Inspira-Journal of Commerce, Economics & Computer Science (JCECS)
ISSN : 2395-7069, Impact Factor: 5.660, Volume 08, No. 01, Jan.-March, 2022, pp. 135-143

CLIMATE CHANGE AND RISK MANAGEMENT USING A FRAMEWORK OF SYSTEM DYNAMICS, BIG DATA ARCHITECTURE AND DATA ANALYTICS

Mr. Sarojkant Singh*
Ms. Nibha Bharti**
Mr. Cedric Goubert***

ABSTRACT

It is pertinent to incorporate global risks like climate change into business projections. With the outburst of the COVID-19 pandemic, climate change has become more important than ever. Lockdowns all over the world have forced mankind to think of re-inventing business models. In the past, climate change, calamities, pandemics etc. were considered as a black swan event and treated with little rigor traditionally. However, the advent of COVID-19 this has changed. It has become important to bring these macro risks into main stream business risk. Access to information differentiates how we handle an operational risk and how we handle a macro risk. In this paper we propose a big data framework to incorporate climate change as part of risk management to improve decision making. The prevalent mode of handling climate change risks in business plans is elaborated, we explain why this is insufficient and how climate change is influencing stock prices of companies. We consider expert stakeholders view point and undertake data exploration on data from World Bank and World Resource Institute to identify the critical variables. These variables are used to select the risk indicators or triggers which could be used for real time data analytics. The framework takes a system dynamics approach to policy making, aimed at helping organizations handle climate change risks and align business policy accordingly.

***KEYWORDS**: Climate Change, Risk, System Dynamics, Big Data Analytics.*

Introduction

Risk management has been traditionally perceived as a specialized area. In industrial projects, the application is limited to a qualitative analysis with a risk register although risks and issues are managed on a daily basis by the project team through their organizational process assets and experience. A robust risk framework requires availability of data on time and decisions thereof. The ISO 31000 standard provides a guideline to make the framework. An area which is underplayed in the prevalent risk procedures are macro risks like calamities, hazards etc. These are analyzed as act of God and treated as exceptions. The Covid-19 pandemic has brought these macro risks into the forefront. The paper tries to highlight how climate change is critical to all projects and should be factored in amongst the macro risks. Timely availability of information, reliability and completeness of data is critical to decision making. A good risk management system should be capable to provide timely information. Wherein 'Big data' can bridge this gap.

---

* Research Scholar, ICFAI University, Jharkhand, India.
** Research Associate, IIFT.
*** Director Synergies.

Literature Survey

(BSI, 2018) provides a framework for risk management.(Renwick et al., 2010) proposes a framework to risk management process with a climate change approach, incorporating predictive and diagnostic techniques. It uses climate information to frame risk.(Hassani et al., 2019)provides a one-stop reference to progress and applications of big data to climate change. (James H. Faghmous, 2014) focus on data methods and processes to make big data successful in climate change application. (D Lopez, 2016) provides a big data architecture for climate change and disease dynamics.(Sarker et al., 2020) provides how resilience to climate change can be enhanced through a big data by formulating right strategies.(Choi et al., 2017) examines opportunities and challenges in big data application in operational risk management.(Cerchiello & Giudici, 2016) aims to present a novel systemic risk model, by combining financial data from stock markets and those from tweets.(Jarosław Górecki, n.d.)shows various ways of data collection and analysis for bigdata insights to improve project risk management.(Papadaki, et al) uses big data analytics from social media to understand the perception about risk management and project success relationships.(Owolabi et al., 2020) illustrates that random forest method can accurately predict project delay risk. System dynamics has been applied to policy making in various fields.(Ahmad et al., 2015) illustrate how solar tariff policy can be guided with a system dynamics approach. (Ghaffarzadegan & Rahmandad, 2020) provide a system dynamics model to predict the magnitude of outbreak thus bridging the gap of underestimated data.(Hosseini et al., 2019) provide a portfolio management solution with system dynamics. (Sisodia et al., 2016) provide a policy making of energy mix through system dynamics modeling.

Prevalent Methods of Macro Risk Handling in Projects

In project management climate change is not in the priority in most projects. However, the Covid-19 pandemic has taken a front seat with the focus on force major clause in contracts.(Hussaini, n.d.) illustrate that just relying to claim under force major may be a wrong premise. The authors guide when this clause can be invoked and consequences of such an invocation with reference to the Indian Contract Act 1872, Section 32. In an order passed in April 2020, the Bombay High Court for the cases of *Standard Retail Pvt. Ltd. v. M/s. G. S. Global Corp & Ors* dismissed a Commercial Arbitration petition. However, the Indian Court has held that the Petitioners cannot resile from their contractual obligations under garb of the lockdown. In other words, a lockdown is not a legal basis for termination or repudiation of a contract. In another case in March 2020, the Delhi High Court rejected the plea of Halliburton for citing Covid-19 disruption for non-performance of contract.

It is pertinent from the above that mere dependence on force major clause is not useful. A full proof system to prove that such incidents affected the contract performance is crucial. Projects utilize risk transfer methods like fire policy, erection all risk insurance, contractor all risk insurance, workmen compensation etc. to hedge climate hazards. However, mere insuring and taking a risk transference approach may not be the only dependable way. Recently news that insurance companies are not paying claims due to surge in numbers is a concern. (Bhuyan, 2020)reports in Business Standard, how patients are denied the health claims. These aspects should be looked into from a climate change perspective and included in the risk management framework.

Global Risk Report 2021 & Climate Change Impact on Business

The global risk report by world economic forum highlights the top risks as 1. respondent perceptions of infectious diseases and livelihood crises 2. “Extreme weather events” They divide the categories into Economic, Environmental, Geopolitical, Societal and Technological. The results show that climate change risks will be the biggest in the coming days.

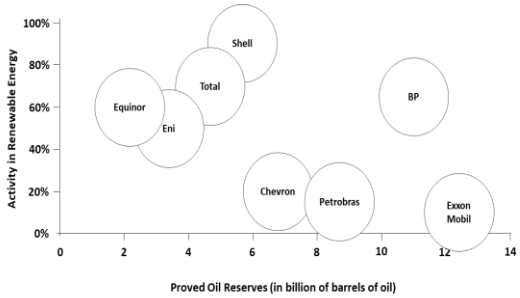
Climate change is a real concern for the future of the planet but it also became a major risk for the stock market, which is already being affected. Countries have been discussing the matter for decades already and many important climate agreements been proposed e.g. Kyoto Protocol (1995) and the Paris Agreement (2016). As a result, countries are taking steps in order to reduce their emissions of CO_2 and legally committed, resulting in a considerable pressure on the private sector. This is not the only vantage point; Major Companies are being exposed to societal pressures not only concerning the existence of environmental accidents e.g., the wreck of the Erika (1999) but also to the agreed efforts towards ‘greenification’ or their activities. We are referring about Major Oil Companies but also of the financial sector now committing to sustainability. Blackrock is now “*dedicated to advancing climate innovation, research and analytics – to help its clients invest sustainably and build a net zero economy that serves us all*” [(1)].

The increased globalization and media attention to environmental activist complements the pressure on public and private sector to climate change tread. In 2019, the Swedish climate activist Greta Thunberg addressed French lawmakers at the French parliament, delivering a powerful and radical speech calling for reforms. Climate change became a major risk for the private sector as it affects both regulation and reputation on social responsibility. CSR policies are being promoted to the strategic level while 'green labels' becomes quite popular when it comes to evaluate efforts towards sustainability. *CVC Growth Partners invested $200 million in sustainability ratings company Eco Vadis in a bid to accelerate adoption* (2). In 2021, Sir Ronald Cohen, a well-known venture capitalist and private equity investor, also social investment pioneer evangelizer, declared that we must green-up finance while referring to Axxon Company who has seen its stock price drooping by two-thirds the last years because of its business focused in fossil energies.

Major oil companies market cap has eroded over the past years while Clean Energy or green-perceived stocks e.g., Daqo New Energy Corp (specialized in solar photovoltaic systems) have witnessed a rise in their stock price stock price. We do observe a similar pattern with a steep decline in February 2020. Indeed, the global oil demand has been hit hard by the novel coronavirus (Covid-19) and amplified further with shutdown of China's economy. Between July 1st 2019 and July 1st 2020, Royal-Dutch-Shell, EXXON MOBIL and BP have seen their stock price decrease by more than 40% (-52.98%, -43.38% and -42.34% respectively).

- **Difference in the diversification strategy and execution**: Although in league with the others in decrease in stock price, Total Energies have been less impacted by the pandemic. Total *rebranded* itself as 'Total Energies' signaling its commitment towards sustainability as the French oil giant focuses on climate change initiatives over the past decade. Over the past 10 years, *it has made a number of strategic investments, which included $1.4bn being spent on acquiring a 60% stake in US solar firm Sun Power in 2011*(Murray, 2020). Though it is behind or at par when compared to some of its competitors in other parameters, when it comes to renewable energy mix within its portfolio (3), Total Energies over-performed Shell or BP. While being ahead of most of the oil major companies, Royal Dutch Shell missed its green energy targets. Shell's investment target for green energy projects was set between $4bn and $6bn for the period from 2016 until the end of 2020 – but with less than a year to go, The Guardian says the sum is "well below" those figures (4) . A court in the Netherlands has ruled in a landmark case that the oil giant Shell must reduce its emissions by 45% compared to 2019 levels by 2030.

Source: London stock exchange



Source: science direct.

Figure 1: Oil and Gas Majors Stock Prices **Figure 2: Renewables V/s Oil Reserves**

- **Dividend stocks and lower-risk investments**: The above illustration reinforces the correlation between renewable as a percentage of company portfolio and stock price over long period is established. However, there exists other factors that might contribute positively or negatively to the stock price e.g. dividends distributed to shareholder. As we can in Figure 2, Royal Dutch Shell has continued over the past decades to increase its dividend payments to investors. With its generous dividend yield, the company has kept loyalty of its shareholder. Despite this, in February 2020, most of the major oil companies witnessed their stock prices literally dropping and losing their market capitalization.

Name	Symbol	Current price	One-year price return
Invesco Solar ETF	TAN	$80.63	76.62%
Invesco WilderHill Clean Energy ETF	PBW	$80.44	64.63%
SPDR S&P Kensho Clean Power ETF	CNRG	$96.27	62.31%
VanEck Vectors Low Carbon Energy ETF	SMOG	$152.38	61.09%
Invesco Global Clean Energy ETF	PBD	$28.56	56.66%
iShares Global Clean Energy ETF	ICLN	$22.10	52.72%
ALPS Clean Energy ETF	ACES	$67.90	46.72%
First Trust Global Wind Energy ETF	FAN	$20.74	27.70%
Invesco MSCI Sustainable Future ETF	ERTH	$64.54	19.96%

Source: Nerdwallet

Figure 3: Green Energy ETF returns

Green companies are attracting investors as the world focuses on ESG concerns (environmental, social and governance). A recent directive of the court in Netherlands, makes the political and legal environment pertinent to business risk. This is a consequence of climate change factor and the increasing pressure from environment activists for a changeover. There is a need for a paradigm shift, and in order to accelerate the 'greenification', private sector is actively seeking to acquire renewable portfolio. As shown in figure 3, clean energy exchange-traded funds are offering high return while reducing social and business risks for investors.

Explaining The Dataset Taken, Key Parameters and Results

We do a data exploration and prepare a correlation matrix, to display correlation between 'Power Generation in Gigawatts', (collected from World Resource Institute) for 5 years (2014-2018), 'Economic factors' from 'The World Bank' for 10 years 2009-2019) and 'Temperature in Celsius 'for India; containing around 1500 data points, 40 variables including broader variables 'temperature' and 'economic factors. The colour code 'orange' indicates positive or strong correlation and dark 'blue' colour code display negative or weak correlation. Each cell in figure4 shows the correlation between two or more variables. Power generation from 'Gas' indicate strong correlation with temperature, followed by 'Coal'. While 'Oil', 'Nuclear' and 'Hydro' depicted negative correlation with the temperature. Correlation is also established among various economic factors (in percentage) that show impact in correlation matrix aligned with the temperature. The analysis also shows the strong and perfect correlation with 'poverty headcount ratio', 'mortality rate' and 'urban population growth'. While there is negative correlation with factors such as 'prevalence of underweight' and 'primary completion rate'.

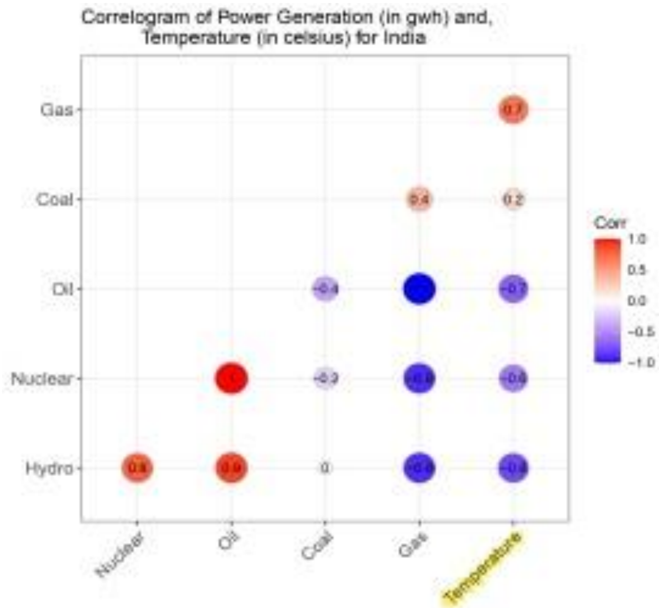
A draft assessment conducted by the Intergovernmental Panel on Climate Change (IPCC) reports that human lives are highly affected by the carbon emission and temperature, a child born in future would face multiple health hazard before turning the age 30. Even the rising temperature will affect the availability of crops, nutritional value. The protein content in the rice, wheat and potatoes are expected to fall by 6 to 14 percent. Not only that, the surge in temperature will reduce the yields and demand of biofuels crops.

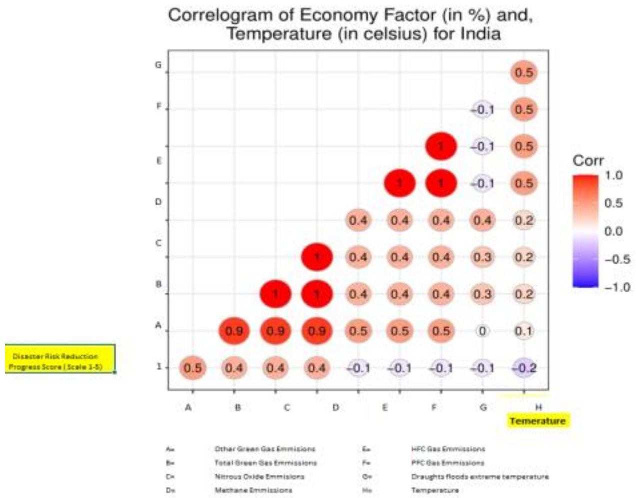
Interesting findings can be seen from the figure, in which factors such as 'draught, floods, extreme temperature', 'PFC gas emission', 'SF6 gas emission', 'HFC gas emission', methane emission are found strong correlation with the temperature, 'CO2 emission from gaseous fuel consumption' and 'CO2 emission from liquid fuel consumption' are also found to have strong correlation with the temperature. While 'CO2 emission from solid fuel consumption' showed negative correlation. Correction evidences from 'electricity production from nuclear sources, hydroelectricity sources and oil sources have lower strength with correlation; electricity production from natural gas sources showed strong correlation. Factors that rural and urban population residing in the areas below 5 meters have positive correlation. Also, the correlation matrix also indicated positive and strong relation with 'marine protected areas' and 'terrestrial protected areas'. The correlation strength through gas emission is very strong with the temperature and are impactful in different ways. Also see Table 1 which indicates P-value and Correlation among different selected factors and Temperature in India.

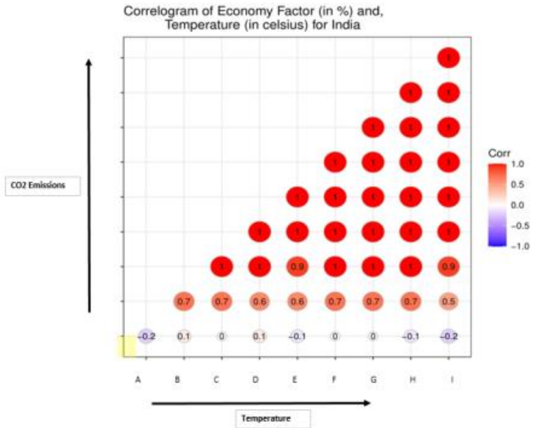
Table 1: P-value and Correlation of Different Factors with Temperature for India

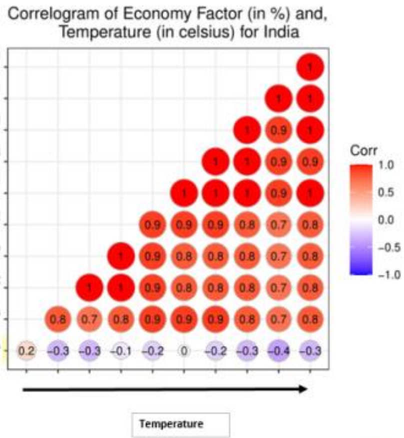
Factors	p-value	Correlation
Nuclear	0.24	-0.63
Oil	0.14	-0.74
Coal	0.69	0.24
Gas	0.23	0.65
Hydro	0.08	-0.83
Draught, Flood, Extreme Temperature (%of population) average 1990-2009	0.08	0.54
PFC Gas Emission (thousand metric tonnes of CO2 equivalent)	0.14	0.46
HFC Gas Emission (thousand metric tonnes of CO2 equivalent)	0.14	0.46
SF6 Gas Emission (thousand metric tonnes of CO2 equivalent)	0.14	0.46
CO2 Emission (kg per PPP $ GDP)	0.98	-0.00064
CO2 Emission (metric tonnes per capita)	0.77	-0.099

Note: p-value is the probability for “null hypothesis” to be true.

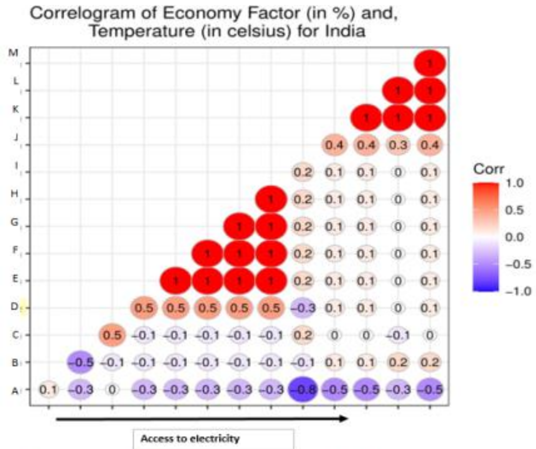








A= Temperature
B= Electricity production from natural gas
C= Electric production from nuclear sources
D= Electric Consumption per capita
E= Electric use/ $1000 GDP
F= Electricity from Hydo sources
G= Electricity from Oil sources
H= Renewable Energy Consumption
I= Renewable electricity Output
J= Electricity production from renewables except hydro



A= Access to electricity
B= Avg precipitation (mm)
C= FDI Inflows (% of GDP)
D= Temperature
E= Rural land below 5m (sq km)
F= Rural land below 5m (%)
G= Urban Land below 5m (sq km)
H= Land below 5m (%)
I= Urban Land below 5m (%)
J= Agricultural irrigated Land
K= Agricultural Land
L= Arable Land
M= Cereal Yeild

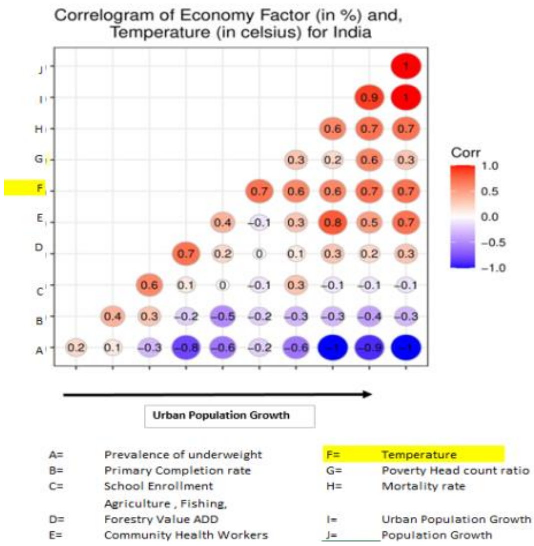


Figure 4: Correlogram of Power Generation (in GWH) and Temperature (in Celsius) for India

Big Data

Data Ingestion
Data is collected with Kafka from data stream and fed to Hive or directly from .csv files.
Schema is created of the csv files and csv is converted to dataset.
Data is then written from Hive to HDFS.
Final dataset is saved in AWS S3 bucket Amazon Document cluster is made and insights are views in Java APIs

We propose an architecture for collecting climate change information to enhance risk management as follows.

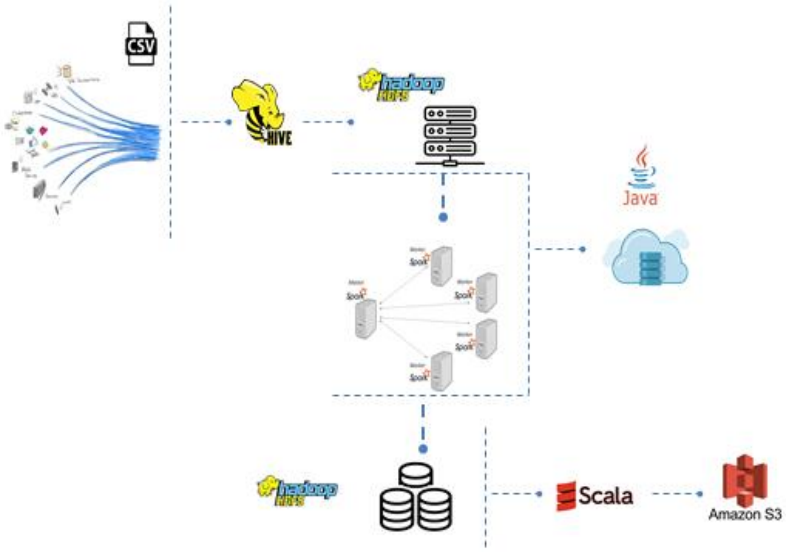


Figure 5: Big Data Architecture Proposed

System Dynamics

The system dynamics framework coupled with the big data architecture proposed will provide a policy making direction to the risk management framework. We briefly explain a system dynamics model. A system dynamics model uses stock and flow diagrams and causal loops. Casual loops (CLD): A causal loop diagram (CLD) is a visualization of different variables in a system and their interrelation. It consists of a node & edge. (Singh, 2021) illustrates how system dynamics is superior to other methods for risk management. System dynamics utilizes CLDs and Stock flow diagrams. A causal loop diagram (CLD) is a visualization of different variables in a system and their interrelation. This along with Stock flow diagrams are used in models.

Policy with System Dynamics

In their paper (Nasution et al., 2017) provide a conceptual framework to integrate Big Data and system dynamics for public policy making. In this paper we provide a Big data architecture for risk management system and we apply an analogous project policy making. The scale of public policy making is much larger to that of a project policy and governance. Many variables affecting a public policy will have a contextual influence on the project governance and hence importance of the variable will depend on nature of the project. From the data exploration we select the parameters with positive and greater impact with the temperature, which include power generation through gas and coal. In addition to these we select, economic factors such as draught and flood; emissions of PFC gas, SF6 gas, HFC gas, methane and nitrous oxide, CO2 and CO2 for liquid fuel consumption, electricity production from natural gas resources, rural land area where elevation is below 5 meter (sq.km) and urban area where elevation is below 5 meters (sq.km), population growth, mortality rate (under age 5 years) and poverty headcount ratio $1.90 a day (PPP 2011). These parameters shall be fed as input to our model.

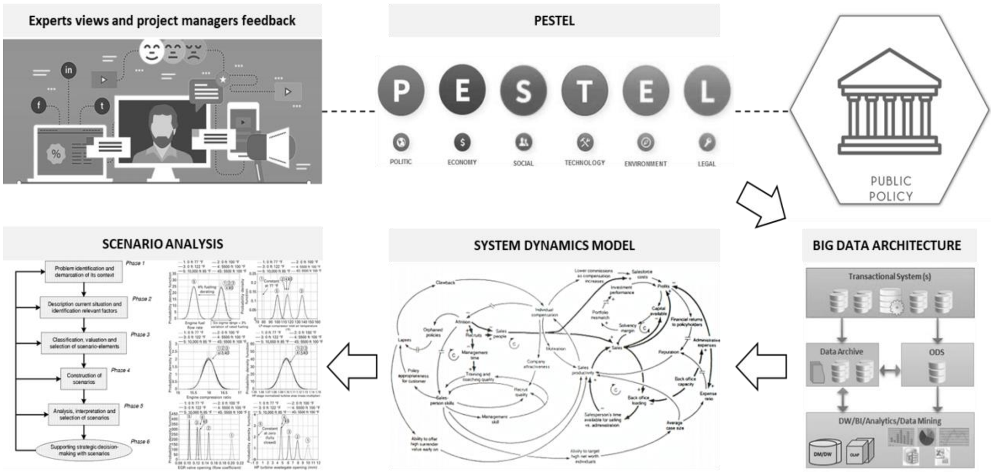


Figure 6: Framework for Risk Management

The PESTLE framework will help guide the policy framework building. (Nasution et al., 2017) take Public, Social and Economic Issues for the combines Big data and system dynamics approach. We include Technological, Legal and Environmental (especially). Some also follow the STEEP model, but the legal aspects are sometimes crucial for projects and it's important to keep that into the equation. We are proposing the following framework of risk management

Conclusion

System dynamics helps to capture the dynamic complexity of complex adaptive systems. This is extremely essential when it comes to effectively take decisions in risk management. Many policies lack the capacity to capture the dynamics of change. This becomes more crucial in projects which last 3-5 years and the project governance decisions which unlike public policy have a shorter horizon. Our research explains how the stock market reacts to sustainable goals announcement and its implementation and illustrates how the stock prices are negatively affected if the announcement expectations are not met. Furthermore, the paper provides the concept on how the dimension of climate change can be integrated into risk management system with help of a Big data framework.

References

1. Ahmad, S., Tahar, R. M., Muhammad-Sukki, F., Munir, A. B., & Rahim, R. A. (2015). Role of feed-in tariff policy in promoting solar photovoltaic investments in Malaysia: A system dynamics approach. *Energy*, *84*, 808–815. https://doi.org/https://doi.org/10.1016/j.energy.2015.03.047
2. BSI. (2018). BS ISO 31000 : 2018 BSI Standards Publication Risk management — Guidelines. *BSI Standards Publication*, 26.
3. Cerchiello, P., & Giudici, P. (2016). Big data analysis for financial risk management. *Journal of Big Data*, *3*(1), 18. https://doi.org/10.1186/s40537-016-0053-4
4. Choi, T., Chan, H. K., & Yue, X. (2017). Recent Development in Big Data Analytics for Business Operations and Risk Management. *IEEE Transactions on Cybernetics*, *47*(1), 81–92. https://doi.org/10.1109/TCYB.2015.2507599
5. Ghaffarzadegan, N., & Rahmandad, H. (2020). Simulation-based estimation of the early spread of COVID-19 in Iran: actual versus confirmed cases. *System Dynamics Review*, *36*(1), 101–129. https://doi.org/10.1002/sdr.1655
6. Hassani, H., Huang, X., & Silva, A. E. (2019). Big data and climate change. *Big Data and Cognitive Computing*, *3*(1), 1–17. https://doi.org/10.3390/bdcc3010012
7. Hosseini, S. H., Shakouri, H. G., Kazemi, A., Zareayan, R., & Mousavian, M. H. (2019). A system dynamics investigation of project portfolio management evolution in the energy sector: Case study: an Iranian independent power producer. *Kybernetes*, *49*(2), 505–525. https://doi.org/10.1108/K-12-2018-0688
8. Hussaini, Y. P. J. ; K. V. and W. (n.d.). *India: Performance Of Contractual Obligations During The COVID-19 Pandemic*. https://www.mondaq.com/india/litigation-contracts-and-force-majeure/932798/performance-of-contractual-obligations-during-the-covid-19-pandemic
9. Jarosław Górecki. (n.d.). *Big Data as a Project Risk Management Tool, Risk Management Treatise for Engineering Practitioners, Chike F Oduoza,*. https://doi.org/IntechOpen, DOI: 10.5772/intechopen.79182.
10. Murray, J. (2020, Jan 16). *How the six major oil companies have invested in renewable energy projects*. Retrieved from https://www.nsenergybusiness.com/
11. Nasution, F. B. B., Bazin, N. E. N., & Hasanuddin. (2017). Conceptual framework for public policymaking based on system dynamics and big data. *International Conference on Electrical Engineering, Computer Science and Informatics (EECSI)*, *2017-Decem*(September), 19–21. https://doi.org/10.1109/EECSI.2017.8239192
12. Owolabi, H. A., Bilal, M., Oyedele, L. O., Alaka, H. A., Ajayi, S. O., & Akinade, O. O. (2020). Predicting Completion Risk in PPP Projects Using Big Data Analytics. *IEEE Transactions on Engineering Management*, *67*(2), 430–453. https://doi.org/10.1109/TEM.2018.2876321
13. Papadaki, Dr Maria and Bakas, Dr Nikolaos and Ochieng, Professor Edward and Karamitsos, Ioannis and Kirkham, R. (n.d.). *Big Data From Social Media and Scientific Literature Databases Reveals Relationships Among Risk Management, Project Management and Project Success*. https://doi.org/http://dx.doi.org/10.2139/ssrn.3459936
14. Pickl, M. J. (2019). The renewable energy strategies of oil majors – From oil to energy? *Energy Strategy Reviews*, *26*, 100370. https://doi.org/https://doi.org/10.1016/j.esr.2019.100370
15. Renwick, J., Mladenov, P., Purdie, J., McKerchar, a., & Jamieson, D. (2010). The effects of climate variability & change upon renewable electricity in New Zealand. In *Climate Change Adaptation in New Zealand*.
16. *Risk management _ System Dynamics Advantages over other methods* (p. 10). (2021).
17. Sarker, M. N. I., Yang, B., Lv, Y., Huq, M. E., & Kamruzzaman, M. M. (2020). Climate change adaptation and resilience through big data. *International Journal of Advanced Computer Science and Applications*, *11*(3), 533–539. https://doi.org/10.14569/ijacsa.2020.0110368
18. Sisodia, G. S., Sahay, M., & Singh, P. (2016). System Dynamics Methodology for the Energy Demand Fulfillment in India: A Preliminary Study. *Energy Procedia*, *95*, 429–434. https://doi.org/https://doi.org/10.1016/j.egypro.2016.09.054
19. https://www.blackrock.com/sg/en/about-us/road-to-net-zero
20. https://resources.ecovadis.com/news-press/ecovadis-secures-c-200m-investment-cvc-growth partners-accelerate-sustainability
21. https://www.sciencedirect.com/science/article/pii/S2211467X19300574
22. https://www.sharesmagazine.co.uk/news/shares/shell-shares-fall-on-disappoint-over-renewable-energy-spending-plans

❑❑❑