX						
PROBABILITY →	Very Likely - 5	5	10	15	20	25
	Likely - 4	4	8	12	16	20
	Possible - 3	3	6	9	12	15
	Unlikely - 2	2	4	6	8	10
	Very Unlikely - 1	1	2	3	4	5
		1	*2*	*3*	*4*	*5*
		Negligible	*Slight*	*Moderate*	*High*	*Very High*
		SEVERITY →				

Risk	Risk Level	Action
1 to 6	Low Risk	May be acceptable but review task to see if risk can be reduced further
8 to 12	Medium Risk	Task should only be undertaken with appropriate management authorization after consultation with specialist personnel and
15 to 25	High Risk	Task must not proceed. It should be redefined or further control measures put in place to reduce risk. The controls should be

List of Tables:

[Table:1- Three element-based Risk Matrix]

Occurrence	**Severity**				
	1	**2**	**3**	**4**	**5**
1	1	4	9	16	25
2	2	8	18	32	50
3	3	12	27	48	75
4	5	16	36	64	100
5	5	20	45	80	125
	1	**2**	**3**	**4**	**5**
	Changing Environmental Geography				

Risk	**Risk Level**	**Action**
1-5	Low	Acceptable against preventive measures
6-50	Medium	Planned approach to control the hazard.
51-125	High	Immediate action is required with communication and preparedness for emergency.

[Table:2- Base to deciding Valuation Factor]

Element	Scale		Components to be consider
	0	1	
Surrounding Environmental Quality	Good	Bad	• Base line data of Air, Soil, Water • wind direction, rainfall • Nearby water bodies, forest land etc.
History of any disaster (Natural/ Manmade)	No	Yes	• Event in past 12 months • From 1km radius • Due to any geological abnormality (like earthquake, volcanic eruption, floods etc) • Emergency due to explosion, fire, toxic gas release. • Based on single event in a year.
Density of population and surrounded impact prone cluster	Less	More	• Appropriate scale is required (like population of 1000 peoples). • Area consideration to surrounding is required (like in surrounding 5km radius)
Increasing Land value	Less	More	• Land valuation for last 5 years. • Less than 5% means less competition • More than 5% means increasing demand of land in particular region, ultimately increasing pollution load.
Availability and Reservation of buffer area.	Possible	Difficult	• Either by Project investor or by governmental officials. • Reviewed every year for fact finding. • No development area with scientific measurements.

[Table:3- Scale selection for Changing Environmental Geography]

Element	Components to be consider	Scale
Surrounding Environmental Quality	• Already contaminated due to surrounding industrial activities.	1
History of any disaster (Natural/ Manmade)	• Area prone to Fire and Explosions due to industrial practices	1
Density of population and surrounded impact prone cluster	• Area is surrounded by dense population	1
Increasing Land value	• Competitive increasing land value.	1
Availability and Reservation of buffer area.	• Closely developed and developing industrial set ups.	1
	Total	**5**