RISK MITIGATION FRAMEWORK FOR HIGH SPEED RAILWAY SYSTEM IN INDIA

A thesis submitted to the
University of Petroleum and Energy Studies

for the award of

Doctor of Philosophy

in

Department of General Management

by

Amit Garg

May, 2022

SUPERVISOR

Dr. Sumeet Gupta

Department of General Management
University of Petroleum and Energy Studies,
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DECLARATION

I hereby declare that this thesis entitled "**RISK MITIGATION FRAMEWORK FOR HIGH SPEED RAILWAY SYSTEM IN INDIA"** has been prepared by me under the guidance of Dr. Sumeet Gupta, Senior Associate Professor, Core Cluster, School of Business, University of Petroleum and Energy Studies, Dehradun, India. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

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CERTIFICATE

I certify that Amit Garg, SAP ID 500064218 has prepared his thesis entitled **"RISK MITIGATION FRAMEWORK FOR HIGH SPEED RAILWAY SYSTEM IN INDIA"** for the award of PhD degree of the University of Petroleum & Energy Studies, under my guidance. He has carried out the work at the Department of General Management, University of Petroleum & Energy Studies.

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ABSTRACT

India has one of the largest rail networks in the world but has no line which can be classified as HSR allowing operational speed of 125mph. The current fastest train runs at 100 mph over a distance of only around 100 miles. However, supported by a robust political willingness, a new HSR corporation has been set up to kick-start the HSR projects from ideation to reality.

The first in this ambitious program is the HSR between Mumbai and Ahmedabad, two major population and commercial centers in the west of India. The success or failure of this project could show the way for future road map of HSR in India.

This research identifies and analyses the countries where HSR systems are in operation – their political, economic and social conditions relevant to HSR systems and then the features of HSR systems themselves to understand the commonalities between the nations that have opted for HSR to identify if there is a common character or a baseline characteristic in terms of geographical, economic, political and social conditions which are essential to be a member of this exclusive club.

The High-Speed Railway project in India has very high financial, social and political consequences. It's success and failure will have huge rippling effect on all sectors of the economy. Investment in a High-Speed Railway system in a developing country like India as an option of transport infrastructure is fraught with serious risks and uncertainties. A framework for identification and mitigation of risks associated with a project of such gigantic nature and long gestation period, in the context of a developing nation, is not available. All literature and studies for HSR systems are based in and oriented towards developed/rich nations which are not relevant to India.

Development of a Risk Management Framework for its High Speed Railway system will help India in predicting and managing the risks better and thus mitigating them to the extent possible.

The objective of this research is to create a Risk Mitigation Framework for the on-going High Speed Railway project in India, the biggest ever in history and to assess the strengths and weaknesses to reaffirm the chances of its success. The results would be relevant not only for India but for all other developing countries who aspire to be HSR countries in near future.

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CHAPTER 1

HIGH SPEED RAILWAY INDUSTRY OVERVIEW

1.1 BACKGROUND:

After the introduction of High-speed Railway system in the Japan, HSR had a huge impact on the world. On introduction of HSR system, transport sector has rapidly changed. It has seen a rapid growth in passenger traffic and enhanced share in transport pie all over the HSR countries.

High Speed Railway systems were possible because of technological advancements like distributed traction, in-cab signaling, tilting technology for coaches, computerized train control systems, reduction in running weight by hollow axles and Al alloy box, smaller diameter wheels etc. High Speed Railway systems were also supported by national policies and by international organizations like the European Union, the WB, ADB and other institutional financing agencies.

Railways have had a great influence on societies by changing the concept of distance and time, making travel generally available to people at large. Railway stations were viewed as a growth towards modernization. The introduction car has dented the growth of rail industry and demand has decreased optimum. Cars in general has luxury and considered as convenient mode of travel. The price and door to door concept enhanced the value and usage of car. In 1960s, oil prices were very low, and the car was an adequate means of establishing rapid economic growth. Therefore, car use increased quickly. This phenomenon was repeated all over the world.

The reasons for the cross-board support to HSR are many. The biggest reason is that High Speed Railway system is the most economical and energy efficient

transport system in comparison to all other modes of transport in the medium distance bracket (100-600 miles), as has been established by numerous studies. HSR has been an unadulterated success in various exploitation and financial models in a variety of contexts and countries. Criticism by the detractors is basically on the grounds of charges of elitism, unaffordability, lack of popular support, worthiness for taxpayers' subsidy, overstated benefits etc. Financial crisis is often cited as the biggest reason, be it the wealthiest nation like the USA or a developing emerging economy like India. It would not be out of place to mention that "High Speed" has always been associated (and yet survived) with "High Cost" since the concept has come into being.

Considering that generally an HSR system is based upon separation of ownership of infrastructure and operations and that the operations in itself are self-sustaining, the state is actually richer by the opportunity cost of the not bearing the responsibility of operations, which in a conventional railway, would have been there. Also of significance is the fact that the cost of building a 6-lane express way is almost the same as the cost of a high-speed railway while the latter has much smaller land and carbon footprint and is three times more energy efficient.

According to the UIC, whose definition of the HSR has the highest international consensus, it is a broad system where trains regularly operate at 200kmph (125mph). Trains regularly operating at the speed of 155 mph (200kmph) is also defined as High-speed trains as per UIC and the same us applied in monitoring international setting. Under this definition, 14 countries in Europe and Asia have resorted to HSR in a big way and the USA too with the Acela (from Washington to Boston) has joined the bandwagon, though it technically runs at the highest speed of 241kmph. The USA has now launched the very ambitious CHSR, a part of President Obama's initiative to revitalize rail passenger transport all over the country with a vision of the HSR playing a big role in the future of American transportation.

1.2 INDIAN SCENARIO:

Even though India has one of the largest rail networks in the world but there is no dedicated line corridor for High-speed trains. HSR allowing operational speed of 155mph. In order to set up High speed trains in India, HSR corporation has been set up and four corridors has been identified for HSR purpose.

The first HSR project to be implemented in India is the corridor between Mumbai and Ahmedabad. These two places are commercial hubs +in Western India. The news reported by Reuters, when the project was launched, was:

Business News | Thu Dec 10, 2015 2:43pm IST

India clears Japan's bid for first bullet train ahead of Abe trip

The Japan International Cooperation Agency (JICA), which had recently submitted its final feasibility report of the project initially estimated a cost of $US 14.7bn (Rs 988.05bn) inclusive of price escalation and interest during construction, and a seven-year construction phase from 2017 to 2023 for what will be India's first high-speed project. A corresponding Japanese loan, with the precondition that 30% of equipment is purchased from Japanese firms, is available with an interest rate as low as 1%.

It is a matter of history that H Neuvon, who was a member of the Japanese delegation (1960) visiting France to study the 25kV overhead traction system and played an important role in the first Shinkansen, was closely associated with the Indian Railways in introducing the Rajdhani Express trains in 1964. While IR is still stuck at the same determined 130 kmph speed, the Japanese have migrated to double the speed already.

This intransigence probably stemmed from the continuing dilemma within the Indian establishment concerning the project's scope, technicalities and popular acceptability. For one, **a huge decision had to be taken over the business/ operation exploitation model** (dedicated or mixed traffic with conventional railway or freight) **which has a direct bearing over the gauge selection** and thus its operating environment and revenue streams. One viewpoint referred to Russia's plan to build its first high-speed line with broad-gauge tracks and arguing that India should follow suit and build its high-speed line at 1600mm-gauge to ensure interoperability with the rest of the network. In contrast there is an argument to follow the example of Japan and Spain, where 300km/h lines use 1435mm-gauge tracks, which have dedicated HSR networks. For its part, JICA has recommended building a standard-gauge network which would make it isolated from the conventional rail network, with attended benefits and consequences.

JICA planned that the line will require construction of 318km of embankments, 162km of viaduct, and 11 tunnels with a total length of 27.01km, including a 2.16km tunnel underneath Thane Creek to link Mumbai with Navi-Mumbai. This is equivalent to nearly 35 % over viaduct and the rest on conventional track. This proposal has an apparent inclination towards the viaduct option which is akin to Japanese style were viaducts are often in excess of 75% of the track.

Given its present challenges of saturated routes and inadequate capacity in crucial sectors like mine and port connectivity, some have argued that it might be more prudent for India to focus on ramping up the speed of existing trains and enhancing capacity of the existing system rather than taking to the fanciful idea of running a high-speed network. However, the enthusiasm for high speed is

equally strong. "India cannot remain blind to the technological advancements made across the world," one IR official said. "It is high time that the country took to the high-speed route." The successful development of the telecom and the air transport sectors in India has shown that supported by political will, technology and entrepreneurship, new models of organization and business have a low risk and high gain future in a high growth economy like India.

Now that India has taken the “plunge” in High-Speed Railway scene, it will be relevant to study the following issues:

1. Identify and study the HSR systems available countries. Study inclusive of train operation, infrastructure set up, countries and conditions like political, social and other economic factors related to HSR
2. The system study of HSR and its financial data augmentation.
3. Lessons for India- on creation of a Risk Mitigation Framework to ensure minimizing failures/losses.

The study detailing HSR systems inclusive of various parameters such as political, economic and other conditions based on their respective GDP, land & countries population index etc., will be taken into consideration. Comparison will also be attempted for the existing transportation system and the geographic, demographic, economic and political factors which contributes to HSR systems. After studying the countries and the context, the governing features of the HSR systems covering who owns and operates the HSR shall be attempted. The final conclusion will be drawn based on the common features of HSR systems available in the various countries.

The results derived from the exercises above shall be used to appreciate the threats and opportunities and create a road map for the HSR dream of Indian Railways.

1.3 Identification of countries where HSR is in operation:

Following data depicts the different countries HSR systems and operational comparison.

Country	Line in operation	Line under construction	Total
China	3529	6696	10225
Spain	1604	2219	3823
Japan	2452	590	3042
France	1872	234	2106
Germany	1285	378	1663
Italy	923	0	923
Turkey	235	510	745
South Korea	330	82	412
U.S.	362	0	362
Taiwan	345	0	345
Belgium	209	0	209
Netherlands	120	0	120
UK	113	0	113
Switzerland	35	72	107

Table 1.1 HSR Systems in different Countries

The first 5 countries can be called the HSR superpowers having nearly 21000km (86%) out of the total 24000km (existing and under construction) of HSR of the world. All these countries are major players in HSR construction and technology transfer in other aspiring HSR nations.

The countries with longest HSR systems owned by China and followed by other countries such as Japan, France, Spain and Germany. China is in the process of expansion of its HSR network and construction for the HSR rail network is in advanced stage. Countries like Spain, France and Turkey also in the process of expanding their HSR rail network on the similar lines of China. HSR systems were first built by Japan with an introduction of HSR commercial service in the

year 1964 and Europe also developed HSR systems in the year 1970 and HSR systems were also become popular and efficient mode of transport.

The countries which operating HSR in the speed of 300 kmph are notably China and France. The high-speed trains require dedicated HSR track to support the speed. In China, maglev trains are running at the speed of 431 km/h as compared to Germany and Japan where the speed trails were conducted at the speed of 550 and 581 km/h respectively. France country has tested non-maglev train at the running speed of 574 km/h.

United State is the only country having exception to HSR speed trains where the running speed is less than 200 km/h. It has now embarked on an ambitious HSR program with the vision of connecting 85% of US citizens by HSR by 2030 with the commitment of financial support to HSR systems & its development.

Japan and French are the only two countries where HSR systems are successful. Japan operates the HSR based on the demand whereas the French operates HSR based on minimizing the cost factor. The successful factors of HSR are high demand and cost minimal construction costs. France was able to recover its investments in 12 years.

Vickerman had concluded that the development of HSR as a new way of transport has accelerated in many European countries and become a key element in the priority TENs. The rationale for this has, however, been somewhat confused so it is not clear whether HSR is simply an updating of the rail system to deal with problems of capacity and thus help maintain rail's market share, whether it is a means of competing with the rapid growth of air travel for medium distance journeys in the 400 to 600 km range, or whether it is a more fundamental agent of economic change with impacts on both competitiveness and cohesion. It also important that nations with high GDP's and high growth rates need an infrastructure which can sustain and promote the level of economic and concomitant social development that such countries experience. (Roger Vickerman)

1.4 REVIEW OF COUNTRY CONDITIONS WHERE HSR IS IN OPERATION:

In order to assess the feasibility of HSR in a developing nation like India, we need to analyze the economic, political and social conditions in the countries with HSR systems. The aggregate quantitative and qualitative data for their geographical, demographical and economic indicators shall be enumerated and compared along with several political and cultural factors which are relevant to projects which are enormous in terms of cost and time like HSR.

1.5 ECONOMIC CONDITIONS

Country	Total HSR	GDP (PPP) Billion $	GDP/capita $
China	10225	8789	6600
Spain	3823	1368	33700
Japan	3042	4137	32600
France	2106	2110	32800
Germany	1663	2811	34100
Italy	923	1760	30300
Turkey	745	863	11200
South Korea	412	1356	28000
U.S.	362	14260	46400
Taiwan	345	718	29800
Belgium	209	381	36600
Netherlands	120	655	39200
UK	113	2149	35200
Switzerland	107	317	41700
India	0	5300	5100

Table 1.2 Economic Conditions

These statistics for mega regions comprising of the states of Gujarat and Maharashtra (together) are:

GDP (PPP) Billion $	GDP / Capita $
128	5725

Table 1.3 GDP Comparison

The above figure displays the size of the economy of the country as measured by Gross Domestic Product (GDP), as well as the GDP per capita, which captures the portion of the economy per person within the country. GDP is important to consider as a factor in HSR systems because it represents the size of the economy as a whole. *The bigger and more advanced an economy is, the more complex transportation infrastructure is necessary, such as air, road and rail transit options, to move people and goods*.

Gross Domestic Product of the country will always decide government taxation and revenue allocation to the projects like HSR since, the HSR system purely working depending upon the government resources and financial support. GDP per capita is an indicator of societies standard of living duly measuring the country's output per person. The GDP per capita gives broad picture of living standards of the country. The countries having higher GDP per capita will ensure to provide their citizens more efficient and fastest mobility thereby reducing de-congestion of metropolitan cities. HSR unlike air travel is less expensive and energy efficient and HSR enroute places act as Hub which leads to higher economic and industrial growth.

India has displaced Japan to become the world's third biggest economy in terms of purchasing power parity (PPP), according to a World Bank. The 2014 round of the bank's International Comparison Program (ICP) ranked India after the US and China. PPP is used to compare economies and incomes of people by adjusting for differences in prices in different countries to make a meaningful comparison.

The survey covered 199 economies. India was now the world's third largest economy, moving ahead of Japan.

The above information places India at a favorable position as far as the GDP is concerned but when converted to per capita GDP, all the HSR nations are far ahead except China. GDP per capita is only the rough indicator and does not endorse for real GDP of the country. It can be correlated other better measures of standard of living. GDP per capita gives an idea that the amount of money that each individual gets in a country where he is living. Hence, we can conclude that the statement of GDP per capita is unable to delineate differences in the output, the employment and the per head earnings of the citizens of the country. It takes into account that the employment vis-a-vis with earning of a region, which inhabit wealthy people from the zones that inhabits comparatively poor people on account of unemployment and economic or poverty situation.

The fact that China has leapfrogged into the HSR world and has now begun to export the technology proves that this could not only be an economy driver within the region and the country but also a sound earning potential from export of technology within a decade.

The increase in HSR fare is due to price competition of aircraft sector. India has a huge population which can sustain the High-Speed Railway network, but ticket prices have to be affordable and competitive to other modes of transport.

The following data depicts the comparison of fare structure between HSR and aircraft:

Country	Cities	HSR	Aircraft
Japan	Tokyo-Osaka	100	100
France	Paris-Lyon	100	130
Korea	Seoul-Busan	100	130
India	Mumbai-Ahmedabad	100	100

Table 1.4 Fare Comparison

Capital cost of TGV of France found to be cheaper. This is possible due to usage of articulated bogies in trains. It lessens the lading tonnage of train on track. Japan on the other hand has more tunnels and bridges because of their land structures.

Country	HSR line	Distance (km)	Construction period in years	Cost (km/m euros)
Tofuku Shinkansen	Tokyo-Morioka	465	20	35
Choetsu Shinkansen	Omiya-Nikata	270	11	41
Country	HSR line	Distance (km)	Construction period in years	Cost (km/m euros)
TGV Atlantic	Paris- Lemans	290	5	10
ICE 2002	Frankfurt- Cologne	180	4	32
KTX	Seoul-Busan	410	13	42
Taiwan	Taipae-Kaoshung	345	6	48

Table 1.5 Cost vs. Construction comparison table

1.6 POLITICAL CONDITIONS- COMPARISON OF GOVERNMENTS:

Country	Total HSR	Type of government
China	10225	Communist, centralized, heavy command and control, policies easy to implement
Spain	3823	Parliament, 17 regional autonomous governments
Japan	3042	Parliament with 47 prefectures, heavily centralized, dependent on center
France	2106	Small country, power centralized in national govt, little powers to local govt
Germany	1663	Parliament with 16 small states, limited powers to states
Italy	923	Parliament, 94 small provinces, heavily centralized and answerable to center
Turkey	745	Parliament with 81 provinces, less autonomy to provinces
South Korea	412	Parliament, 9 provinces, 7 cities, semi-autonomous provincial govt
U.S.	362	Parliament with high federal character
Taiwan	345	Parliament, 18 counties, centralized
Belgium	209	Parliament

Netherlands	120	Small country, Parliament, 12 provinces, heavily centrally inclined
UK	113	Parliament with strong states
Switzerland	107	Parliament, 26 cantons, highly autonomous
India	0	Parliament, 26 states, highly autonomous

Table 1.6 Comparison table of Political conditions

HSR system implementation depends upon the government policy, rules and regulations. Strong government will dominate the implementation of HSR systems since its policies, laws and regulations are consistent in nature. Greater independence will always ensure growth and speedy implementation of the HSR project. If HSR policies are decentralized, then project implementation is purely depending upon the sub-national governments which always pose threat to HSR implementation as the policies and regulations may change depending upon the government is in power. The concept of federal systems such as one in US are entirely different as the sub-national government also enjoy the same powers of national government. The situation in China is different as the China political system is authoritarian, so laws and regulations for implementation of HSR systems are more powerful and consistent one. The Central authoritative government in China can easily implement the HSR systems compared with its peers.

Since HSR systems are large in terms of cost and time, investors, particularly foreign look for a stable and peaceful environment over the long-term horizon. Other than the first BOT in HSR, Taiwan was a leader in providing this enabling environment by creating a constitutional body to govern HSR which will not be affected by change in the government.

India stands at a vantage point in this factor considering that it has a stable democracy which is devoid of any major political and social turbulence. But following the footsteps of Taiwan by creating an authority which is insulated from possible political fracas will be a step in the right direction.

1.7 GEOGRAPHIC AND DEMOGRAPHIC FEATURES

The tables below give an understanding and insight information about HSR systems available in the countries vis-à-vis with its geographic and population. The population index will play major role in deciding the implementation of HSR as the High-speed rail network require dedicated rail network for which land availability is the major concern in implementation of HSR systems.

Country	Land area sq km	Population million	Population density	Urban Population %
China	9569901	1340	140	43
Spain	498980	40	81	77
Japan	364485	127	350	66
France	549970	62	113	77
Germany	348672	82	236	74
Italy	294140	58	200	68
Turkey	769632	76	100	69
South Korea	96920	48	500	81
U.S.	9161966	308	34	82
Taiwan	32260	23	712	-
Belgium	30278	10	344	97
Netherlands	33893	17	493	82
UK	241930	61	252	90
Switzerland	39997	8	190	73
India	3287570	1189	361	34

Table 1.7 Geographic and Demographic Features

From the above, it can be concluded that densely populated countries show a high possibility of developing railways. Korea has 500 persons/㎢, Japan 350 persons/㎢, German 236 persons/㎢, France 113 persons/㎢. This confirms that Japan's rail passenger traffic shows 26.8% of the modal share in transport. Korea has a higher population density than Japan. If Korea wanted to expand its rail system, the passenger traffic is also likely to increase. Considering the speed and transport, railway transport are superior to road and aircraft if the speed of 200km/h and distance of 500 km is concerned.

The data available between region will not normally reflect the differences between regions. The countries prevailing situation may different from the available country data. With the context of the Mumbai-Ahmedabad HSR corridor in mind, the aforementioned data for the mega regions comprising of the states of Gujarat and Maharashtra (together) which will be the primary catchment area for the HSR corridor are:

Land area sq km	Population Million	Population density per sq km	Urban Population
503737	176	334	45%

Table 1.8 Population features

HSR system depends upon economic condition, citizen support and patronage towards commuting in HSR from one place to another. The successful rate of HSR will normally increase if the country having large populated and urban centers and good GDP contribution. Research has suggested that, HSR system will work efficiently if the distance between two population centre is more than 100 miles. If more than 600 miles, the preferrable mode of transport is airway and less than 100 miles car will be the efficient transport system.

It can be seen from the above chart that majority of HSR system available countries are having less than 5,50,000 sq km of land area. The only exception is China and United States where the land area is more than 5,50,000 sq kms but HSR systems are very limited. The following data reveals the average moving distance of HSR per person as follows:

France	Germany	Japan	Korea
456 km	308 km	258 km	240 km

In France distance between station is 142 km, whereas in Japan, it is 34.5km. The reason behind less distance in Japan is due to its major cities along HSR sector.

Countries with HSR system having density of more than 200 people per sq km as compared with United States where considerably less population is found. Urbanization rate in the US is different from other countries giving a considerable thought that US population is denser compared to other countries. In countries like countries like China also, despite having large land area has dense population centre. Hence HSR to be implemented in a most efficient and effective way in those regions. Hence it can be concluded that concentrating and implementing HSR within region would prove more economical and viable.

India, on the other hand is much smaller than China and US but much larger than other HSR countries. The population density of over 300 in the country and 350 in the HSR corridor augers well for the proposed HSR corridors.

1.8 EXISTING NON HSR TRANSPORT INFRASTRUCTURE IN HSR COUNTRIES:

Country	Land Area sq km	Airports	Railways route km	Standard Gauge	Paved roads In km	Express ways (km)
China	9,569,901	195	77,834	77,084	3,583,715**	53,913
Japan	364,485	49	26,435	3,978	961,366	7,560
South Korea	96,920	25	3,381	3,381	80,642	3,367
Turkey	769,632	49	8,697	8,697	426,951**	1,987
Taiwan	32,260	16	1,582	345	40,843	976
Germany	348,672	65	41,896	41,641	644,480	12,600
U.K.	241,930	41	16,454	16,151	398,366	3,520
Belgium	30278	14	3233	3,233	119,079	1,763
Italy	294,140	39	19,729	18,317	487,700	6,700
France	549,970	41	29,213	29,046	1,027,183**	10,950
Netherlands	33,893	11	2,896	2,896	136,827**	2,582
Spain	498,980	30	15,288	1,392	681,224	13,872
Switzerland	39,997	7	4888	3397	71,384	1,793
E.U.	4,324,782	456	229,450	NA	5,454,446**	NA
U.S.	9,161,966	419	226,427	226,427	6586610	75,040
INDIA	3287570	132	65348	-	4865000	1324

Table 1.9 Non-HSR Transport Infrastructure features

Non HSR transport infrastructure-

Relative numbers in terms of per 1000 sq km of land area

Country	Airports per 100k sq km	Railways route km per 100k sq km	Paved roads km per 100k sq km
Asia			
China	2.04	8.13	374.47
Japan	13.44	72.53	2637.6
South Korea	25.79	34.88	832.04
Turkey	6.37	11.3	554.74
Taiwan	49.60	49.03	1266.05
Europe			
Germany	18.64	120.15	1848.38
U.K.	16.95	68.01	1646.6
Belgium	46.24	106.77	3932.8
Italy	13.26	67.07	1658.05
France	7.45	53.11	1867.7
Netherlands	32.46	85.44	4037.02
Spain	6.01	30.63	1365.23
Switzerland	17.50	178.47	1784.7
North America			
U.S.	4.57	24.71	718.9
INDIA	4.02	19.87	1479.8

Table 1.10 Comparison of Non-HSR Transport Infrastructure

Air travel infrastructure in most HSR countries with the high-level availability of airports. The concept is proved in Europe. In countries like US and China where geographically much larger size than Europe countries has a smaller number of airports. The availability of HSR system is an indicator of rail-based growth infrastructure in a country. The rail network may be of any type like freight or passenger trains. In US, the availability of HSR system is very less wherein it has other good rail infrastructure. The roadways and exclusive express ways give an indication of good road-based infrastructure in the country. United states has significantly good road infrastructure as compared with any HSR country. China and France also have large roadway infrastructure as compared with US.

There is no relationship between road infrastructure and HSR systems. As per the research of HSR system, car travels are more convenient and easily accessible for shorter trips, and HSR system having significant advantage if the travel distance is more than specified kilometers or longer trips.

India stands at the middle of the infrastructure spectrum in terms of airports, railways and roads in HSR nations meaning thereby that it has adequate supporting infrastructure to create efficient synergy in the overall transport environment.

1.9 CULTURAL CONDITIONS:

Culture can play a major role in deciding people perspective vis-à-vis with efforts and policies which require to develop HSR systems. Culture always provides and supports the government policies and collective actions in implementing HSR systems.

According to Geert Hofstede has linked cultural dimensions that have been used to support business with other governments and also to understand the cultural background of the country where the business operation operates.

The dimension listed are Power-Distance Index, Uncertainty Avoidance Index and Long-Term Outlook.

Power Distance Index (PDI) refers to the degree of inequality that exists between people with power and without power. A high PDI score indicates that a society accepts an unequal, hierarchical distribution of power, and that people understand their role in the system. Countries with high PDI score where individuals defer to and respect only authorities with the power in a government. This will impact HSR system where people more likely to confront with the government decision where high PDI score available in a country. As compared to China, US has lower PDI score.

One perhaps less obvious condition to consider in relation to countries with HSR systems is the culture of the given country. Culture can play an important role in how people view collective efforts and policies, such as those required to develop HSR systems, as well as how people view, trust, interact and defer to government and others authorities. In this latter sense, culture provides the context within which political conditions and governments exist. In this way, some cultures can be more amenable to certain government policies and collective actions than others.

While it is difficult to generalize culture for countries and to definitively determine whether culture actually has a significant impact on something such as HSR, some commonalities and trends do exist. Business consultant and social psychologist Geert Hofstede has mapped several dimensions of culture that have been used to assists businesses that have relations with foreign governments and business partners to better understand the cultural environments they operate in.

The dimensions listed here include*: Power Distance Index (PDI), Individualism IDV), Uncertainty Avoidance Index (UAI), and Long-Term Outlook*

Country	PDI	IDV	UAI	LTO
China	80	20	30	118
Japan	54	46	92	80
S. Korea	60	18	85	75
Turkey	66	37	85	0
Taiwan	58	17	69	87
Germany	35	67	65	31
Country	PDI	IDV	UAI	LTO
U.K.	35	89	35	25
Belgium	65	75	94	0
Italy	50	76	75	0
France	68	71	86	0
Netherlands	38	80	53	44
Spain	57	51	86	86
Switzerland	34	68	58	0
U.S.	40	91	46	29

Table 1.11 Social/Cultural Dimension features

Cultural dimensions score in India:

Source: Going Local in India: Carol Barnum, Anant Patil, Dec 2010

Index	India	World Average	HSR Average	Range	Consequence for India
Power Distance	77	56.5	52.85	34-80	Very positive
Individualism	48	40	57.57	18-91	Positive
Uncertainity Avoidance	40	65	68.5	35-94	Not positive
Long Term Orientation	61	48	61.125	29-118	Positive

Table 1.12 Cultural Dimensions Score features

Power Distance Index (PDI) defined as the degree of inequality that exists between people with authority and without authority. A high PDI score always indicates that a society accepts an inequality, degree of distribution of power and that people understand that where there have been placed in the system. If any country is having more PDI, then the development and implementation of HSR is easy as the people will easily accept and cooperate with the authority in implementing the project. On the other hand, countries where there is a lower PDI are more likely to defer with the decision and challenge the authorities. It is seen that China has high PDI score as compare with US, since US has low PDI. In other words, HSR system implementation is very easy with the score above 50 as seen from the HSR available countries.

The PDI score of India is 77 as compared with the world average PDI score of 56.5. The high PDI score indicates that inequality of wealth, power are accepted by the society. (Hofstede et al., 2010, p. 54). It implies that if the government has rules and policies regarding implementation of HSR, then the same will be implemented without any difficulty or resistance from the public s the authority decisions are support by large public.

The Individualism score is defined as a preference for a loosely-knit social framework in which individuals are expected to take care of only themselves and

their immediate families. Some of sort of selfishness in individual actions in the society rather collective sensibilities. Countries with a high IDV score always represent the strong individualism, whereas counties with a low score would indicate strong collective responsibilities. In contrast, China despite having low IDV score having HSR systems and rapidly expanding its network length without any problem. In contrast, the United States has a very high IDV score but not able to implement HSR systems successfully as compared with other countries having high IDV.

India's low individualism score (IDV) suggests that its culture stresses the interdependence and long-term mutual obligations between individuals and organizations. This interdependence influences an individual to want to be in an environment where he feels belonged and integrated. Hence, collective cultures enjoy group work and derive their identity from being part of a collectivity

The Uncertainty Avoidance Index is defined as how well people can cope with anxiety. In societies that score highly for Uncertainty Avoidance, people attempt to make life as predictable and controllable as much as possible. A high UAI score indicates that the society is likely to favour rules regulations where uncertainty is present. People who are not having familiarity with HSR may view HSR project as a new and uncertain technology and may lead to closure of HSR projects.

It may be concluded that if there is high UAI scores in a country then the country wanted to prefer HSR structure and also to deal with the uncertainty. In Europe, it contrasts with China on the UAI score (Lowest amongst other countries) which implies that Europe where the HSR systems is a boon for mitigating climate change. China, with its low UAI, wanted to deal with rapid growth and economic expansion and HSR system being a new technology to solve the problems on hand. United States having average score indicating that it does not endorse in dealing with uncertainty.

I**ndia is having Uncertainty Avoidance (UAI) score at 40** when compared to the world average of 65. The score of 40 UAI implies that the culture in India is acceptable to unstructured ideas and situations. The limited rules and regulation are tries to attempt unknown and unexpected situation.

Long-Term Outlook is referring to a measure of culture orientation in a future period of time. A High LTO score indicates a strong culture that yields long-run results. A low LTO score indicates a greater focus on decisions ovr a period of time. High LTO scoring countries are willing to take up big infrastructure projects like HSR even though the project will take a greater number of years to get completed. The HSR projects involves creating basic infrastructure like track and will take lot of time in completing with the operations.

China has a very high LTO score similar to that of United States. In Europe, which already have developed HSR system because its development is the result of immediate response to needs of the people. In the case United States, it could possible for the development of HSR, where such development as a result of political compulsion until there is a perceived need to address issue. **India's high LTO score** indicates that the country has a rich values and respect for tradition culture and always repay the hard work put in present to get a desirable result in future.

The outcome from the above foregoing analysis of culture, do not represent a comprehensive picture of culture in any given country. In general, cultural difference may be experienced from region to region and country to country within the parts of country. Cultural generalization cannot be made based on the culture available in parts or the region concerned.

The cultural scenario available in the countries plays an important role in deciding the development of HSR like people preference of car over the public transport system. Such cultural factors should also be given due consideration. **However, from an Indian perspective, it can be said that from these social psychological indicators, HSR can be a long-term project which would be acceptable to the population in general.**

1.10 HSR AND PASSENGER RAIL SYSTEM FEATURES

The following table depict the size, ownership structures and financing of HSR in these countries. Privatizations and the breaking apart of monolithic state companies are usually done because of the losses incurred by the state-run companies and because of perceived gains in efficiency and profits from making public HSR companies more competitive or from privatization. This latter consideration has driven EU laws **mandating the breaking apart of monolithic state railway companies and the separation of those companies into independent operations and infrastructure companies.**

The initial infrastructure like track and other basic infrastructures require for the operation of HSR are funded by government in most of the cases in view of large cost involved in setting up of basic infrastructure of HSR systems. In some countries, HSR services are either privatized or HSR operations carried out with the help of international consortium associated companies.

Country	Infrastructure ownership	Operations ownership	FINANCING
China	State owned corporation CRC	State owned corporationCRC	50% national government, 40% bonds by MoR, 10% states
Japan	State owned JRCTTA	Private companies	Infrastructure on lease to private companies
South Korea	State owned Construction & Transportation ministry	State owned corporation KTX	National government, loans
Turkey	State owned company TCDD	State owned company YHT/TCDD	State funding
Taiwan	Privately owned THRSC	Privately owned THRSC	Privately owned THRSC for 35 years, then transfer to government
Germany	State owned DB Netz	State owned DB	Both owned by BEV (Federal rail property agency)

U.K.	Privately owned Network rail	Private Rail operators	Government grants subsidies
Belgium	state owned Infrabel	State managed by NMBS/SNCB; Operated by 4 private JV's	
Italy	**State owned RFI**	**state owned Trainitalia**	**Both owned by FS holdings (State Railways)**
France	**State owned company (RFF)**	**State owned company (SNCF)**	**Both owned by French Ministry of Transport**
Netherlands	**State owned company Prorail**	**2 international JV's (Thalys and Intercity Express)**	
Spain	**State owned company**	**State owned company RENFE & 2 PRIVATE COMPANIES**	**National Funding**
Switzerland	**Private company BLS**	**Private company BLS**	**Fully Privately owned**
U.S.	**Privately owned companies**	**State Owned Amtrak**	**Federal Funding for upgrading**
INDIA	**State owned Ministry**		**TBD**

Table 1.13 Comparison of HSR and Passenger Rail System features

The conclusions can be enumerated as follows:

1. There are no single formulae for constitution of the structure for an HSR company. Simplistically speaking, the organization model is as follows:

Infrastructure	Operations	Examples
Private	Private	Taiwan,Switzerland,UK,Japan
Private	State	USA
State	Private	Belgium, Netherland, Spain
State	State	Turkey, China, S. Korea, Italy, Germany, France

Table 1.14 Comparison of operation features

Most of the European HSR systems have separated ownership of infrastructure and operations under mandate by the EU. However, either both or one are being owned by the government or by private companies.

2. Debt associated companies are having full support from the government in order to clear their debts related to HSR by the way of extension of credit facilities like soft loan or in the form of low interest loan from the government so that the debt driven companies can able to repay their debts from the financial assistance extended.

3. It is seen that initial capital resources are from government sources which are required for HSR, EU law mandates the separation of operations and infrastructure companies in order to encourage private competition to public operators and to encourage more transparent pricing and bidding for access to track owned by public infrastructure companies.

4. It is noticed that in several companies' profitable operations were made in HSR systems duly privatizing the operations.

High Speed Railways worldwide generate surpluses from their operations because they attract more passengers and generate more revenues at lower unit costs of production (for ex. crew can make two rounds of trips instead of one). In most of the countries, HSR systems generate enough revenue to cover 'Operational Costs' and most of the HSR lines cover some of their 'Construction Costs'. Tokyo-Osaka generated enough operation surpluses in its first decade to completely match capital costs.

Analyzing the business exploitation model and the infra structure creation model adopted by all the HSR countries, it is seen that, as in the case of ownership study earlier, there is no pattern which runs through the HSR system suggesting a straight jacketed structure regarding exploitation model. Every country has adopted different models for different projects within the same country. One philosophy which probably runs common to all is that the track gauge adopted by them for HSR lines is the same as that of the mainline railway system. Since choosing a particular exploitation model is a decision affected by the comparison of the costs of building new infrastructure versus the costs of upgrading (and maintaining) the conventional network, or a combination of both, the definition and decision of HSR model immediately becomes not only a technical question but also a (very relevant) economic one.

1.11 SUMMARY OF THE ABOVE STUDIES:

POLITICAL ENVIRONMENT:

In HSR systems, it is observed that the national involvement is must. Without support of national involvement, it is very difficult to implement the policies related to HSR in the state-oriented projects. If the national and state government having different ideologies and regulations, support in implementation of HSR systems will be very much difficult as the resistance from state may lead to failure implementation of HSR.

In terms of the political environment, most of the HSR countries are democracies with a stable and strong central government. In India, the structure of the government has a strong federal tilt with states having a large portfolio of subjects

to legislate upon, much like that in the USA. However, a lot depends upon the political lines the ruling parties in the states are affiliated to. The project in question in India (Mumbai- Ahmedabad) serves the states which have the same ruling party as that in the center and both have long tenures ahead. This would allow both the state and central level to carry out smooth operations in implementing HSR systems without any resistance. What would be necessary is to create an arrangement of coalition of states and the center that facilitates (including funding) and provides a stake and ownership in the system.

It is observed that India and US are having similar and strong federal character of the government with states having greater autonomy. China, on the other hand, has an authoritative government. The Chinese central government is in a relatively strong position in terms of financial and administrative power, and it is also relatively strong in implementing national policies. In all other countries where the HSR systems exist, the national governments are much stronger have a much larger say in the course of policies than the state and local governments do.

It is common in HSR systems available countries that the cost towards operation and maintenance are met out from the fare that has been collected from HSR network. The other infrastructure cost towards track is sourced from the government financial assistance in view of large capital investment required for the basic infrastructure. In Japan also government has initially extended the initial cost towards basic infrastructure and further private companies are able to do the operation and maintenance from their financial sources like fare collection etc., Even in the case of Europe HSR systems also implemented on the similar lines of Japan that initial funding from government towards basic infrastructure and maintenance and operation from the revenue collection.

All large infrastructure projects including HSR (save a few nations like Japan) have been built by borrowing money. It is only the financial leverage that a country can expect to possess by which the repayment of loan is possible. Also of note is that in a conventional railway system, the infrastructure and the trainsets and the operations, including staff has to be provided by the state whereas in an

HSR, the state provides for only the infrastructure and leaves the rest to the private parties. Thus, the financial burden on the state and in turn the common taxpayer through tax on GDP is not much higher than the conventional railway system where as the quality of service is much superior.

CULTURAL ENVIRONMENT:

This study attempts to generalize the cultural ethos of a society and there are obvious pitfalls. However, it does give a broad conceptualization about how mature and ready a population is for accepting a decision of such large consequences.

India ranks high indicating on the PDI score which results cooperation with the government authorities in implementation of HSR systems. The PDI results in imposing HSR through a government decision (particularly with a favorable political environment) may not find much resistance.

In terms of **individualism**, India ranks low and that means that collectivism often masks individuality in India and the population is more amenable to collective national decisions. This could be a favorable turn in the decision making towards HSR. However, the HSR should be presented to the public as the American Highway effort was placed in the 1960s. Though it was a collective effort, it was presented as a quintessential American endeavor because of the independence it would provide to people.

In terms of UAI, India ranks pretty low meaning that Indians are normally highly risk averse than other HSR countries with the exception of China. Which means that the people of have embarked upon its HSR implementation. The HSR policy to be transparent ad to be accepted at all levels of public citizens so that the hurdles of implementing HSR systems will be reduced. The government has to initiate and spread awareness and educating common public about the HSR systems and its benefits.

The LTO is favorable to HSR in India where this index is fairly high suggesting that the Indians have a more “long-term” thinking compared to others in the HSR

group. If HSR is presented as a long-term solution to a long-term need, support in India is likely to be much higher.

Overall, it can be concluded that as a society, in India, HSR can expect to be greeted with cautious optimism but the government will have to present it to the public tactically with a bottom-up approach.

ECONOMIC AND GEOGRAPHIC CONDITIONS:

In order to implement the HSR network, huge funding is required, which can be afforded only by well supported GDP growth supported countries. All countries cannot afford HSR infrastructure in view of their financial position.

HSR systems funding not only depending upon the government financial assistance, it also requires external capital support. The government financial assistance alone cannot lift the HS project in view of large financial implication of HSR systems. Hence, capital infusion from public sector and other foreign funding agencies supports also require to implement the HSR systems in order to make the project financially viable and technically feasible. Whatever form HSR governance and ownership might take in India, it is likely that it will require an infusion of capital from the public sector. Now that the JICA has come forward with a proposal of a soft loan, the National government in India has fewer troubles as far as funding of the project is concerned.

Even geographic wise selection, most HSR systems available countries are relatively very small when compared with China and USA. In both the countries like China and USA as compared with India relatively larger in size and operation of HSR systems are in particular region only i.e in east coast region. Even the USA is not planning an East West high-speed connection relying on the rule of thumb of 100 – 600-mile range for HSR to be cost effective. India HSR program qualifies well on this account.

HSR AND PASSENGER RAIL SYSTEM FEATURES:

HSR service provider companies are classified based on the funding from the government as following:

1. A company with independent source, public funding, private companies having entrusted with operation of rolling stock without government assistance.

2. Private rail infra companies responsible for maintaining track and allowing other private players to use the rack infrastructure.

3. A state owned companies with assistance of government funding.

Having highlighted this commonality, it is observed that there is a wide difference in the structure of almost all HSR systems, particularly in regard to ownership of the system and the business exploitation models they have opted for. Some HSR's have privately owned infrastructure with publicly owned operators (USA) and others have the opposite (Spain). Some have completely dedicated new lines for HSR and some share their lines with conventional railway systems, either passenger or freight. The models adopted are based upon operational exigencies and economic/ financial considerations.

The cost towards building HSR infrastructure is normally very huge in nature and companies will normally looking the support or financial assistance from government. In some case HSR services are owned by private who in turn having financial back up with the support of international consortium of companies.

In general, the state-owned companies are bound to work with limitations and may ended up with less profit or no profit, for which the only solution is to privatize these loss making state owned companies so as to make them profitable. This step will be a major obstacle to crack in terms of Indian conditions where the railway is owned and operated by the national government. Being the largest employer in the country, it has forceful unions which have a strong influence over long term decisions like breaking up organizational structures.

In common, companies having independent business do not receive any type of government assistance and basically defined as private companies. Companies operating with the assistance or subsidies are state owned railways and operated on the basis of no profit no loss basis. Few countries have exception like Taiwan where private companies entered with BOT agreement with Government and get assistance from government sources for operation of HSR.

Since HSR is undeniably a transport trend of the future, India will have to show confident pragmatism and create the right conditions for a positive attractive alternative.

1. From the point of view of political stability, social maturity and economic tenacity (in terms of GDP and supporting infrastructure), it appears that India is reasonable well placed to take a confident step towards going ahead with the HSR dream. The corridor chosen is among the highest in India in terms of industrialization, urbanization and per capita GDP, all primary ingredients of a success HSR scenario.
2. Formation of a state–nation high powered authority will go a long way forward to regulate and facilitate the policy, finances and construction monitoring.

CHAPTER-2

HIGH-SPEED RAILWAY IN INDIA

2.1 INTRODUCTION

Transport infrastructure is critical to a country's development. One cannot overstate the importance of transportation by referring to it as a nation's 'lifeline.' Everybody wishes for the quickest and most efficient mode of transportation infrastructure. Economic growth requires adequate physical connectivity in urban and rural areas. India, the world's seventh-largest country with a population of over a billion, has one of the world's major transportation sectors.

Domestic transportation is critical for economic growth, and transportation concerns and infrastructural delays impede a country's progress; India requires significantly faster and more efficient transportation networks.

Rail transit is one of the most efficient and cost-effective modes of transport compared to vehicle. Additionally, rail building costs are lower than road construction costs for equal traffic volumes. Historically, the Indian railways have been instrumental in transporting passengers and freight across the country's large territory.

There are various compelling arguments and justifications in favor of the country's introduction of HSR. IR transported 8.26 billion people and 1.16 billion tons of freight in the fiscal year ended March 2018. HSR creating new opportunities by diverting people from road and air. HSR enables settlements 500 kilometers apart to be within two hours of one another.

According to a JICA poll, Indians are travelling greater distances. By 2020-21, Indians will have travelled around three times as much as they did in 2000-01. The country is densely packed with commercial and industrial businesses. The implementation of HSR is a critical facility that is anticipated to reduce travel time and cost across critical financial sectors or connections. This will pave the way for additional investments and firms, as well as a general boost to "Make in India" programmes. One of the major issues in recent years has been the country's high unemployment rate. The introduction of HSR would create thousands of jobs, particularly in areas like Pune, Surat, and Ahmadabad, where industrial businesses are rising at a rapid pace.

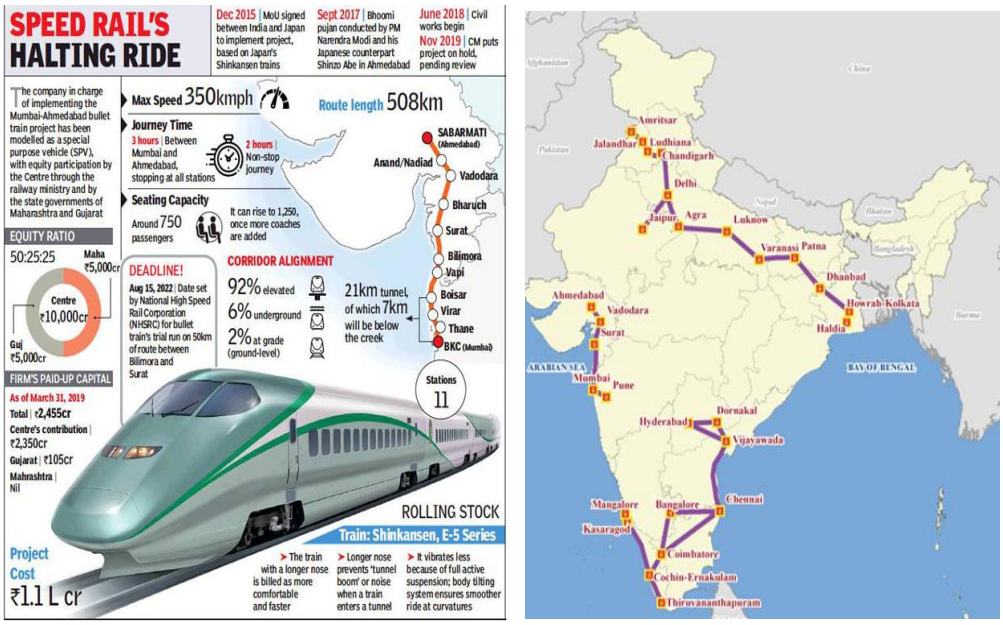


Fig 2. 1 Salient features of India's first HSR System and Proposed HSR projects

2.2 AHMEDABAD

Ahmedabad is India's fastest growing metropolis and the third fastest expanding city in the world, behind China's cities. Ahmedabad's GDP was US $ 64 billion in 2014. The city is well-known for its cotton textiles, gem stones, and jewelries, and industries such as automobiles and chemicals are expanding at a rapid pace.

Population in 2011 (2001)		
Ahmedabad City	5,570,585	(3,520,085)
Ahmedabad Metropolitan Region	6,352,254	(4,525,013)
Decadal Growth Rate (%)		
Ahmedabad City	58.3	
Ahmedabad Metropolitan Region	40.4	
Area (2011)		
Ahmedabad City	464 km^2	
Per Capita Income (2006)	Rs 63,000	
DDP at Current Prices 2006-2007	Rs 4,010,890(in lacs)	
DDP Annual Growth Rate (%) (2001-2006)	9.38	

Key Industry Sectors	Textiles-apparel	Drugs-Pharmaceuticals
	Agro- food processing	Automobiles
	Engineering	Biotechnology
	Diamond Processing	IT
	Tourism	

Fig 2. 2 Ahmedabad socio-economic facts

Transport System in Ahmedabad

Ahmedabad is one of the Railway divisions of Indian Railways and comes under Western Railway. Ahmedabad Railway lines connect to Gujarat and other Cities. This Railway station is a main terminus and MEGA Metro system is under construction to various places in and around Ahmedabad.

The city is served by railway lines that connect it to towns in Gujarat and major Indian cities. Ahmedabad railway station, colloquially referred to as Kalupur station, serves as the primary terminus, alongside 11 others. MEGA, Ahmedabad and Gandhinagar's mass-transit metro system, has been under development since March 2015.

Ahmedabad is connected to Delhi and Mumbai via NH 48. Ahmedabad is also connected to Gandhinagar by National Highway 147. National Expressway 1, a 94-kilometer-long (58-mile-long) expressway with two exits, connects it to Vadodara.

Ahmedabad is one of the most polluted cities in India. The Gujarat Pollution Control Board offered auto rickshaw drivers a cash incentive to convert all 37,733 auto rickshaws in Ahmedabad to cleaner-burning compressed natural gas. As a result, Ahmedabad was placed 50th in India's most polluted cities in 2008.

Domestic and international flights are available from Sardar Vallabhbhai Patel International Airport. With an average of 250 aircraft operations each day, it is Gujarat's busiest airport and the ninth busiest in India. Another airport, the Dholera International Airport, is being considered in the vicinity of Fedara (30 km from city). It will be India's largest airport, covering an area of 7,500 hectares.

2.3 VADODARA

With a population of 1.67 million, it is one of the major cities in Gujarat, second only to Ahmedabad and Surat. Vadodara is a city where numerous large-scale enterprises have been established, including India Oil Cooperation, IPCL, GACL, and numerous more big government and private authority large-scale industries. This city is home to almost 35% of India's manufacturing industries

for electricity transmission and distribution equipment. Numerous more IT and stock exchange development initiatives are currently underway.

Fig 2. 3 Vadodara rail network

Transport System in Vadodara

Vadodara is well-connected by rail and road to Delhi and Mumbai, as well as to Ahmedabad. The following sections detail the transportation activity in Vadodara via air, rail, and road.

Air

Vadodara airport is located in the city's north-eastern section. It is India's second green airport. It serves major cities such as Mumbai, New Delhi, Hyderabad, Chennai, Kolkata, and Bangalore via connecting flights.

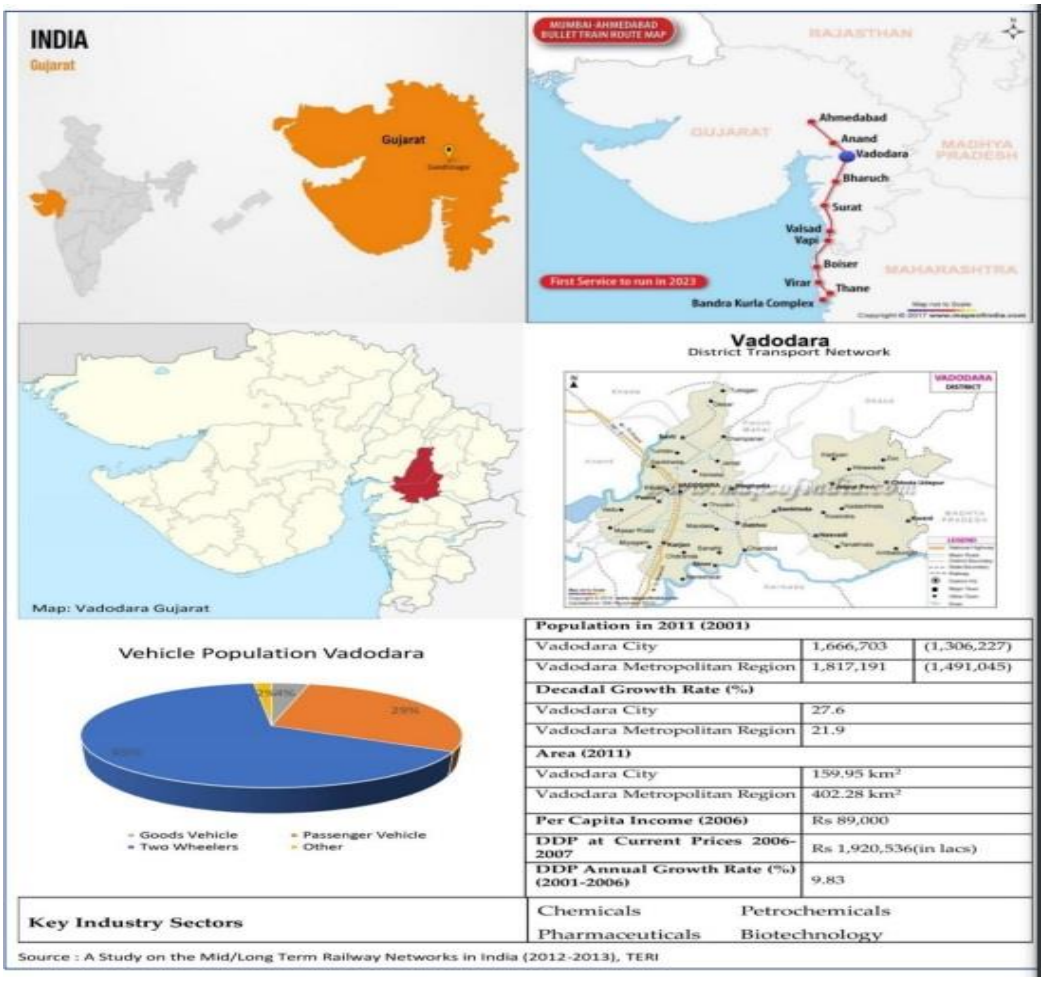


Fig 2. 4 Vadodara socio -economic facts

Railway

The Vadodara railway is one of India's oldest railways. Pratapnagar, Vishwanitri, Makarapa, Karajan, Miygan, Itola, Varnama, Bijwa, Ranoli, and Nandesar are the ten major railway stations in Vadodara. It is presently part of the Indian railway's main line's Western railway zone. It is Gujarat's busiest railway, with 358 trains passing daily. These places are served by major long-distance trains such as the Rajadhani, Shabari, Durando, and various mail/express trains.

Road

The Vadodara route connects Delhi and Gandhinagar with Ahmadabad and Surat via the National Highway, which runs through Mumbai. Numerous road extension projects along the National Highway that passes through Vadodara have been undertaken.

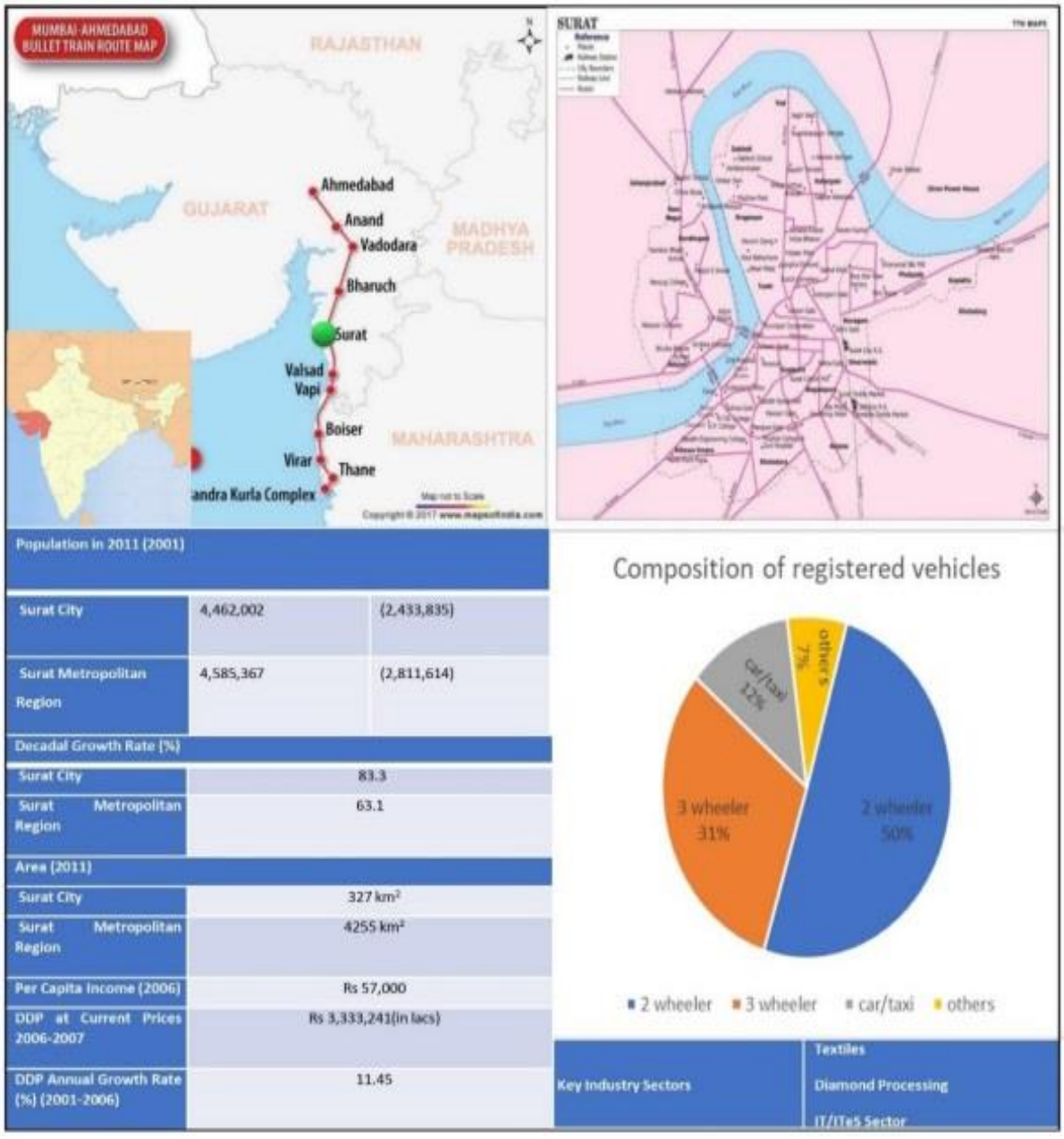
In Vadodara, there are approximately one hundred buses with a seating capacity of 33 to 50 passengers. The people who use public and private transportation on this road have numerous difficulties during peak hours owing to congestion.

2.4 SURAT

Surat is a big metropolis and India's eighth largest city. It features the world's largest seaport and has developed into a Centre for the diamond industry. It is one of the fastest growing cities in the country (11.5 percent GDP growth over the last seven years) and is known as India's first smart IT city. The city has a total of 2.97 million internet users, or 65 percent of its population.

The Surat railway was constructed in 1860. The railway connects 245 bus lines that connect important cities. Surat's international airport is located near

Magalala, 11 kilometers south of the city. Apart from the major city, Surat airport also serves remote areas of South Gujarat.



Population in 2011 (2001)		
Surat City	4,462,002	(2,433,835)
Surat Metropolitan Region	4,585,367	(2,811,614)
Decadal Growth Rate (%)		
Surat City	83.3	
Surat Metropolitan Region	63.1	
Area (2011)		
Surat City	327 km²	
Surat Metropolitan Region	4255 km²	
Per Capita Income (2006)	Rs 57,000	
DDP at Current Prices 2006-2007	Rs 3,333,241(in lacs)	
DDP Annual Growth Rate (%) (2001-2006)	11.45	
Key Industry Sectors	Textiles Diamond Processing IT/ITeS Sector	

Fig 2. 5 Surat socio-economic and transport scenarios

Transport Systems:

The majority of individuals in the region travel by vehicle. As a result, these areas confront traffic issues such as congestion, air pollution, and noise pollution. Surat's road network expanded from 372 kilometers in 1976 to 644 kilometers in 1990, an increase of 18 kilometers each year.

Fig 2. 6 Transport network of Surat

The city's three extant railway stations are served by 36 pairs of passenger trains, totaling 72 trains in each direction.

2.5 MUMBAI

Mumbai is India's most populous metropolis, with an estimated 12.4 million residents. Mumbai, like the majority of metropolitan cities, accounts for

somewhat more than 6.16 percent of the Indian economy, accounting for 10% of industrial employment, 30% of income, and 40% of foreign commerce. Mumbai receives a tremendous influx of people seeking employment from rural areas.

Table 2.1 Socio economic facts, Mumbai

Socio Economic Facts		
Population in 2011 (2001)		
Mumbai City	3,145,966	(3,326,837)
Mumbai Suburban	9,332,481	(8,587,000)
Greater Mumbai (Total)	12,478,447	(11,913,837)
MMR	20,748,395	(18,414,288)
Decadal Growth Rate (%)		
Mumbai City		(-) 5.75
Mumbai Suburban		8.01
Greater Mumbai (Total)		4.74
Area (2011)		
Mumbai City		157 km^2
Mumbai Suburban		446 km^2
MMR		4,355 km^2
Per Capita Income (2010-2011)		Rs 1,41 lakh
GDDP at Constant Price in 2010-2011(2004-2005 Prices)		Rs 1,689,730 million

Mumbai's transportation infrastructure must adapt to the city's growing demand. Mumbai has 16.4 million dwellings, or more than twice the population of New York City.

Roads Eastern Freeway:

It connects Ghatkopar to South Mumbai, covering a distance of approximately 16.8 kilometers. Of the 13.59 kilometers of the freeway, two of the three segments are operational, with the remaining portion to be completed.

Fig 2. 7 Mumbai Road map

Coastal Road (West):

The coast road runs along the western shore for 35 kilometers, from Narima point to Malad, with 18 interchanges connecting key roadways. Additionally, it connects western and southern Mumbai.

Railways

Metro Rail:

The metro train system covers a distance of 146 kilometers. It runs through the greater Mumbai region from north to south, connecting the airport and the city's central business district, which are located on the island's southern tip.

Mono Rail:

Between Chempur and Walada depot, the Mumbai monorail is 19.54 kilometers long and features 17 stations. It connects Avalmaidan to Virar via the Western Railway.

CHAPTER 3

LITERATURE REVIEW

3.1 INTRODUCTION

This chapter deals with the theoretical foundation for this research by reviewing existing literature and gaining practitioner insight into the fundamental concerns of risk management in logistics infrastructure development projects. This review of the literature focuses on several theoretical and practical components of risk management. This chapter outlines the fundamental principles of the constructs used in this study. This chapter initially covers risk in infrastructure development. The relevance of risk associated in infrastructure projects and the different risk strategies used in the sector.

3.2 RISK MANAGEMENT IN INFRASTRUCTURE PROJECTS

Risk management is essential for every infrastructure development project's success. Despite huge expenditures in infrastructure development projects such as energy, electricity, rail, roads, airports, and so on throughout the globe, there is relatively little evidence accessible about the performance of these investments in terms of real value and hazards [2]. This section discusses the findings of research on risk management in infrastructure projects.

3.2.1 CONCEPTUAL PERSPECTIVE PROJECTS AND PROJECT RISKS

A project in terms of project management can be defined as an endeavour to accomplish objectives to create a unique product or service [3]. Different

stakeholders may view project success in different manner. To some, it may be completing the project within timelines to others it may be completing project within certain cost while compromising on the risk of time and quality [4]. This view is also as per the Project Management Institute (PMI), which defines successful project which are accomplished within planned time, cost and desired quality. The uncertainty in a project, which leads to variation and objectives delivers project risk [5]. These three project objectives are also known as Triple Constraints or the Iron Triangle.

Mega infrastructure projects involve huge investment and are subject to risks which may result in monetary losses due to delayed development or lack of resources [6]. Risk is a concept which is the product of likelihood that an event will occur and the impact it may have if it happens [7]. Risk assessment involves the identification of individual risk factors [8]. Project success focused organizations not only are concerned on successful project implementation but also on how they execute and manage the projects [8]. It is seen that land development communities across the world experience diminished infrastructure performance and increased costs, both operating and capital resulting from unmanaged development. Cost overrun happens in roughly in 90% of the cases where final project costs may be higher in range of 28% as compared to their estimated costs. For instance, large multi-phased transportation infrastructure highway project in the United Arab Emirates (UAE) with an initial budget approved approximately US $100 million was completed at a cost nearly 4 times of estimated cost with significant time delays and contractual issues [9].

The mega projects require high focus on project completion time, cost management and quality control while strong coordination between the project entities. The issue of overshooting the cost of project is a global phenomenon whereas project characteristics of reasons can be local region specific. It therefore becomes very important that all these features and indicators are closely evaluated and monitored. Risk environment may change with project specific conditions, management techniques and construction management.

3.2.2 PUBLIC-PRIVATE PARTNERSHIP (PPP) PROJECTS

Public-Private Partnership (PPP) is a contractual agreement structure, which is very keenly progressed as a model for infrastructure growth and is used to finance infrastructure projects in both developed and developing countries [10]. While PPP model has been very effectively used in various countries globally to source private equity in recent years, there is varied outcome in terms of success of these projects [11]. PPP procurement processes are complex by nature, with longer time frames and wider scope of contracted services [12]. Private sector has been seen to control the risks as compared to public sector to get it implemented through their stakeholders and partners [13]. The existing problems in PPP model and its intrinsic characteristics can be addressed with enhanced control over the partners making apart with high level of diligence. Strong Governance in project management and control plays a critical role in project success. This, governance, risk and compliance can bring enormous benefits to an organization when used and implemented correctly in projects.

The risk of failing large infrastructure projects is due to a decrease in risk management at different stages of the project life cycle. Companies' sophistication in risk management practice determines the level of maturity of their risk management on projects. Work together on recommendations and strategies for joint energy and project cost management [14]. The overall organizational factor such as optimism level, complexity, open culture, and effective communication in project organizations strongly influences early risk warning.

The planning framework can support looking into the risks, openness or flexibility in the planning process. Improper bidding pricing is one of the critical causes of cost deficiencies. There are multiple causes for the project to fail such as gap in project objectives linkages between the project organization priorities and developer alignment to the same. There needs to be agreed measures of success with intermediate milestones. Project priorities should have proper integration with programme. Training and education of project team and

managers play an important role to support risk management practices execution on ground [15].

3.2.3 IMPORTANCE OF RISK MANAGEMENT IN INFRASTRUCTURE PROJECTS

Table 3. 1 Share of Successful, Challenged and Failed Projects

	2012	2013	2014	2015
Successful 29%	27%	31%	28%	29%
Challenged 49%	56%	50%	55%	52%
Failed 22%	17%	19%	17%	19%

Source- CHAOS Report 2015 by Standish group

Risk management analogy can be drawn from software projects where the risk management practices are relatively more stable. According to the Chaos report 2015 released by the Standish Group, only 33% i.e., less than one out of three projects are only successful. There is different level of risks posed in different phases of the project development life cycle (SDLC). Companies are required to take risk in innovation and launch of new products. It is only the timely identification and management with mitigating measures to keep the impact under control.

Project management in infrastructure projects becomes challenging when goals are not defined properly [16]. Large infrastructure projects development becomes more risky as the capital investment is very high, the payback period is large, multiple stakeholders and the integration becomes a huge challenge. The focus on project success with regards to various agencies is also different [17]. Also, when there is lack of focus on risk management, the challenges in project success increases and chances of project losing to meet the objective reduces [18].

Table 3. 2 Salient project risks characteristics

Author	Risk Characteristics
Boehm, (1991) [19] **Leleur & Salling, (2015) [20]**	• Gold plating of a project improper assessment • Quality concerns of resource supplies Improper outsourcing • Quality and performance issues
Addison& Vallabh, (2002) [21]; Kardesetal.2013[22]	• Lack in defining project scope/objectives. • Improper understanding of requirements. • Limited involvement of project owners. • Senior management commitment. • Improper schedule and budget planning. • Change in requirement specifications • Inadequate skills of project Team members • Ineffective project management • Gold plating
Boateng, etal.2015[23] **Boateng, etal.2015[23]**	• Insufficient management commitment to the project • Misunderstand the requirements Change is not managed properly. • User failure to achieve customer commitment • Ineffective project management skills Inadequate user participation by the user • Inadequate to maintain stakeholder expectations • In effective project management methodology • Vague / unclear scope / goals • Frequent changes in scope / objectives

Alinaitwe et al. (2013) [24]	• Lack of Project Champion • Lack of commitment of senior management • Project ambiguity • Improper alignment of the system using local methods and process • Political games or conflicts • Lack of required knowledge or expertise Project team changes • Organizational instability • Resources are not enough
Wangetal.,(2016)[25]	• The project requirements are constantly changing • Project requirements are not adequately identified • Lack of effective project management methodology • Insufficient project planning • Inadequate assessment of resource requirements • Lack of use of new technology • The progress of the project is not adequately monitored • On corporate politics that negatively impacts the project

3.3 PROJECT RISK MANAGEMENT (PRM)

3.3.1 DEFINITION OF RISK

Risks have been defined differently by various sources. To put it simply, Merriam-Webster defines a risk as "the chance of a loss or a harm." In the context of project management, risk is defined as an occurrence or situation that might have an impact on at least one project goal. Known risks may be expected, however unknown risks cannot be predicted in advance.

3.3.2 RISK SOURCES, RISK TYPES AND CLASSIFICATION RISK SOURCES

Although uncertainty and risk are two different concepts, they can all be used in the same way. Uncertainty is the existence of multiple previously unknown events, and risk is a type of uncertainty with unintended consequences. 80% of managers see only side effects as harmful. When uncertainty is measured, there is only one parameter, that is, an additional impact parameter, usually based on the risk and risk of a future situation. From this description it is clear that uncertainty creates risk and that risk leads to loss.

For quantitative measurements, the probability and effect matrix can be used. Managers prefer qualitative or verbal characteristics rather than risks because they suspect that a single number does not accurately represent a wide range of risks [26]. In other words, uncertainty cannot be measured in the sense that the likelihood of future conditions is unknown and the risk of future outcomes is unknown. Therefore, this definition of risk is not only based on probability, but also on the likelihood and effectiveness of most risk management techniques and tools currently used. Risk can have multiple causes and multiple effects. In other words, one accident leads to another. Therefore, risk inter-relations can be modelled as the strength of the relationship as a network or graph of risk nodes, edges, causal relationships and edge weights. It helps to better understand each risk and re-evaluate risks and risks [27]. As the complexity of the project increases, the network becomes more complex.

3.3.3 TYPES OF RISKS IN INFRASTRUCTURE PROJECTS

It is important to evaluate these risks in detail at various stages of the project life cycle. While performing the risk analysis for any infrastructure project, there can be combinations of various risk as described under various classification approaches. The key risks to be evaluated under various approached studied above are:

Macroeconomic risks

These risks are related to the macroeconomic environment of a country and also related to the global macro environment. These are related to external factors which companies cannot control and also includes political factors. [28].

Commercial Risks

Risks that directly affect the environment in which the project operates and the trade-offs it interacts with (suppliers, associations, customers, local authorities and the environment) [29].

Competitive risks associated with competition risks associated with the market environment and all the forces that affect the market or themselves. Competitive factors and their effects fall into this category [30] .

Cost Risk

Cost risk increases due to inaccurate cost estimation or other factors due to incorrect planning and project execution. The cost increase is defined as the final cost of the project compared to the estimated cost when deciding to proceed with the project.

Environmental Risk

The risk of environmental problems affecting project development, e.g., Changes in environmental clearance or environmental regulations or project impact on the environment.

Financial risk

This is a risk that arises from a lack of proper capital and financial structure, as well as hedging. Financial risks connected with infrastructure projects must be addressed by identifying characteristics such as project scope and associated expenses; risk is further assessed by evaluating comparable projects in India.

A project's profitability and cash flow are the two most important financial metrics. Various factors, such as high interest rates, inaccurate project costs, price inflation, on-time payments, profit margins, changes in the scope of the work, the availability of funds from banks and lenders abroad, currency

fluctuations, and client or contractor defaults on financial obligations, influence both of these parameters in the construction industry. Authors such as [31], [32], and [33] have proposed this classification in their work.

Technology

Risk due to some technology going obsolete or change or wrong selection of technology.

Construction Risk

This risk entails unanticipated effects occurring within the built-in period, resulting in an increase in time and cost or a deterioration in the final project's performance standards. Projects that need a large amount of money and take a long time to complete are prone to delays and cost overruns. As a consequence, the building risks in the energy, highways, telecommunications, and urban services sectors are significant. [34] [35].

Operating Risk

During the project, the technical performance of the project may be worse than what investors anticipate. This is particularly true in quickly changing industries such as telecommunications, where technology has not been well tested. The operation of experimental operations and maintenance contractors/agencies reduce operational hazards. The contract with such firms may include a provision for liquidated damages. Some risks, including some force majeure risks, are not economically insurable at the operational stage [36].

Market Risk

Market risks may go unnoticed while considering project viability. Failure to satisfy demand expectations is sign of market risk. Investments like telecommunications, ports, and highways will incur market risk if the private maker interacts directly with intraindividual users, and consumers are generally presented with competing alternatives. Investors perform market research to

ensure that market demand projections provide appropriate profits as soon as feasible [37].

Interest Risk

Interest rate risks may arise if interest rates fluctuate throughout the course of a project's life cycle. Because of the high capital intensity and lengthy payback times in infrastructure projects, they are crucial. High capital intensity suggests that interest expenditure accounts for a significant fraction of overall cost; extended return periods imply that funding should be accessible for a long time when interest rates fluctuate. One method of dealing with interest rate risk is to pass it on to customers, who, during testing, take into account the effect of interest rate changes on unit prices exceeding tariffs [38].

Foreign Exchange Risk

There are two sorts of foreign exchange risks to be aware of. The first is exchange convertibility, which ensures that local currency proceeds may be turned into foreign currency for international payments. This risk must be borne by the government by guaranteeing a proper transition. Another sort of risk is exchange rate risk, which occurs when changes in exchange rates produce a significant rise in the internal currency cost of a payment denominated in a foreign currency [39].

Payment Risk

These may be linked to the consequence of government acts or to power. Infrastructure investors run the risk of not being able to pay for delivery services. The significance of this risk varies according to geography. This is particularly true when an independent sector power producer is required to deliver energy to a monopoly customer. There is no other market for manufacturing output since the economic situation of public sector utilities in underdeveloped countries is quite poor [40].

Regulatory Risk

Changes in the regulation of specific parts of the company, such as law and tax, are among these risks. Regulatory risk develops when infrastructure project developers must interact with numerous government and regulatory organisations during the project's life cycle, as with PPP projects. Control measures are implemented. Extensive regulatory permissions are necessary both at the start and during the project's implementation. Another source of regulatory risk is that as the project progresses, environmental expenses and requirements grow more strict, increasing operating costs [41].

Political Risk

Infrastructure projects are very visible and constantly a source of public attention. It hurts them in business operations that disrupt or disrupt commerce; in severe situations, this may result in licence revocation or nationalisation. Arbitration procedures may be addressed by integrating suitable compensation amounts into the project contract, which is subject to international arbitration. Another new instrument that may be beneficial in this context is the World Bank risk guarantee tool, which includes payments when there is an interruption in the fulfilment of certain government duties [42].

Design Risk

When a project brief is clarified and instructions are prepared, design is the process of generating a solution. As a result of design efforts, many risk factors have contributed to the project's delays. Delays and errors in the preparation of design information, inadequate surveys and tests of feasibility, misunderstandings of customer needs by the design engineer, differences in site (ground) circumstances and a lack of experience among the construction team are just a few of the problems that can arise [32].

Resource

All of the resources required for an infrastructure project, including material, labour, and equipment, must be procured in large quantities. Planning and timely purchase and administration of these resources need considerable effort. A number of resource-related risks have been identified in the previous study,

including a lack of sufficient labour and equipment, a lack of high-tech equipment, and delays in the acquisition and delivery of materials [32].

3.4 RISK CLASSIFICATION

Approaches to Infrastructure Project Risks Classification

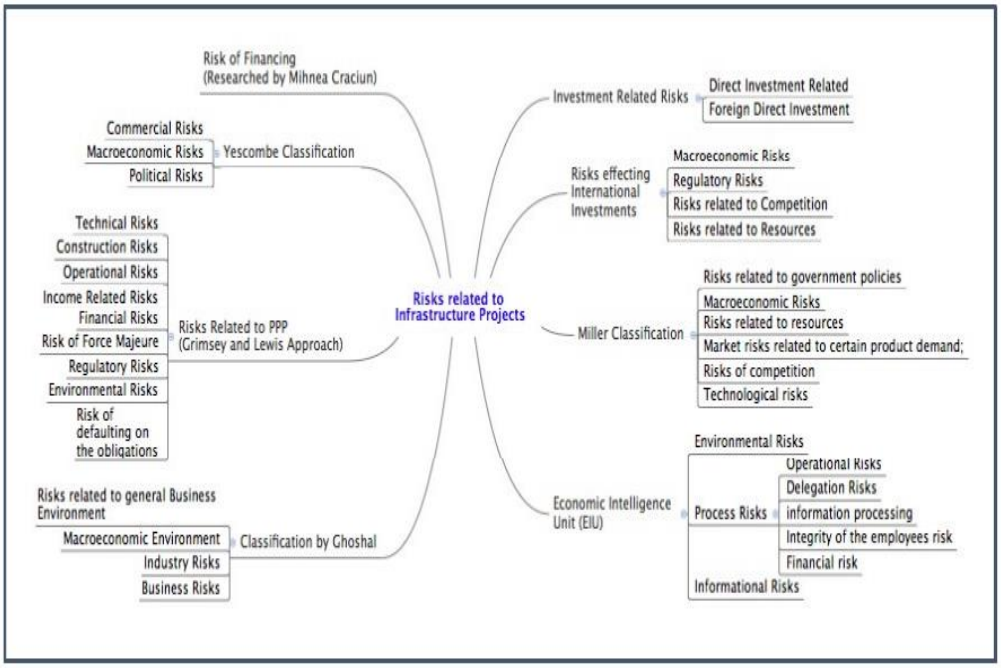


Fig 3. 1 Salient approaches to risk classification

As indicated in Fig. 3.1, there are various approaches to classify risks in infrastructure projects. This can depend upon the nature of the infrastructure projects, i.e., mega public projects like transport infrastructure, airports, energy projects or projects development on PPP model, private commercial development projects, etc.

The broad classification can be based on Investment-related (Direct Investment or Foreign Direct Investment) - From this perspective, the risks of an investment project in infrastructure are related to risks having effects on any FDI. The risk analysis, however, involves the same tools of analysis.

Miller's Classification (2007) - It classifies risks into six main categories: government policy risks, macroeconomic losses, resource losses, market losses related to certain product needs, competitive risks and technical risks.

Classification based on the Economic Intelligence Unit (EIU) As per this classification, risks are divided into three categories - Environmental (common risks that do not affect the company), Process risks (relative risks to the company's objectives, but not the risks) and Informational (risk related to inadequate information). The EIU classification sub-classifies each risk. Process risk involves operational risk related to customer satisfaction, human resource efficiency, efficiency, product cycle and environmental impact.

Classification based on approach macro parameters The approach was put across by [43] which identifies four types of risks affecting international investments which are Macroeconomic Risks, Regulatory Risks, Competition related and resource related risks.

Classification by [44] A relative simplified classification approach which categories risks into three major areas commercial, macroeconomic and political risks has been presented.

Risk of Financing This is the fourth dimension suggested by [45] in addition to the three above. This is related to risks of financing propped up during the global financial crisis during 2008-10. This risk is determined by events which can lead to loss of project funding opportunities.

Risk Management Process

Risk assessment involves assessing the risks and impacts of expertise or experienced team members using common methods such as describing responses or using advanced techniques such as analytics, risk analysis, risk matrix and SWOT analysis. Sequence process, complex path method and Monte Carlo simulation.

Risk response planning involves developing plans to mitigate the effects of inadequate rewards and minimize the negative impacts of inevitable risks. This includes plans to transfer risks to a more appropriate agency to handle risks through insurance and contracts.

Risk control and monitoring, periodic risk review, overcoming project costs from budget and project time according to schedule, proper risk reporting through communication and knowledge management.

Table 3.2 A: Summary of Risk Management Techniques in literature

Strategies		Descriptions
Risk Control	Risk avoidance	Organization refuses to accept any exposure to loss arising from a particular activity
	Risk terminating	Eliminate the risk completely(refer by some scholars as Risk avoidance)
	Risk prevention	Limit the possibility of undesirable outcome being realized (refer also by some Scholars as Risk reduction)
	Risk reduction	Limit the likelihood of occurrence of a loss and the severity of the impact
	Risk directive	Ensure that a particular outcome is achieved
	Risk detective	Identify undesirable outcomes experience after the event
	Risk corrective	Correct undesirable outcome that have happened, providing a route for recovering
Risk Financing	Risk retention	Maintain risk within the organization
	Risk toleration	Accepting and retaining the risk or opportunity
	Risk sharing	Sharing the risk with other entities through the establishment of a contract or agreement
	Risk transfer	Transfer the risk to a subject that provides support in exchange of a premium

3.5 TOOLS, TECHNIQUES AND RISK ASSESSMENT MODELS

Although systematic methodology, expertise, and experience in project management are required for an effective and efficient risk management strategy, past research in Chile has revealed that both project promoters and developers do not employ suitable risk management techniques, which has an influence on project performance. It is also critical that risk management strategies be used in any construction project from the start of the project to get the most out of the procedures. The measurement of risk management procedures is the beginning point for determining an organization's risk management capacity. A significant amount of work has gone into establishing different approaches, tools, standards, and procedures for dealing with project risks. Many various strategies are based on the integration of risk management into a structured process to tackle complexity and uncertainties in a project [46].

Most risks are usually difficult to detect due to inadequate information available or inadequate access [47]. Monte Carlo simulations have been used to large-scale the statistical distribution functions of project duration at the end of a project [48]. The most commonly accepted methods are to assess the likelihood of risk and its effects on common criteria, e.g., Limits can also be defined numerically from 1 to 5 or more. The quantitative methods used in risk assessment currently include an event (probability) and its consequences or effects sensitivity analysis, and the estimation ranking method of the Monte Carlo simulation, Fuzzy Set, Analytic Hierarchy Process (AHP). Analytic Hierarchy Process (AHP) is an effective technique used to solve a problem in a complex, unpredictable and multi-criteria situation. Monte Carlo simulations are commonly used for this analysis to reduce the impact of uncertainties and risks on project budget and schedule [49].

3.6 RISK ASSESSMENT MODELS

Various risk management models have been examined in order to present an acceptable framework for construction project risk management. The models explored by Kangari and Riggs (1989) [50] were classed as classical or conceptual. It's not uncommon for key models to serve several purposes, such as public-private partnerships or High Speed Railway projects and their application to economic and social growth. Only a few models depend on well-known phenomena, such as matrix propagation and network analysis, for their foundations. Others are based on linguistics and the manager's own experience. These models have been studied and combined and modified to overcome their flaws. The goal is to come up with an all-encompassing framework.

Researchers suggest a formalized, structured approach to identifying, measuring and mitigating risk. These include the Delphi method, checklists, module decomposition, energy field analysis, control analysis, SWOT analysis, root-cause analysis, process flow charts, impact diagrams, and scenario analysis [51].

The Fuzzy Logic telephone framework allows not only zeros and values to be values, but any real number between zero and one as opposed to Boolean logic.

Many mathematical models based on fuzzy logic are designed to test risk- based scenarios of supplier selection, capacity estimation and appropriate warehouse environmental issues [52].

The Artificial Neural Networks (ANN) method of combining computer science and biological science is used to create vendor management systems, expertise systems for sales and raw materials, needs to be evaluated based on various factors, most notably the major distributed network bullwhip impact minimization and others.

Although this short literature review covers current issues on resource / distribution risk management, it also highlights the potential for research to model supply risk using wide spectrum of risks covering political, social, technical, economic, financial and also Human resources areas. There is still the possibility of integrating the methods reviewed above from a industry perspective. Some recent studies have developed the BBN model, but not all of the industry-specific supply chain risk factors are comprehensive. This research provides an empirical model for estimating industry-specific risks by combining the relevant aspects of the various methods mentioned above, including economic, financial, supply chain and natural disasters. A growing body of literature includes methods for risk assessment, which are used for supplier assessment and selection [56].

The Bayesian network modeling approach [57] is the latest model to incorporate quantitative data and the opinions of subjective experts. [58] explored a new methodology using Bayesian networks to determine the overall risk of a supplier and the impact that the supplier has on company cash flows. Distributing risk profiles may help detect and isolate risk events that have a bigger influence on cash flow, according to these researchers. [59] used Bayesian trust network modelling to predict supply chain risk. The model's binary presentation of risk variables leaves out critical supply chain risk considerations, which is one of the model's flaws.

Financial ratings and proxy variables taken from financial statements can be used to model supply risks, even though contemporary challenges in resource /

distribution risk management are included. For scalable subjective factors, a solution can be found using the Bayesian network model. The ex-Anti-Supply Network Risk Assessment Model, based on Orders of Magnitude AHP (OM-AHP), developed by [55], allows the comparison of intangible and intangible factors that affect distribution risk. However, there is no guidance structure on how to pivot using OM-AHP. Risk assessment in different product categories using cognitive maps and AHP methodology. There is still the possibility of integrating the methods reviewed above from an industry perspective. Some recent studies have developed the BBN model, but not all of the industry-specific supply chain risk factors are comprehensive. This research provides an empirical model for estimating industry-specific risks by combining the relevant aspects of the various methods mentioned above, including economic, financial, political, environmental, funding, technical and human resource risks.

Here are some qualitative and quantitative tools / techniques often used for project risk management in the literature:

Checklists: Checklists contain questions about risks, risks and risks and are a control tool for assessing against established security levels. Hazardous

Activity: It is used to identify reasons for not meeting the quality and product objectives specified for the process plant [60].

Risk Matrix: It involves the production of probabilities and consequences. Obtaining quantitative data is difficult, so it may be the subjective judgment of experts.

Risk Mapping: Individuals engaged in various risk areas measure risk in the relevant risk area according to user-defined criteria.

Delphi-Technique: Many evaluation questions are answered anonymously by the Expert Panel. It is necessary to do the evaluation once again. It is now possible for experts in different fields to set different standards of performance. Until a decision is made, this procedure is repeated.

Fault Tree Analysis (FTA): looks at what causes fatal accidents.

Jonson Analysis: Analyzes probabilities and consequences and categorizes them to a certain extent.

Simulation Methods: Methods such as Monte Carlo and Petrie Nets are used to estimate the likelihood of an event and the impact of risk prone events.

Decision trees: Analyzing objectively and subjectively through practices such as expert knowledge.

3.7 RISK MANAGEMENT FROM LOGISTICS' INFRASTRUCTURE PROJECTS PERSPECTIVE

The fundamentals of risk management are widely understood. There should be a way to divide the costs between those who can bear them and those who can't. As a result, the project's risk may be reduced by transferring these risks to other authorities. In most cases, the sponsor's tariff covers the costs associated with this process of reversing losses. A lower tariff and lower risk management costs result from successfully transferring risks to people with the necessary skills.

Complex risk mitigation strategies are common because of the various players involved, including project sponsors, financiers, government agencies, and regulatory bodies. Legal and commercial agreements specify the responsibilities of each partner and the consequences of failure to do so. Investors are protected against events that are beyond of their control. Implementation is typically delayed due to the intricacy of these arrangements. Many governments don't know about these agreements since they aren't used by the public sector. PSUs that acquire gasoline from other PSUs are exempt from the punitive penalties demanded by the private sector in fuel supply agreements. For example, they do not want the same degree of security, such as a promise to ensure power purchase agreements or incentives or penalties for power purchase. A more broad definition is that public sector mediators for conflicting commitments are typically regarded as flexible, without the need to engage into carefully specified and legally bound agreements. When interacting with the private sector, anticipate a high degree of passion.

Risk Mitigation - The issue is whether private sector initiatives requiring risk reduction are too costly as compared to public sector ones. This is dependent on whether the project is undertaken by the public sector and whether the risks are real and there is a high premium paid to reduce the risk.

The possibility of not having public sector initiatives might be a problem for private sector projects. Many private investors are worried about the lack of transparency in government policies, the absence of a credible regulatory agency, and the unjust political actions of the political establishment. Many investors are put off from making investments in the private sector because of their high-risk awareness, leaving only those prepared to take a risk for the sake of a higher return on their investment. In the end, the customer pays the price for this high revenue in the form of increased tariffs (or lower license fees received by the exchequer, where the tariff is constant). The greater expenses in these cases are not related to risk reduction, but rather to lower risks and make more money in the long term.

3.8 RISK MANAGEMENT STANDARDS

While risk management may be defined variously up until it is a process or a global strategy. Subsequently, risk management may include activities involved in recognizing, analyzing and judging risks, taking steps to minimize or predict them, and monitoring and reviewing progress Office of Government Commerce [61]. It pertains, furthermore, to the formal process through which people, organizations and communities identify and mitigate risks following general goals [62]. Risk management refers, furthermore, to all actions associated to discover, assess, and evaluate possible risks, take the right steps to address them, and monitor such risks by monitoring and evaluating risk management effectiveness [63][64]. Moreover, it has contributed to growing knowledge regarding risks and their management. However, likewise it has led to recognizing risk management as a management discipline in its own right [66].

In this context, we have observed a proliferation of risk management standards. This predicament is a consequence of the increased relevance of risk

management for both commercial and governmental businesses. If many private firms employ risk management; they want to cope with uncertainty, fulfill their objectives, and strengthen their resilience. While, public organizations who are confronted by their quest of efficiency, the diversification of public procurement instruments and the establishment of numerous partnerships; integrating risk management inside adding furthermore to resources optimization. This is especially true for municipal administrations too. However, the function and professions of municipal authorities cannot be equated to those of any commercial or public entity. As a territory manager, local authorities in addition to the pursuit of performance, they are in charge of a supplementary and distinctive social mission which consists of insuring people well-being [64].

Table 3.3: Linguistic definition of risk impact

Standard	Author	Year	Scope
AS/NZS 4360: 1997 Risk Management	Standards Australia/Standards New Zealand Standards Association	1995	This Standard provides a generic guide for the establishment and implementation of the risk management process involving the identification, analysis, assessment, treatment and ongoing monitoring of risks.
BS 8444-3:1996 : Risk management - Part 3: Guide to risk analysis of technological systems	British Standards Institution	1996	This Standard provides guidelines for selecting and implementing risk analysis techniques, primarily for risk assessment of technological systems
CAN/CSA-Q850-97: Risk Management: Guideline for Decision-Makers	Canadian Standards Association	1997	This Standard is intended to assist decision-makers in effectively managing all types of risk issues, including injury or damage to health, property, the environment, or something else of value
Treasury Board of Canada:Integrated Risk Management Framework	Secretariat of the Treasury Board of Canada	2001	This Standard provides a comprehensive approach to better integrate risk management into strategic decision-making.
JIS Q 2001:2001 Guidelines for Development and Implementation of Risk Management System	Japanese Standards Association	2001	This Standard provides principles and elements for the establishment of a risk management system.
OGC: Management of Risk: Guidance for Practitioners, The Stationery Office Books	Office Government Commerce	2002	This Standard is intends to help organization put in place an effective framework for taking informed decisions about risks
FERMA, AIRMIC,ALARM, IRM: Risk Management Standard	Institute of Risk Management (IRM) and Al	2002	The standard represents best practice against which organizations can measure themselves.
COSO Enterprise Risk Management - Integrated Framework	Committee Of Sponsoring Organizations Of The Treadway Commission	2004	This framework provides practical illustrations of techniques used at various levels of an organization in applying enterprise risk management principles.
ISO : 31000 Risk management - Principles and guidelines	International Organization for Standardization	2009	Standard provides principles and generic guidelines on implementation of risk management.

3.9: THEORETICAL PREMISE OF THE STUDY

The study is pertaining to the area of unsystematic risk management in construction and operation of India's first High Speed railway system. A few theories of Risk Management which prominently find a mention in the risk management literature are:

- Financial Economic approach (Market Financial Risk)
- Agency Theory (Separation of ownership and control)
- New Institutional Economics (Improving Governance process for Risk Management)
- Stakeholder Theory (Freeman, 1984)

Considering the vastness of the project in time, money and environmental externalities, the stakeholder's view (multiple) has to be kept at the center.

In the subject case under research, the researcher, after a profound erudition on the subject, is of the opinion that that reconciliation of interest of stakeholders are the main determinants of a corporate Risk Policy and therefore the Stakeholders Theory would provide an ideal underpinning to the subject research.

This study would add to the theoretical development by integrating the Stakeholder theory with the concept of risk differentiation between similar risk dimensions but in different backgrounds and contexts. The present study attempts to address the gaps that exist in literature in respect of mega infrastructure projects, particularly the High Speed Rail project, in developing countries like India.

Chapter-4

Research Methodology

4.0 RESEARCH GAPS

Though quite good research has been conducted on various facets of project risk management, there is limited study in identifying why big infrastructure companies do not follow a framework for risk identification and mitigation. Though various risk assessment methods are available and suggested in earlier research, there is a need for in-depth Risk impact assessment and presence of strong risk management framework as a tool, which can be used by the project leaders to identify, analyze, prioritize and address relevant risks on priority in the very beginning of the projects. Irrespective of many tools developed due to complexity and lack of data, project managers lose sight of risk assessment, so there is a need to develop a new assessment framework, which integrates all stakeholder and all the project phases and aligned towards the overall strategy of Infrastructure development. E.g., the risks management framework would integrate both strategic goals and execution of the research because in most of the cases the execution team is not aligned to the overall strategy and purpose of the project thereby the strategic objectives and execution plan remains disintegrated at all levels. The framework also needs to be tested for its applicability. A Risk Management Model is not developed for a High-Speed Railway system and the relationship with Operating Losses is not analyzed.

Problem Statement:

A recent article published in the November issue of "National Geographic" was titled "Massive Infrastructure Projects Fail at Unprecedented Rates." It stated

that "in India, multiple big energy projects in Assam, Tamil Nadu, Arunachal Pradesh, and other states have been stopped owing to farmer protests and natural calamities." A variety of ecological, social, market, and investment dynamics have recently aligned on six continents to thwart many governments' development ambitions."

Hydroelectric power projects pale in comparison to the size and scope of investment required for a High-Speed Rail project. The massive magnitude of this gigantic High Speed Rail project's designing, engineering, and planning confounds construction timetables and cost evaluations, making it more difficult and riskier than previously.

Infrastructure projects such as High-Speed Railways are massive in scale. The causes of a typical infrastructure project's failure are extensively documented. However, risk variables that can cause a High-Speed Rail project in a developing country to function and succeed or fail are not studied considering the fact that such a scenario never existed. Now with India taking the plunge into this uncharted territory of HSR, any of these reasons are interconnected and can be avoided if they are anticipated ahead of time.

Such initiatives have only been done by wealthy and high-GDP-per-capita countries, not by any underdeveloped country. It is the first time that a developing (if not impoverished) country like India has undertaken such a costly and challenging endeavor.

Business Problem:

There is a shortage of research estimating the demand for HSR in India and other developing countries, as well as the hazards involved with it. Without a risk management model, the majority of countries' high-speed rail systems are already operating at a loss. The emphasis on building new HST systems is a consequence of dealing with the relationships between climate change, transport, and space, in which the logic of speeding up and increasing efficiency through new road construction and expansion is losing support. The available literature is scarce on the subject of passengers’ preference for High-Speed

Railways (HSRs) and High-Speed Trains (HSTs). Though the transport mode is seen as green, safe, and sustainable, and the network also has important economic and social effects at the regional level, the evaluation of passengers' preference and other risks that may afflict the HSRs/HSTs in the context of developing nations like India presents some gaps that need to be addressed in future studies.

4.1 RESEARCH PROBLEM

A Risk Management Model is not developed for a High-Speed Railway system in a developing country like India and the relationship with Operating Losses is not analyzed.

Research Questions

RQ1: What are the risks associated with High-Speed Railway System in India?

RQ2: What is the Risk Management Model for the High-Speed Railway System in India and what is its relationship with Operating Losses?

4.2 RESEARCH OBJECTIVES

RO1: To identify the risks associated with High-Speed Rail system in India.

RO2: To suggest a Risk Management Model and its relationship with Operating Losses.

Objective 1:

Various risk variables along with their categorization relevant to large infrastructure projects shall be identified through Literature review, then were revised by Nominal Group Technique while formulating the Questionnaire. Research Design is exploratory research.

Sampling Design

- Non-probabilistic sampling
- Judgmental sampling due to limited expertise in the area

Statistical tools:

In order to answer this research objective, initially an exploration method based shall be utilized on the secondary data analysis of literatures for risk variables. Initially, this involves classifying of all the available risk variables identified

Since these risk variables are generic to infrastructure projects, and to befit the objective of this study, these risk variables will be further analyzed using Nominal Group Technique.

Source of data: National Statistics, IMF, World Data Bank, UIC, Paris, Ministry of Railways, Federal Rail Authority, USA

Objective 2:

Significant risk variables identified from Objective 1 will be utilized for the analysis towards **formulation of the Risk Management Model**, using both exploratory and quantitative research design.

Sampling Design

- Non-probabilistic sampling
- Judgmental sampling due to limited expertise in the area

Anticipated uses of the Research:

- The High-Speed Rail project between Mumbai and Ahmedabad can be the first in a series of many similar projects. This research for developing a Risk Management Framework for High-Speed Rail projects in India is anticipated to be used in justification of all future HSR projects in India including validation of forecasts and ascertaining the project feasibility and financial viability.

4.3 DATA COLLECTION

A relatively informal method to assist in identification of a problem, classifying issues relevant to a topic and to evaluate problems is a method of expert opinion. A group of experts is a better option for consultation to bring in wide range of

experience and knowledge. It should be ensured that the prior knowledge of the design or the evaluated product is not made available to these experts.

Considering the exceptional knowledge and experience in dealing with infrastructure projects of such gigantic nature, the experts were identified and their opinion was sought.

Thus, academics and practitioners with relevant expertise in the High-Speed Rail industry have participated in this study. 70 experts were asked to participate in the Research survey by completing online questionnaire which was sent by email to them. As a result, 45 experts' opinion were received as a response to questionnaire. Because more than 45 experts responded and engaged in this research, this decision-making challenge is classified as Large-Scale Group Decision-Making (LSGDM). At least 20 professionals are needed to solve LSGDM problems.

4.4 MONTE CARLO METHOD

Monte Carlo simulation has been employed in this study. Computerized Monte Carlo simulation is a risk-aware quantitative analysis and decision-making tool. In areas as diverse as finance, manufacturing, engineering, research and development, insurance, oil & gas, transportation and environment, professionals are using this method.

A probability distribution is substituted for any element that has inherent uncertainty in a Monte Carlo simulation to generate models of likely outcomes. A fresh set of random values from the probability functions is used each time the results are recalculated. A Monte Carlo simulation may need hundreds or thousands of recalculations until it is complete, depending on the quantity of uncertainty and the ranges selected for them. Distributions of possible outcome values are provided through Monte Carlo simulation.

By employing probability distributions, variables may have various odds of distinct events happening. Probability distributions are a far more realistic approach of representing uncertainty in variables of a risk analysis.

Monte Carlo simulations are frequently taught by analogizing them to any type of chance, hence the slot machine image. At any point in time, based on an action, several events can occur in the subsequent time step. Monte Carlo simulations allow us to run as many trials as we desire within the simulation. Monte Carlo's fundamental formula is as follows:

$$Today's\ Event = Prior\ Event * e^{(Drift + Random\ Spirit)}$$

Monte Carlo Simulation Model runs stepwise as the following:

- All project tasks are assigned and data is sent into the Monte Carlo automation.
- The program displays various timetables, including the likelihood of completing a task within a certain number of days (as discussed in the example given above).
- After generating plausible timetables for the individual jobs, a series of simulations is performed using these probabilities. There are many thousand Monte Carlo simulation project management tools available, and they all generate end dates.
- Thus, the Monte Carlo Analysis produces a PROBABILITY CURVE rather than a SINGLE result. This curve illustrates the anticipated completion dates and probability values for specific jobs.
- This curve enables project managers to develop the most likely and sensible plan for the project's completion and to present a believable timeline report to clients and upper management.
- Similarly, the Monte Carlo method of project management is used to develop a project's costing or budget.

Monte Carlo is an appropriate risk assessment tool since it helps professionals to convey their subjective judgment using language factors. It is used in the HSR for risk assessment and ranking. As far as latent variables are concerned, a few latent variables or happiness , morale quality of life, conservatism etc which cannot be directly measured.

4.5 RISK IDENTIFICATION

Following the extensive literature review, consultations and discussions with experts, the following risks factors have been identified and have been segregated in the following 6 categories for carrying out further research and analysis:

CATEGORY - 1: POLITICAL, REGULATORY, ENVIRONMENTAL AND MACROECONOMIC RISKS (PREM)

It includes:

- Risks related to decline in stakeholder support (Sovereign- at the Central government level)
- Risks related to decline in stakeholder support (Sub-Sovereign- a regional or local government body)
- Risk that an investor's returns could suffer as a result of political changes or instability in the country
- Risks related to possible economic and political sanctions.
- Legal and litigation risks on miscellaneous reasons
- Environmental risks related to observance of ecosystem of the area in sensitive zones,
- Risks related to management of waste, noise, air pollution, loss of green cover in residential zones
- Failure to perform hazard and operability (HAZOP) studies
- Risk related to a possible Cyber-attack
- Risk related to a possible *Global fiscal crisis*
- Risk related to a possible Internal *fiscal crisis*
- Risk related to a Global *Energy Price shock*

CATEGORY - 2: FINANCING/ FUNDING RISKS (FFR)

It includes:

- Risks related to arrangement of finances from foreign Multilateral/ Bilateral conditional/ tied loans

- Refinancing risks in construction/ operating phase
- Risks related to foreign exchange rate variation, Currency transfer and convertibility risks, Credit risks with financial institutions (donors unable to meet contractual arrangements of funding)
- Risks related to Non-compliance of contractual arrangements (by the borrowers) with Multinational Development Banks
- Risks related to financing or funding of increase in cost estimates (prices and quantities), Liquidity Risks of Construction / Operating companies
- Inflation risk leading to erosion of purchasing power of Indian currency, Interest rate risks during construction and operation phase, both India and in donor countries

CATEGORY - 3: HUMAN RESOURCE, DESIGN, CONSULTANCY AND MANAGEMENT RISKS (HRDCM)

It includes:

- lack of skilled experts on HSR technology on client's side, risks due to
- lack of skilled executive teams with construction companies
- Lack of knowledge to understand your project by contractors.
- Absence of standard specifications for High-Speed Rail in India for components like signaling, safety, Rolling Stock and interface issues
- *Risk related to possible sub- optimal* designs, both in a concept design or a detailed design, *Failure to identify the optimal location of stations in the cities to ensure ideal multi-modal connectivity*
- Failure to identify intra-organizational communication system.
- Restrictions on use of professional consultation and alternative designs by foreign / Indian companies, particularly related to possible conditions in the bilateral financing arrangement
- Risks related to successful long-term operations due to lack of an appropriate management structure, particularly regarding separation of ownership of Infrastructure and Operations
- Lack of optimum work culture (in India) required to construct and

operate such complex large infra projects

- Risks related to management capacity in handling possible revenue shortfalls, mounting debts and handling refinancing options

CATEGORY - 4: CONSTRUCTION, TECHNOLOGY, LAND ACQUISITION, QUALITY, CONTRACT RISKS (CTLQC)

It includes:

- Right of way (Land) acquisition delays due to poor record and disputed ownership
- Right of way (Land) acquisition delays due to inadequate /unsatisfactory compensation leading to litigation
- Preventing implementation of the project in agricultural lands
- Preventing implementation of project in government-owned lands
- Lack of proper implementation plan including swift decisions to contractors
- Lack of appropriate advanced of material /equipment including poor quality and adequate safety arrangements at construction sites

CATEGORY - 5: COMPLETION, COMMISSIONING AND HANDING OVER RISKS (CCHO)

It includes:

- Risks related to Testing and Commissioning of the HSR system-inadequate experience
- Risks related to final Approvals/Permits
- Risks related to inadequate repository of knowledge with the Public Authority granting approvals
- Change of Control or Transition Risk on completion of the project.

CATEGORY - 6: REVENUE, O&M COSTS, RIDERSHIP, NON-FARE REVENUE, REPLACEMENT COSTS RISK (RORNR)

It includes:

- Risks in Contractual robustness/ enforceability in regard to Operation contracts
- Risks of inflated ridership estimates leading to reduced fare revenues
- Risks of inflated non-fare revenues like advertisements etc.,
- Reduced success in commercial exploitation of station area real estate due to complicated processing and uncertainty in lease/ownership rights
- Time and cost escalation of the project due to various risks discussed earlier
- Risk of lower O&M costs at estimation stage and higher O&M costs during operation
- Risk in insufficient attention to development of stations as commercial profit centers
- Risks of dispute in sharing of revenues among shareholders and the SPV
- Risks of refinancing or change in concession agreements in case of reduced ridership.

4.6 Qualitative Data

The current analysis of the literature demonstrates that a variety of methodologies have been utilized to evaluate the risk associated with construction projects and to rank them. In general, these techniques can be classified as qualitative or quantitative. Qualitative methods were employed less frequently in risk assessment procedures than quantitative methods. Quantitative risk assessment and ranking strategies included the relative relevance index, probabilistic and statistical approaches, analytical hierarchical process (AHP), fuzzy analysis, and Bayesian network. The relative relevance

index was the most often used quantitative tool for risk estimation, followed by probabilistic and statistical approaches.

To evaluate risks, a questionnaire was developed and a survey was conducted. The questionnaire's first section dealt with risk assessment while the second section of the questionnaire sought responses from academics and practitioners with relevant knowledge in the High-Speed Rail business on their opinion on each of the risks categories and risk factors identified above.

The Likert scale of five points has been chosen to allow the experts to express how much they agree or disagree with a particular statement.

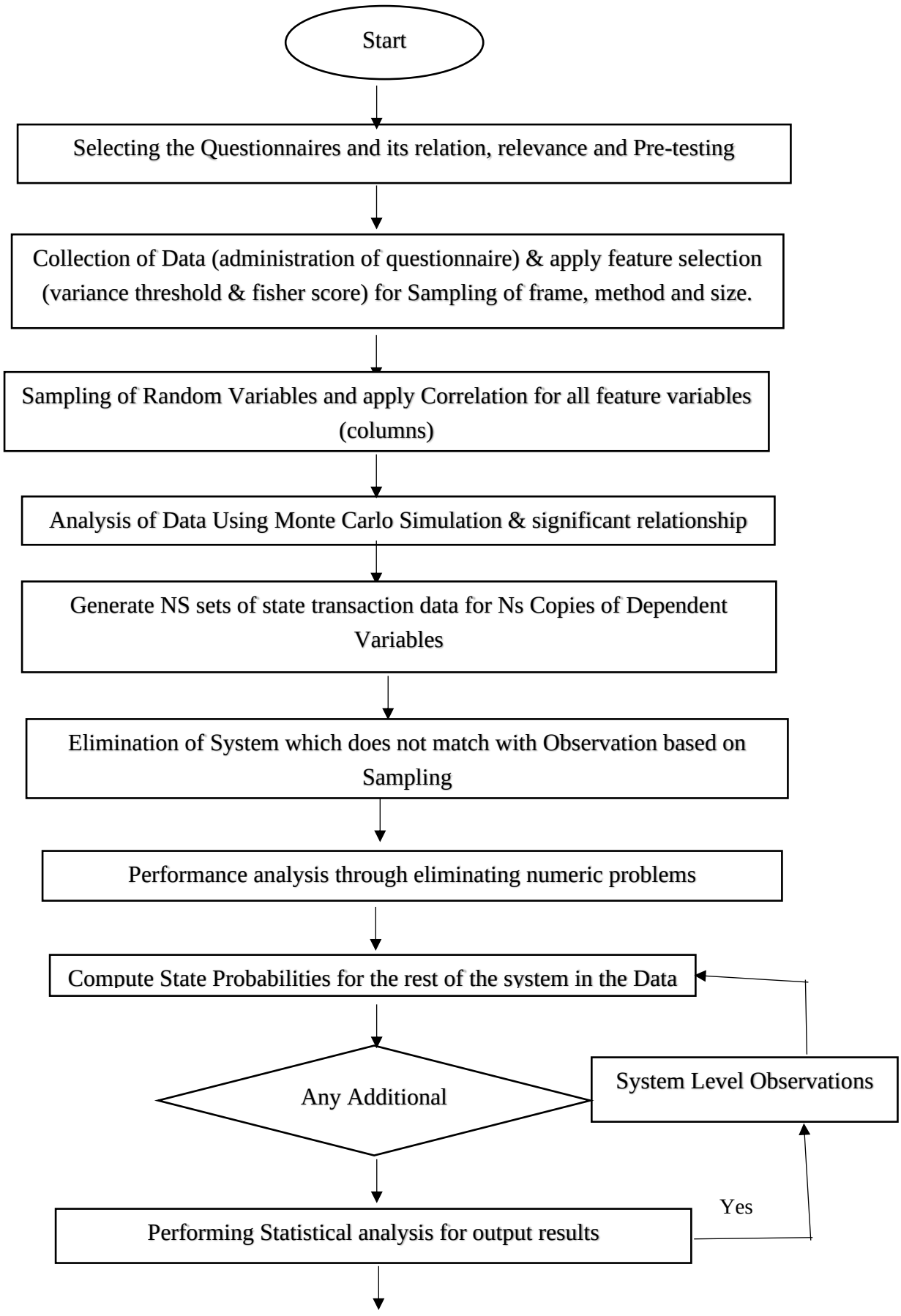
A five-point linguistic scale with corresponding definitions of possible RI (risk identification) and D (description) values is chosen as responses to each of the questions (risk factors) in the questionnaire for Risk factors identified above.

Table 3.3 Linguistic definition of risk impact

Risk Impact	Description
Very low	Cost and time overrun is less than 1%; project scope or quality change is not noticeable.
Low	Cost and time overrun is between 1% and 4%; few areas of project scope or quality are affected.
Moderate	Cost and time overrun is between 4% and 7%; major areas of project scope or quality are affected.
High	Cost and time overrun is between 7% and 10%; changes in project scope or quality are unacceptable.
Very high	Cost and time overrun is more than 10%; project scope or quality does not meet business expectations.

4.7 FLOW CHART FOR ANALYSIS OF DATA:

The following is the flow chart of the process adopted to carry out the analysis of the Data collected, as described above. First the data will be analyzed for the risk dimensions within each category separately and then an overall analysis will be carried out for the 6 categories among themselves using the same flow chart.


Start
Selecting the Questionnaires and its relation, relevance and Pre-testing
Collection of Data (administration of questionnaire) & apply feature selection (variance threshold & fisher score) for Sampling of frame, method and size.
Sampling of Random Variables and apply Correlation for all feature variables (columns)
Analysis of Data Using Monte Carlo Simulation & significant relationship
Generate NS sets of state transaction data for Ns Copies of Dependent Variables
Elimination of System which does not match with Observation based on Sampling
Performance analysis through eliminating numeric problems
Compute State Probabilities for the rest of the system in the Data
Any Additional
System Level Observations
Yes
Performing Statistical analysis for output results

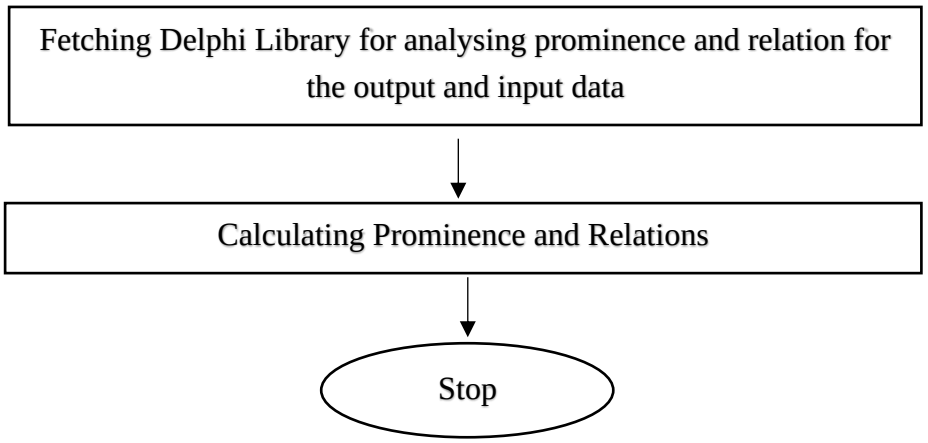


Fig 4.1 Flow Chart of work

1. Collecting and Dividing the Data into 6 Categories via performing feature selection and extraction: -
   a) PREM = Political, Regulatory, Environmental and Macroeconomic Risks.
   b) FFR = Financing/ Funding risks
   c) HDCM = Human Resource, Design, Consultancy and Management risks
   d) CTLQC = Construction, Technology, Land acquisition, Quality, Contract Risks
   e) CCHO = Completion, Commissioning and Handing Over Risks
   f) RORNR = Revenue, O&M Costs, Ridership, Non-fare revenue, Replacement costs Risk
2. Sampling of all variables and calculating correlation matrix of all the features (variables).
3. Starting Monte Carlo analysis from the correlated data based on its correlation significance.
4. Generating a set of transition data and copy of its dependent variables.

5. Eliminate the system which does not match the observation results from the correlation in Monte Carlo.
6. Compare output possibilities to the rest of the system and if there is any inspection data, apply system-level observation.
7. Statistical analysis for output data from Monte Carlo.
8. Calculate Prominence and Relation using analysis matrices the from Delphi model library.

The next chapter (Chapter 5) deals with the analysis of the data and the results obtained.

CHAPTER-5

DATA ANALYSIS AND FINDINGS

The risk categories identified and enumerated in Chapter 4, are listed below. The abbreviations are used for ease of reference. The data obtained as responses from experts is the raw data used for analysis. The methodology of analysis is according to the flow chart mentioned in chapter 4 at page ---.

5.1 Following are the risk categories considered for analysis of data to generate a Risk Mitigation framework:

Category	Abbreviation	Risk Dimensions	Number of Risk dimensions
C1	**PREM**	Political, Regulatory, Environmental, and Macroeconomic Risks.	
C2	**FFR**	Financing/ Funding risks	
C3	**HDCM**	Human Resource, Design, Consultancy, and Management risks	
C4	**CTLQC**	Construction, Technology, Land acquisition, Quality, Contract Risks	
C5	**CCHO**	Completion, Commissioning, and Handing Over Risks	
C6	**RORNR**	Revenue, O&M Costs, Ridership, Non-fare revenue, Replacement costs Risk	

Source - Author Self Made

C1- PREM Dataset Attributes (the actual response received from experts)

	Risks related to decline in stakeholder support (Sovereign- at the Central government level)	Risks related to decline in stakeholder support (Sub-Sovereign- a regional or local government body)	Risk that an investor's returns could suffer as a result of political changes or instability in the country	Risks related to possible economic and political sanctions during the course of the project	Legal and litigation risks on miscellaneous reasons	Environmental risks related to observance of ecosystem of the area in sensitive zones	Risks related to management of waste, noise, air pollution, loss of green cover in residential zones	Failure to perform hazard and operability (HAZOP) studies	Risk related to a possible Cyber attack	Risk related to a possible Global fiscal crisis	Risk related to a possible Internal fiscal crisis
1	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	4.0	3.0
2	4.0	2.0	4.0	5.0	4.0	4.0	5.0	5.0	3.0	4.0	3.0
3	5.0	5.0	5.0	5.0	4.0	3.0	3.0	3.0	4.0	4.0	4.0
4	5.0	4.0	4.0	4.0	5.0	3.0	4.0	4.0	4.0	4.0	4.0
5	3.0	3.0	4.0	4.0	5.0	4.0	3.0	3.0	3.0	3.0	4.0
6	4.0	4.0	4.0	4.0	4.0	5.0	5.0	2.0	2.0	5.0	4.0
7	2.0	4.0	3.0	2.0	4.0	4.0	4.0	2.0	2.0	4.0	4.0
8	5.0	5.0	5.0	5.0	4.0	3.0	2.0	2.0	2.0	4.0	5.0
9	4.0	4.0	4.0	4.0	NaN	5.0	5.0	3.0	3.0	4.0	4.0
10	4.0	4.0	5.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	4.0
11	5.0	5.0	5.0	4.0	4.0	5.0	4.0	4.0	5.0	3.0	4.0
12	5.0	5.0	5.0	4.0	5.0	5.0	5.0	5.0	3.0	5.0	5.0
13	4.0	3.0	1.0	2.0	5.0	3.0	3.0	3.0	4.0	2.0	2.0
14	3.0	5.0	5.0	2.0	3.0	5.0	5.0	4.0	5.0	4.0	2.0
15	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0	4.0
16	5.0	5.0	5.0	5.0	5.0	3.0	3.0	5.0	2.0	3.0	5.0
17	3.0	4.0	4.0	3.0	5.0	2.0	2.0	1.0	2.0	2.0	4.0
18	4.0	5.0	3.0	3.0	2.0	2.0	2.0	2.0	2.0	3.0	3.0
19	4.0	4.0	4.0	4.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0
20	3.0	3.0	4.0	4.0	3.0	4.0	3.0	2.0	3.0	2.0	3.0
21	2.0	4.0	2.0	1.0	5.0	5.0	3.0	3.0	4.0	2.0	2.0
22	4.0	5.0	4.0	3.0	3.0	4.0	4.0	3.0	4.0	3.0	3.0
23	1.0	3.0	3.0	3.0	3.0	3.0	3.0	4.0	4.0	3.0	2.0
24	3.0	3.0	4.0	3.0	3.0	3.0	2.0	3.0	2.0	2.0	3.0
25	3.0	3.0	4.0	4.0	4.0	3.0	3.0	4.0	3.0	4.0	4.0
26	4.0	3.0	4.0	4.0	3.0	4.0	4.0	4.0	3.0	4.0	4.0
27	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.0	3.0	3.0	3.0
28	5.0	5.0	5.0	3.0	3.0	4.0	4.0	3.0	3.0	4.0	3.0
29	3.0	4.0	2.0	2.0	2.0	1.0	1.0	2.0	2.0	2.0	3.0
30	2.0	2.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0	1.0
31	5.0	5.0	5.0	5.0	5.0	4.0	3.0	3.0	3.0	2.0	2.0
32	3.0	3.0	4.0	3.0	3.0	4.0	3.0	4.0	3.0	3.0	4.0
33	3.0	4.0	5.0	5.0	4.0	3.0	3.0	4.0	4.0	4.0	4.0
34	4.0	5.0	3.0	2.0	4.0	4.0	5.0	4.0	3.0	5.0	4.0
35	1.0	1.0	2.0	3.0	1.0	3.0	2.0	1.0	1.0	1.0	2.0
36	3.0	3.0	3.0	2.0	3.0	2.0	2.0	2.0	3.0	2.0	2.0
37	1.0	4.0	5.0	5.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
38	4.0	3.0	5.0	4.0	4.0	5.0	3.0	3.0	2.0	4.0	3.0
39	4.0	4.0	5.0	4.0	3.0	4.0	3.0	3.0	2.0	2.0	2.0
40	5.0	5.0	3.0	3.0	3.0	2.0	2.0	3.0	2.0	4.0	4.0
41	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
42	4.0	4.0	4.0	3.0	5.0	5.0	1.0	5.0	4.0	4.0	5.0
43	5.0	3.0	5.0	1.0	3.0	3.0	3.0	4.0	4.0	3.0	3.0
44	5.0	4.0	5.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

Fig 5. 1 Dataset (Actual Responses) for C1- PREM Source - Author Self Made

The first step is to fetch the entire portion of data related to a particular risk dimension (individual question in the questionnaire) in each of the 6 risk categories (category -wise). The data regarding category -1 is as shown in fig 5.1.

Using the *Pandas* software library which provides tools for working with tabular data, i.e., data that is organized into tables that have rows and columns, the tabular data is modified and aggregated for use in other Python modules like Monte Carlo Simulation (for statistical analysis, in our case) or Matplotlib (for visualization).

Feature Selection & Extraction:

We applied feature selection and extraction on our selected dataset so that we can provide a suitable sampling of data so that data is in the form that is accepted by the Monte Carlo method. In this feature selection and extraction, we used 2 important predefined methods with the help of the Scikit-learn (SKLearn) library file, which are (1) *Variance Threshold* (which calculates the variance of each feature and compares based on the formula predefined in that method) and (2) *Fisher Score* (which calculates the score of constants called Fisher predefined in the method) and comparison of data is carried out. The variance threshold is a simple baseline approach to feature selection. **It removes all features in which variance doesn't meet some threshold value**. By default, it removes all zero-variance features, i.e., features that have the same value in all samples. Its underlying idea is that **if a feature is constant (i.e., it has 0 variance), then it cannot be used for finding any interesting pattern and can be removed from the dataset**. Fisher score is another one of the most widely used supervised feature selection methods.

5.1.1 Category-1: PREM: Dataset Attributes:

The abbreviated form each risk feature is as follows:

P_R1 = Risks related to decline in stakeholder support (Sovereign- at the Cent ral government level)

P_R2 = Risks related to decline in stakeholder support (Sub-Sovereign- a regi onal or local government body'

P_R3 = Risk that an investor's returns could suffer due to political changes or i nstability in the country
P_R4 = Risks related to possible economic and political sanctions in course of the project
P_R5 = Legal and litigation risks on miscellaneous reasons
P_R6 = Environmental risks related to observance of ecosystem of the area in sensitive zones
P_R7 = Risks related to management of waste, noise, air pollution, loss of gre en cover in residential zones
P_R8 = Failure to perform hazard/operability study
P_R9 = Risk related to a possible Cyber-attack
P_R10 = Risk related to a possible Global fiscal crisis
P_R11 = Risk related to a possible Internal fiscal crisis

Feature Selection & Extraction:
First the Variance Threshold feature selection will find the variance of every single data (of the feature) which is provided from the raw data as above. After the variance is calculated, the Fisher Score is calculated by the system. Based on this score the constant and non-constant features are separated. All this is done using the software library file. The variance threshold is kept as zero 0 as the base value,
The raw data set as in Fig 5.1 is fed in the library file.
Find constant (which has no variance and is not suitable for the statistical anal ysis) and Non-Constant Features: The result from the software is as follows:

[True True True True True True True True True True True]
No. of Non-Constant Features: **11 (out of 12)**

5.1.2 Correlation Comparison and distribution:

After the feature selection and extraction, we will calculate the correlation between each feature in the selected dataset to find which feature is highly correlated to which feature and which feature is not correlated to others at all. These are decided based on the marks given in the correlation table in which we determine the highly correlated variable by comparing the correlation value

with base value (default=0.5[can be changed manually]). If the value is more than 0.5, then the 2 feature values are highly correlated, else they are not. The correlation between each 2-feature data is calculated using the formulae:

Cor (X, Y) = (sum (x - mean(X)) * (y - mean(Y))) * 1/(n-1)

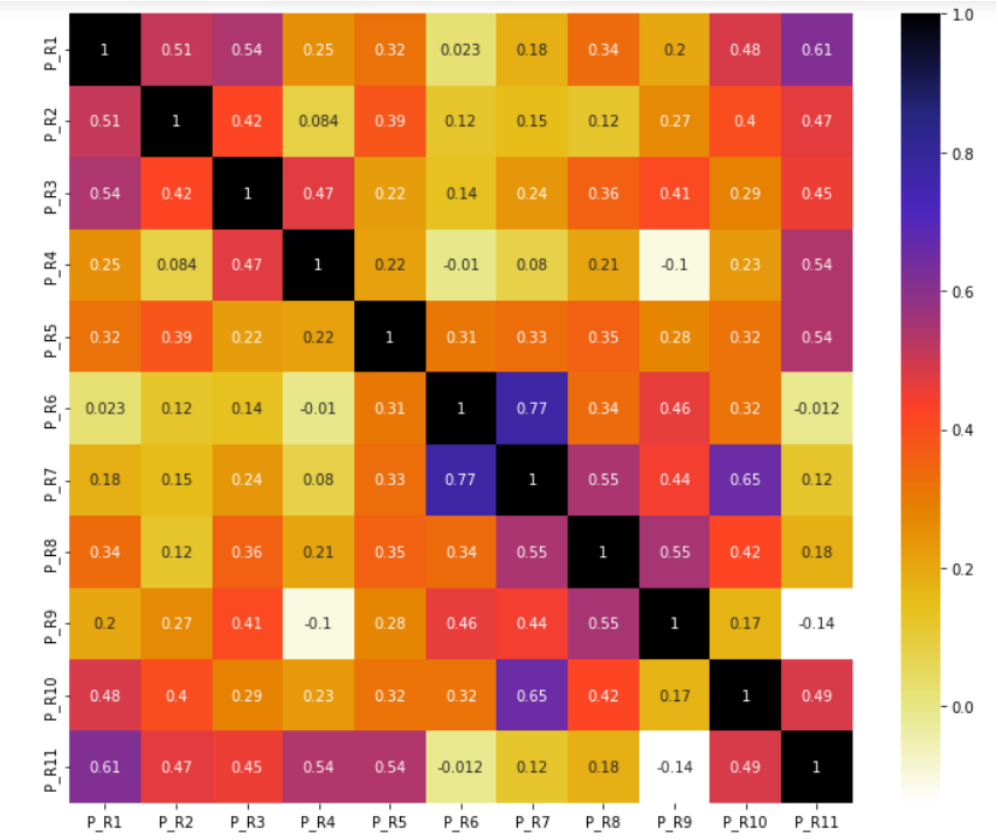


Fig 5. 2 Correlation matrix heat map (graphical) for C1-PREM

Source - Author Self Made

High Correlation and non-correlation of features are shown in *graphical format* based on the above description in fig 5.2. High Correlation and non-correlation of features are shown in *table format* in fig 5.3 (which will be helpful to perform several calculations related to correlation) based on the above description.

	P_R1	P_R2	P_R3	P_R4	P_R5	P_R6	P_R7	P_R8	P_R9	P_R10	P_R11
P_R1	1.000000	0.512640	0.542391	0.253530	0.321569	0.023018	0.184608	0.336143	0.200859	0.484958	0.614108
P_R2	0.512640	1.000000	0.417558	0.084195	0.385375	0.119859	0.151178	0.120172	0.267856	0.401352	0.469285
P_R3	0.542391	0.417558	1.000000	0.474221	0.223448	0.138738	0.237796	0.359124	0.410337	0.285276	0.454453
P_R4	0.253530	0.084195	0.474221	1.000000	0.215774	-0.010179	0.080241	0.206478	-0.103467	0.230470	0.539649
P_R5	0.321569	0.385375	0.223448	0.215774	1.000000	0.310016	0.328304	0.354982	0.275315	0.315645	0.537702
P_R6	0.023018	0.119859	0.138738	-0.010179	0.310016	1.000000	0.774096	0.336575	0.462926	0.315680	-0.011933
P_R7	0.184608	0.151178	0.237796	0.080241	0.328304	0.774096	1.000000	0.546303	0.443947	0.653951	0.121349
P_R8	0.336143	0.120172	0.359124	0.206478	0.354982	0.336575	0.546303	1.000000	0.551534	0.420239	0.182426
P_R9	0.200859	0.267856	0.410337	-0.103467	0.275315	0.462926	0.443947	0.551534	1.000000	0.167861	-0.139244
P_R10	0.484958	0.401352	0.285276	0.230470	0.315645	0.315680	0.653951	0.420239	0.167861	1.000000	0.485755
P_R11	0.614108	0.469285	0.454453	0.539649	0.537702	-0.011933	0.121349	0.182426	-0.139244	0.485755	1.000000

Fig 5. 3 Correlation matrix for C1-PREM Source - Author Self Made

After the Correlation calculation is done, as shown in the above table, the Highly Correlated features will be passed into Monte Carlo Simulation model as a set of Transition Data while all the non-correlated data will be passed to Monte Carlo Simulation model as Dependent Variables.

As per the above correlation matrix, number of most correlation features are: 6

1. Legal and litigation risks on miscellaneous reasons
2. Risk related to a possible Cyber-attack
3. Risk related to a possible Global fiscal crisis
4. Risk related to a possible Internal fiscal crisis
5. Risks related to decline in stakeholder support (Sub-Sovereign- a regio nal or local government body)
6. Risks related to management of waste, noise, air pollution, loss of gree n
   cover in residential zones

5.1.3 Monte Carlo Simulation Method:

Now the Transition data and the data of dependent variables are going to pass into the Monte Carlo Simulation method.

First the Data Ratio Graph from raw Transition data and Dependent Variables is prepared without any statistical analysis using the Monte Carlo Risk Management Method. Then the execution of the Monte Carlo Simulation starts for statistical analysis.

A screenshot of the back-end process in the Monte Carlo Simulation method is as below:

Applied NN Model inside Monte Carlo - Details

Model: "sequential_1"

Layer (type)	Output Shape	Param #
lstm_3 (RNN)	(None, 11, 50)	10400
lstm_4 (RNN)	(None, 11, 50)	20200
lstm_5 (RNN)	(None, 50)	20200
dense_1 (Dense)	(None, 1)	51

Total params: 50,851
Trainable params: 50,851
Non-trainable params: 0

Fig 5. 3A Correlation matrix for C1-PREM Source - Author Self Made

After calculating the probabilities from performance analysis, we will check for additional inspection and based on the criteria (inside Monte Carlo's predefined method) if met - will perform system level observation.

Predicted Data for each attribute From Monte Carlo Risk Analysis

```
array([[3.756576 ],
       [3.6475167],
       [2.5230374],
       [2.4059536],
       [2.2885013],
       [2.1488183],
       [2.0326383],
       [1.9180554],
       [1.7143209],
       [1.6831634],
       [1.562201 ]], dtype=float32)
```

Fig 5. 4 Correlation matrix for C1-PREM **Source - Author Self Made**

If criteria do not meet additional inspection, Monte Carlo will perform some st atistical analysis and **print the following graph** after performing certain calcu lations of raw and statistical data. The result of the Monte Carlo Simulation an d its predicted values are depicted in the graph below:

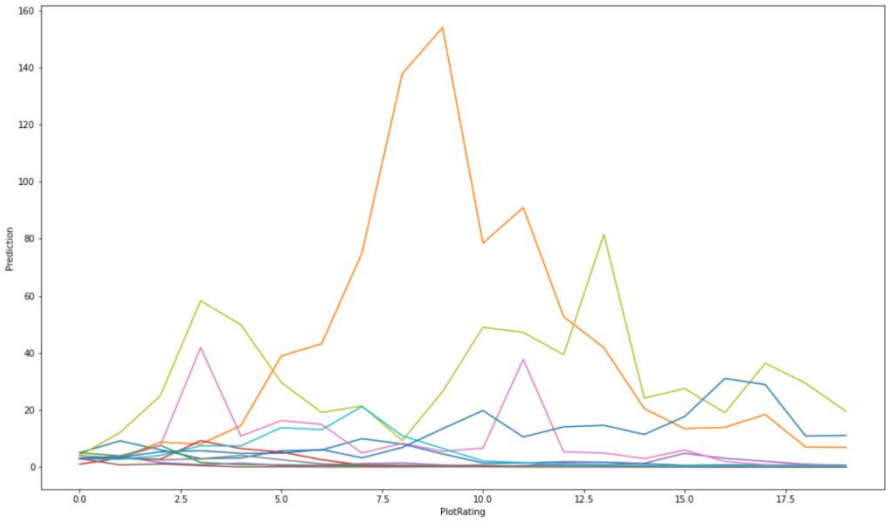


Fig 5. 5 Analysis of results as obtained from Monte Carlo Simulation for C1-PREM

Source - Author Self Made

After this Statistical Analysis (as above), Monte Carlo model will perform risk factor probability calculation (shown below as "marks") which are in the range of low-high review score of numeric problems of each feature (in this case 1-5) as shown in table 5.1.

RISK FACTOR	MARKS (Risk probability-prediction as per MCS)
Risks related to decline in stakeholder support (Sovereign- at the Central government level)	3.756576
Risks related to decline in stakeholder support (Sub-Sovereign- a regional or local government body)	3.6475167
Risk that an investor's returns could suffer as a result of political changes or instability in the country	2.5230374
Risks related to possible economic and political sanctions during the course of the project	2.4059536
Legal and litigation risks on miscellaneous reasons	2.2885013
Environmental risks related to observance of ecosystem of the area in sensitive zones	2.1488183

RISK FACTOR	MARKS (Risk probability-prediction as per MCS)
Failure to perform hazard/operability study	2.0326383
Risk related to a possible Cyber attack	1.9180554
Risk related to a possible *Global fiscal crisis*	1.7143209
Risk related to a possible Internal *fiscal crisis*	1.6831634

Source - Author Self Made

Result: From the results of the Monte Carlo Simulation method, after performing the risk factor probability analysis, the MARKS as shown in the table above signify how much probability of occurrence each of the above features have in the Indian HSR project. *Risk related to decline in stakeholder support (sovereign- at the central government level)* is most likely to happen and *Risk related to a possible Internal fiscal crisis* is least likely.

5.1.4 After we get output marks for each risk factor from the Monte Carlo Simulation method, we will calculate the **Prominence** and **Relation** of the *total effect given* and *received* by each risk to other risk factor or each risk from other risk factor and will help us find Impact Receiver Ratio. Here: -

Prominence = (ri + ci)

Relation = (ri - ci)

where ri (Rank) = Total effect given by each risk to other

ci (Consensus) = Total effect received by each risk from other risks,

which will be calculated with the help of predefined methods like (defuzzyfyCOA, maptoFuzzy Number, Memu etc.) inside the Delphi library (only methods required for calculating ri& ci). *ri* (total effect given by each risk to other) is determined through how high the *rank* of a certain feature is. *ci* (total effect received by each risk from other) is determined through how high the *consensus* of a certain feature is.

AttributeName	Rank	Consensus	Verdict
Risk related to a possible Internal fiscal crisis	15.360	0.325521	Retained
Risk related to a possible Global fiscal crisis	7.680	0.651042	Retained
Risk related to a possible Cyber attack	3.840	1.302083	Retained
Failure to perform hazard and operability (HAZOP) studies	1.920	2.604167	Retained
Risks related to management of waste, noise, air pollution, loss of green cover in residential zones	0.960	5.208333	Retained
Environmental risks related to observance of ecosystem of the area in sensitive zones	0.480	10.416667	Retained
Legal and litigation risks on miscellaneous reasons	0.240	20.833333	Retained
Risks related to possible economic and political sanctions during the course of the project	0.120	41.666667	Retained
Risk that an investor's returns could suffer as a result of political changes or instability in the country	0.060	83.333333	Retained
Risks related to decline in stakeholder support (Sub-Sovereign- a regional or local government body)	0.030	166.666667	Retained
Risks related to decline in stakeholder support (Sovereign- at the Central government level)	0.015	333.333333	Retained

Table 5. 1 Ranking table (ri) for analyzed data using Monte Carlo for C1-PREM

Source - Author Self Made

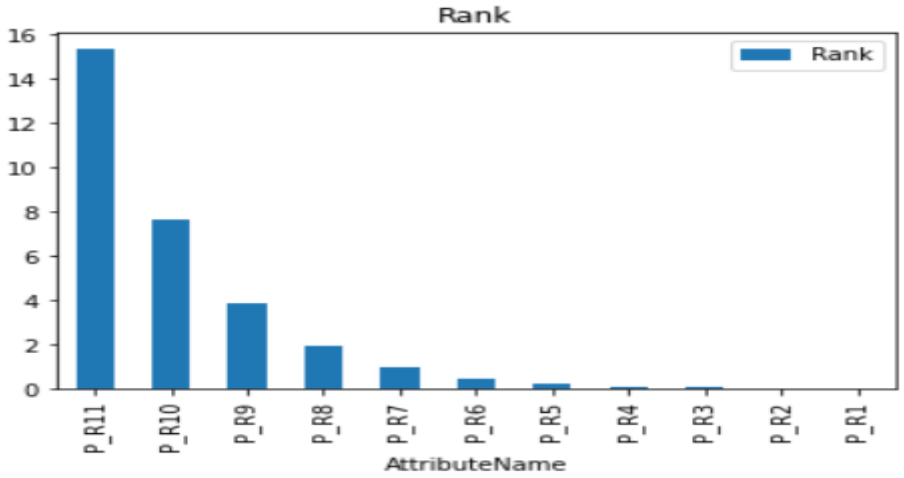


Fig 5.6 Ranking Table in graphical form for C1-PREM

Source - Author Self Made

AttributeName	Rank	Consensus	Verdict
Risks related to arrangement of finances from foreign Multilateral/ Bilateral conditional/ tied loans	0.07500	66.666667	Retained
Refinancing risks (replace a debt obligation with new debt at a critical time for the borrower) in construction/ operating phase	0.07475	66.889632	Retained
Currency transfer and convertibility risks	0.07450	67.114094	Retained
Credit risks with financial institutions (donors unable to meet contractual arrangements of funding)	0.07425	67.340067	Retained
Risks related to Non-compliance of contractual arrangements (by the borrowers) with Multinational Development Banks	0.07400	67.567568	Retained
Risks related to financing or funding of increase in cost estimates (prices and quantities)	0.07375	67.796610	Retained
Liquidity Risks of Construction / Operating companies	0.07350	68.027211	Retained
Inflation risk leading to erosion of purchasing power of Indian currency	0.07325	68.259386	Retained

Table 5. 2 Consensus table (ci) for analyzed data using Monte Carlo for C1-PREM

Source - Author Self Made

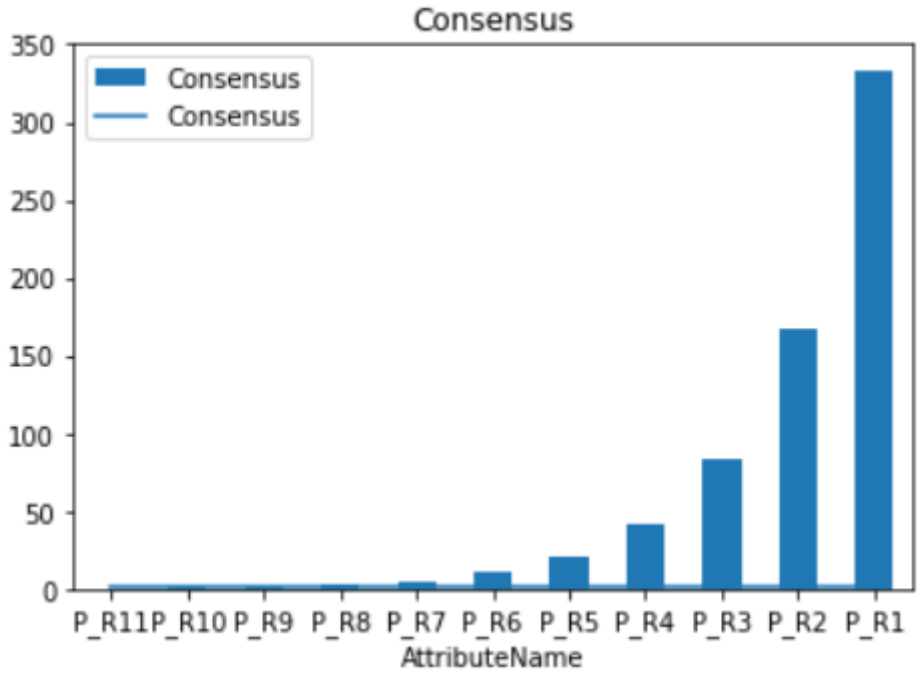


Fig 5.7 Consensus Table in graphical format for C1-PREM

Source - Author Self Made

AttributeName	Rank	Consensus
Credit risks with financial institutions (donors unable to meet contractual arrangements of funding)	0.19425	109.006734
Currency transfer and convertibility risks	0.13450	150.447427
Inflation risk leading to erosion of purchasing power of Indian currency	1.99325	70.863552
Liquidity Risks of Construction / Operating companies	1.03350	73.235544
Refinancing risks (replace a debt obligation with new debt at a critical time for the borrower) in construction/ operating phase	0.10475	233.556299
Risks related to Non-compliance of contractual arrangements (by the borrowers) with Multinational Development Banks	0.31400	88.400901
Risks related to arrangement of finances from foreign Multilateral/ Bilateral conditional/ tied loans	0.09000	400.000000
Risks related to financing or funding of increase in cost estimates (prices and quantities)	0.55375	78.213277

Table 5. 3 Prominence table for C1-PREM

Source - Author Self Made

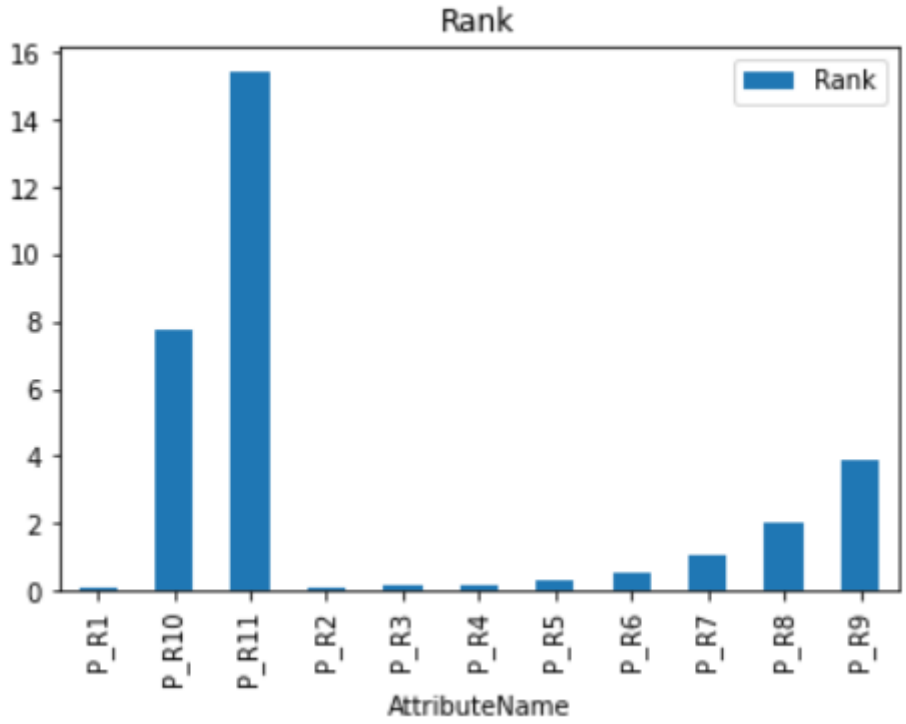


Fig 5.8 Prominence analysis in graphical form for C1-PREM

Source - Author Self Made

AttributeName	Rank	Consensus
Environmental risks related to observance of ecosystem of the area in sensitive zones	0.40625	-57.379944
Failure to perform hazard and operability (HAZOP) studies	1.84675	-65.655219
Legal and litigation risks on miscellaneous reasons	0.16600	-46.734234
Risk related to a possible Cyber attack	3.76700	-67.191067
Risk related to a possible Global fiscal crisis	7.60725	-68.077481
Risk related to a possible Internal fiscal crisis	15.28750	-68.639996
Risk that an investor's returns could suffer as a result of political changes or instability in the country	-0.01450	16.219239
Risks related to decline in stakeholder support (Sovereign- at the Central government level)	-0.06000	266.666667
Risks related to decline in stakeholder support (Sub-Sovereign- a regional or local government body)	-0.04475	99.777035
Risks related to management of waste, noise, air pollution, loss of green cover in residential zones	0.88650	-62.818878
Risks related to possible economic and political sanctions during the course of the project	0.04575	-25.673401

Table 5. 4 Relation Table for C1-PREM

Source - Author Self Made

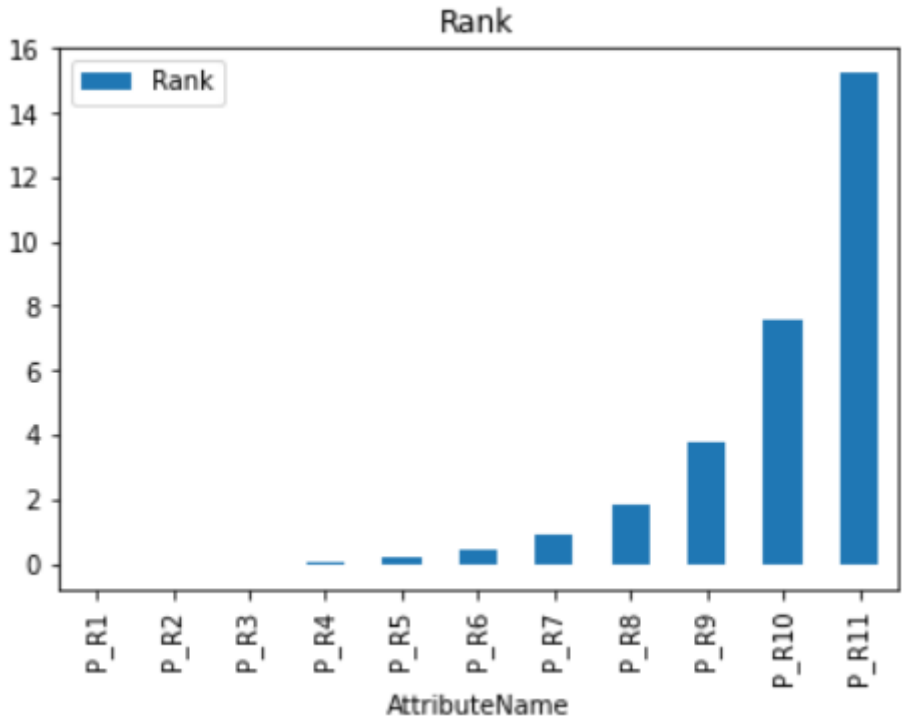


Fig 5. 9 Relation analysis in graphical form for C1-PREM

Source - Author Self Made

Result: From the above Prominence and Relation analysis, it is observed that PR11(Risk related to a possible Internal fiscal crisis) has the highest effect over all others features in this category and also receives the most effect from all risk features in the category. Thus, from the management perspective, this risk feature needs to be mitigated on high priority. The risk parameters PR1 (Risks related to decline in stakeholder support (sovereign- at the central government level)) and PR2 (Risks related to decline in stakeholder support (sub-sovereign- a regional or local government body) have the highest probability of occurrence and have to be monitored.

The above analysis for risk probabilities and correlation and dominance has been carried out using the Monte Carlo simulation method and the process flow hart for risks in Category 1. ***All the above steps of the process flow are carried out for all other 5 Risk categories and the result of each analysis will be enumerated.***

5.2. C2- FFR: Financing/ Funding risks:

FFR Dataset Attributes (Actual response received from experts)

	Risks related to arrangement of finances from foreign Multilateral/ Bilateral conditional/ tied loans	Refinancing risks (replace a debt obligation with new debt at a critical time for the borrower) in construction/ operating phase	Currency transfer and convertibility risks	Credit risks with financial institutions (donors unable to meet contractual arrangements of funding)	Risks related to Non-compliance of contractual arrangements (by the borrowers) with Multinational Development Banks	Risks related to financing or funding of increase in cost estimates (prices and quantities)	Liquidity Risks of Construction / Operating companies	Inflation risk leading to erosion of purchasing power of Indian currency
1	2.0	3.0	3.0	2.0	1.0	3.0	3.0	4.0
2	4.0	5.0	4.0	3.0	4.0	5.0	5.0	4.0
3	3.0	3.0	4.0	3.0	2.0	4.0	3.0	2.0
4	4.0	4.0	5.0	4.0	4.0	5.0	4.0	4.0
5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
6	4.0	4.0	4.0	4.0	3.0	5.0	4.0	4.0
7	4.0	4.0	1.0	3.0	4.0	5.0	4.0	4.0
8	4.0	3.0	3.0	3.0	3.0	3.0	3.0	NaN
9	2.0	4.0	4.0	2.0	2.0	4.0	3.0	4.0
10	3.0	3.0	4.0	3.0	3.0	5.0	5.0	4.0
11	3.0	5.0	1.0	2.0	4.0	4.0	3.0	4.0
12	2.0	2.0	2.0	1.0	2.0	5.0	5.0	4.0
13	1.0	3.0	4.0	2.0	2.0	5.0	3.0	3.0
14	2.0	2.0	2.0	2.0	3.0	5.0	3.0	2.0
15	3.0	4.0	3.0	3.0	4.0	3.0	3.0	4.0
16	4.0	5.0	4.0	3.0	5.0	4.0	3.0	5.0
17	4.0	3.0	2.0	1.0	2.0	5.0	4.0	2.0
18	2.0	3.0	2.0	2.0	2.0	3.0	2.0	2.0
19	4.0	4.0	4.0	5.0	4.0	5.0	4.0	4.0
20	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0
21	2.0	2.0	5.0	2.0	4.0	4.0	4.0	4.0
22	3.0	3.0	4.0	3.0	2.0	4.0	4.0	4.0
23	4.0	4.0	3.0	3.0	3.0	4.0	3.0	1.0
24	3.0	4.0	2.0	3.0	3.0	4.0	4.0	3.0
25	3.0	3.0	3.0	3.0	4.0	5.0	3.0	4.0
26	3.0	4.0	3.0	3.0	3.0	4.0	4.0	3.0
27	3.0	3.0	3.0	4.0	4.0	3.0	2.0	2.0
28	3.0	3.0	4.0	4.0	3.0	5.0	4.0	4.0
29	1.0	2.0	3.0	2.0	2.0	3.0	3.0	2.0
30	2.0	2.0	2.0	2.0	2.0	4.0	4.0	2.0
31	3.0	3.0	2.0	2.0	2.0	2.0	2.0	2.0
32	4.0	4.0	3.0	4.0	3.0	4.0	4.0	3.0
33	3.0	4.0	4.0	2.0	3.0	4.0	4.0	4.0
34	3.0	2.0	3.0	1.0	3.0	5.0	4.0	4.0
35	1.0	1.0	3.0	2.0	1.0	2.0	2.0	1.0
36	2.0	2.0	2.0	2.0	2.0	3.0	2.0	2.0
37	4.0	4.0	3.0	3.0	3.0	4.0	4.0	3.0
38	4.0	5.0	4.0	3.0	3.0	4.0	3.0	3.0
39	1.0	2.0	3.0	1.0	1.0	5.0	4.0	NaN
40	3.0	4.0	4.0	3.0	4.0	4.0	3.0	2.0
41	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
42	5.0	4.0	3.0	1.0	3.0	5.0	3.0	4.0
43	2.0	4.0	4.0	2.0	2.0	5.0	3.0	3.0
44	4.0	4.0	4.0	3.0	4.0	4.0	4.0	4.0

Fig 5.10 Dataset (Actual Responses) for C2- FFR

Source - Author Self Made

Abbreviated form of each risk feature (as in Category-1, is not done here. Full form is used.

Feature Selection & Extraction: The results of the Variance Threshold feature selection and the Fisher Score method is as follows:

Find Constant and Non-Constant Features:

[True True True True True True True True]

No. of Non-Constant Features: **8 (out of 8)**

Fig 5. 11 Correlation matrix heat map for C2- FFR Source - Author Self Made

	Risks related to arrangement of finances from foreign Multilateral/ Bilateral conditional/ tied loans	Refinancing risks (replace a debt obligation with new debt at a critical time for the borrower) in construction/ operating phase	Currency transfer and convertibility risks	Credit risks with financial institutions (donors unable to meet contractual arrangements of funding)	Risks related to Non-compliance of contractual arrangements (by the borrowers) with Multinational Development Banks	Risks related to financing or funding of increase in cost estimates (prices and quantities)	Liquidity Risks of Construction / Operating companies	Inflation risk leading to erosion of purchasing power of Indian currency
Risks related to arrangement of finances from foreign Multilateral/ Bilateral conditional/ tied loans	1.000000	0.819515	0.372496	4.783739e-01	0.601041	5.962848e-01	0.436049	0.418330
Refinancing risks (replace a debt obligation with new debt at a critical time for the borrower) in construction/ operating phase	0.819515	1.000000	0.454532	5.424543e-01	0.588006	4.042260e-01	0.409048	0.604990
Currency transfer and convertibility risks	0.372496	0.454532	1.000000	6.264578e-01	0.333359	7.808688e-02	0.160506	0.511305
Credit risks with financial institutions (donors unable to meet contractual arrangements of funding)	0.478374	0.542454	0.626458	1.000000e+00	0.680367	-1.295541e-16	-0.126848	0.204666

Fig 5. 12 Correlation matrix for C2- FFR Source - Author Self Made

Number of most correlation features are: 3

1. Inflation risk leading to erosion of purchasing power of Indian currency
2. Liquidity Risks of Construction / Operating companies
3. Refinancing risks (replace a debt obligation with new debt at a critical time for the borrower) in construction/ operating phase

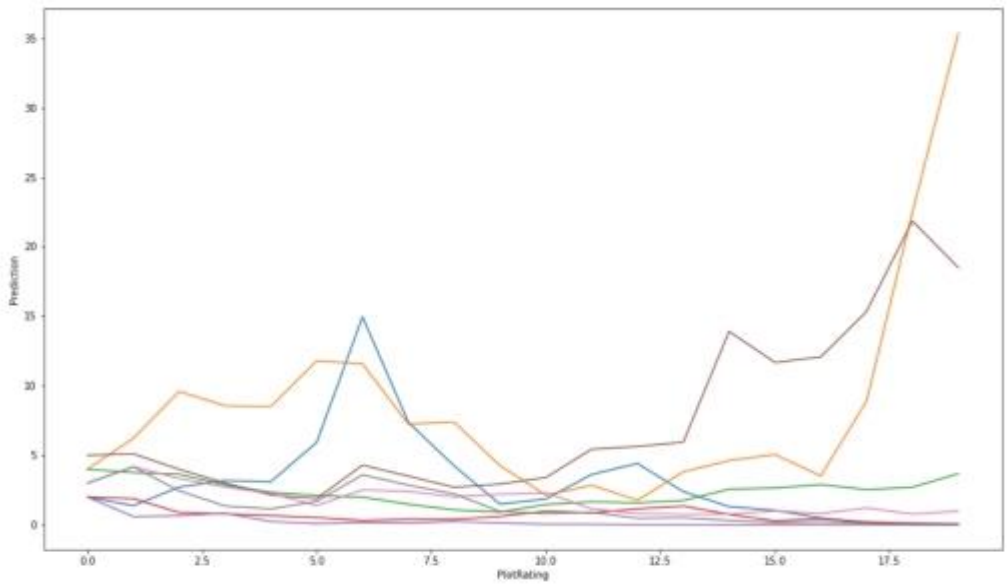


Fig 5. 13 Analysis of results obtained from Monte Carlo for C2- FFR

Source - Author Self Made

RISK FACTOR	MARKS (Risk probability-prediction as per MCS)
Risks related to arrangement of finances from foreign Multilateral/ Bilateral conditional/ tied loans	4.0050188
Refinancing risks in construction/ operating phase	3.4501925
Currency transfer and convertibility risks	3.42181
Credit risks with financial institutions (donors unable to meet contractual arrangements of funding)	3.4166508
Risks related to Non-compliance of contractual arrangements (by the borrowers) with Multinational Development Banks	3.2271917
Risks related to financing or funding of increase in cost estimates (prices and quantities)	3.1515958
Liquidity Risks of Construction / Operating companies	3.2440374
Inflation risk leading to erosion of purchasing power of Indian currency	2.9317708

Table 5. 5 Statistical analysis output of each variable for C2 – FFR

Source - Author Self Made

5.2.1 Result: From the results of the Monte Carlo Simulation method, after performing the risk factor probability analysis, the MARKS as shown in the table above signify how much probability of occurrence each of the above features have in the Indian HSR project. *Risk related to arrangement of finances from foreign Multilateral/ Bilateral conditional/ tied loans* is most likely to happen and *Inflation risk leading to erosion of purchasing power of Indian currency* are least likely.

AttributeName	Rank	Consensus	Verdict
Inflation risk leading to erosion of purchasing power of Indian currency	1.920	2.604167	Retained
Liquidity Risks of Construction / Operating companies	0.960	5.208333	Retained
Risks related to financing or funding of increase in cost estimates (prices and quantities)	0.480	10.416667	Retained
Risks related to Non-compliance of contractual arrangements (by the borrowers) with Multinational Development Banks	0.240	20.833333	Retained
Credit risks with financial institutions (donors unable to meet contractual arrangements of funding)	0.120	41.666667	Retained
Currency transfer and convertibility risks	0.060	83.333333	Retained
Refinancing risks (replace a debt obligation with new debt at a critical time for the borrower) in construction/ operating phase	0.030	166.666667	Retained
Risks related to arrangement of finances from foreign Multilateral/ Bilateral conditional/ tied loans	0.015	333.333333	Retained

Table 5. 6 Ranking table (ri) for analyzed data using Monte Carlo for C2 – FFR

Source - Author Self Made

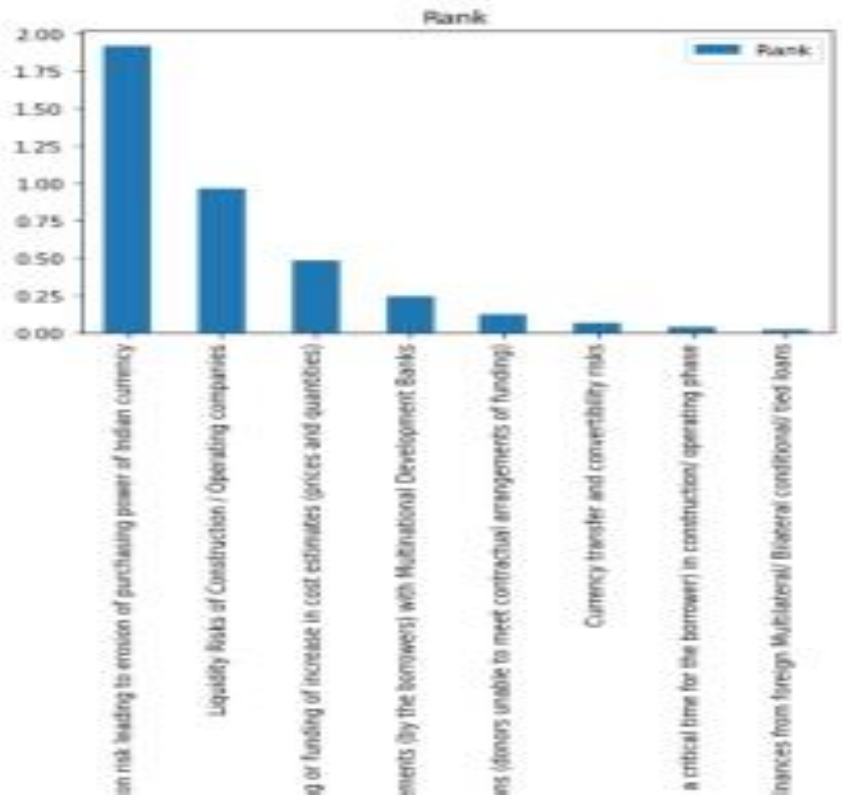


Fig 5. 14 Ranking Table in graphical form for C2 – FFR

Source - Author Self Made

AttributeName	Rank	Consensus	Verdict
Risks related to arrangement of finances from foreign Multilateral/ Bilateral conditional/ tied loans	0.07500	66.666667	Retained
Refinancing risks (replace a debt obligation with new debt at a critical time for the borrower) in construction/ operating phase	0.07475	66.889632	Retained
Currency transfer and convertibility risks	0.07450	67.114094	Retained
Credit risks with financial institutions (donors unable to meet contractual arrangements of funding)	0.07425	67.340067	Retained
Risks related to Non-compliance of contractual arrangements (by the borrowers) with Multinational Development Banks	0.07400	67.567568	Retained
Risks related to financing or funding of increase in cost estimates (prices and quantities)	0.07375	67.796610	Retained
Liquidity Risks of Construction / Operating companies	0.07350	68.027211	Retained
Inflation risk leading to erosion of purchasing power of Indian currency	0.07325	68.259386	Retained

Table 5.7 Consensus table (ci) for analyzed data using Monte Carlo for C2 –FFR

Source - Author Self Made

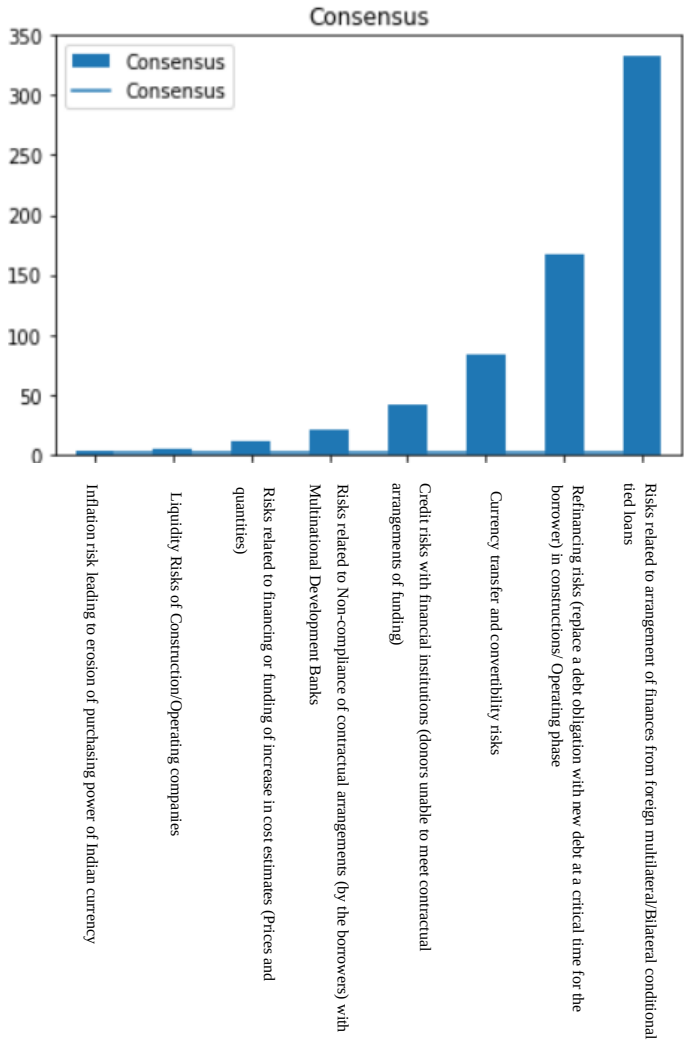


Fig 5. 15 Consensus Table in graphical format for C2 – FFR Source - Author Self Made

AttributeName	Rank	Consensus
Credit risks with financial institutions (donors unable to meet contractual arrangements of funding)	0.19425	109.006734
Currency transfer and convertibility risks	0.13450	150.447427
Inflation risk leading to erosion of purchasing power of Indian currency	1.99325	70.863552
Liquidity Risks of Construction / Operating companies	1.03350	73.235544
Refinancing risks (replace a debt obligation with new debt at a critical time for the borrower) in construction/ operating phase	0.10475	233.556299
Risks related to Non-compliance of contractual arrangements (by the borrowers) with Multinational Development Banks	0.31400	88.400901
Risks related to arrangement of finances from foreign Multilateral/ Bilateral conditional/ tied loans	0.09000	400.000000
Risks related to financing or funding of increase in cost estimates (prices and quantities)	0.55375	78.213277

Table 5. 8 Prominence table for C2 – FFR Source - Author Self Made

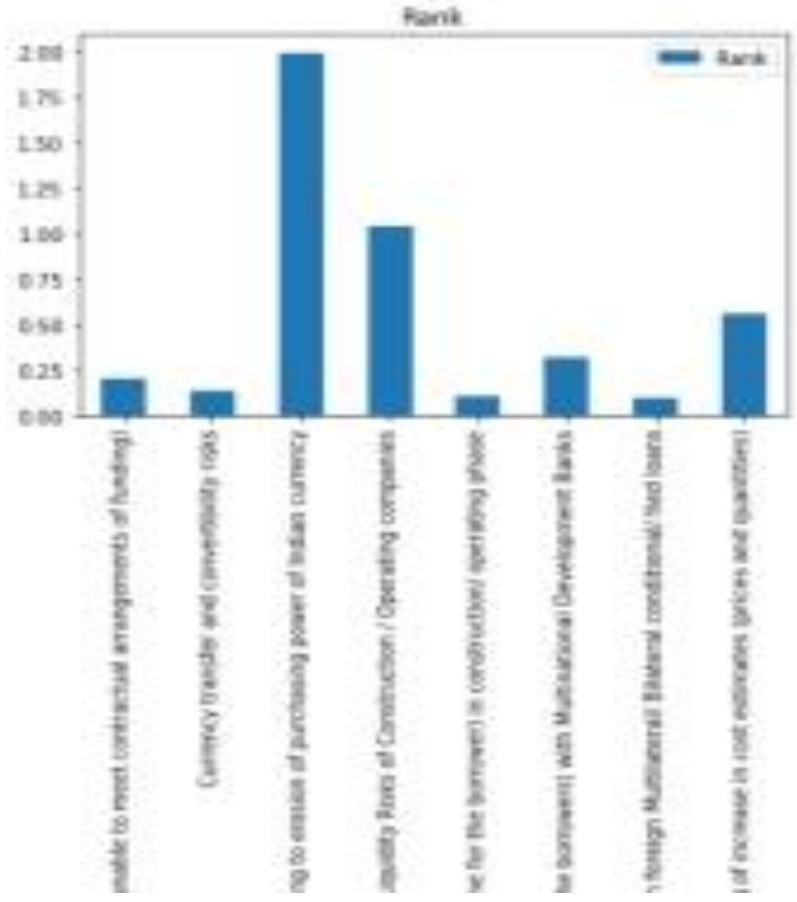


Fig 5.16 Prominence analysis in graphical format for C2 – FFR

Source - Author Self Made

AttributeName	Rank	Consensus
Credit risks with financial institutions (donors unable to meet contractual arrangements of funding)	0.04575	-25.673401
Currency transfer and convertibility risks	-0.01450	16.219239
Inflation risk leading to erosion of purchasing power of Indian currency	1.84675	-65.655219
Liquidity Risks of Construction / Operating companies	0.88650	-62.818878
Refinancing risks (replace a debt obligation with new debt at a critical time for the borrower) in construction/ operating phase	-0.04475	99.777035
Risks related to Non-compliance of contractual arrangements (by the borrowers) with Multinational Development Banks	0.16600	-46.734234
Risks related to arrangement of finances from foreign Multilateral/ Bilateral conditional/ tied loans	-0.06000	266.666667
Risks related to financing or funding of increase in cost estimates (prices and quantities)	0.40625	-57.379944

Table 5. 9 Relation Table for C2 – FFR Source - Author Self Made

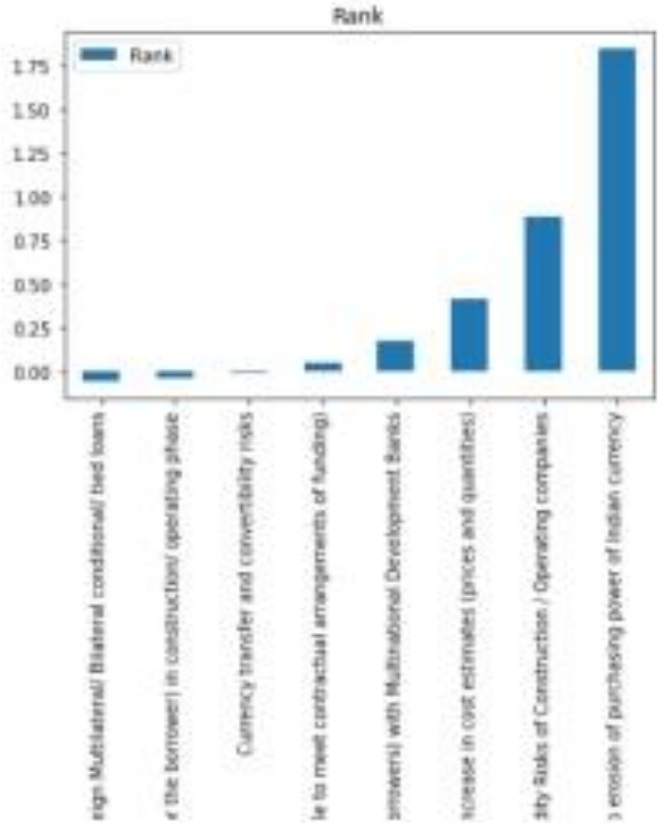


Fig 5.17 Relation table in graphical format for C2 – FFR

Source - Author Self Made

5.2.2 Result: From the above Prominence and Relation analysis, it is observed that **Inflation risk leading to erosion of purchasing power of Indian currency** has the highest effect over all others features in this category and also receives the most effect from all risk features in the category. Thus, from the management perspective, this risk feature needs to be mitigated on high priority. The risk parameters **Liquidity Risks of Construction / Operating companies** and **Inflation risk leading to erosion of purchasing power of Indian currency** have the highest probability of occurrence and have to be monitored.

5.3 C3- Human Resource, Design, Consultancy and Management risks:

HDCM Dataset Attributes (actual response received from experts)

	The lack of skilled experts on HSR technology on client's side	The lack of skilled experts in consultant's side	Risks due to lack of skilled executive teams with construction companies	Failure to understand the project and activities associated with it by client/ contractors	Absence of standard specifications for High Speed Rail in India for components like signaling, safety, Rolling Stock and interface issues	Risk related to possible sub-optimal designs, both in a concept design or a detailed design	Failure to identify the optimal location of stations in the cities to ensure ideal multi-modal connectivity	Failure to identify the executive processes of the project, particularly regarding management of interface among different systems and establish intra-organizational communication	Restrictions on use of professional consultation and alternative designs by foreign / Indian companies, particularly related to possible conditions in the bilateral financing arrangement.	Risks related to successful long-term operations due to lack of an appropriate management structure, particularly regarding separation of ownership of Infrastructure and Operations	Lack of optimum work culture (in India) required to construct and operate such complex large infra projects
1	4.0	2.0	4.0	4.0	4.0	4.0	4.0	4.0	3.0	4.0	5.0
2	5.0	4.0	5.0	4.0	4.0	4.0	3.0	4.0	5.0	3.0	2.0
3	5.0	3.0	3.0	3.0	2.0	2.0	3.0	4.0	3.0	4.0	2.0
4	2.0	3.0	3.0	3.0	4.0	4.0	3.0	4.0	4.0	4.0	4.0
5	3.0	3.0	3.0	3.0	5.0	4.0	4.0	4.0	3.0	5.0	5.0
6	5.0	4.0	4.0	3.0	2.0	2.0	4.0	4.0	3.0	3.0	4.0
7	4.0	1.0	3.0	3.0	1.0	3.0	3.0	4.0	4.0	4.0	2.0
8	2.0	2.0	2.0	4.0	4.0	5.0	1.0	3.0	5.0	4.0	4.0
9	4.0	4.0	4.0	4.0	3.0	3.0	2.0	2.0	4.0	2.0	2.0
10	5.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0	4.0	4.0	4.0
11	3.0	5.0	3.0	2.0	3.0	2.0	4.0	5.0	5.0	4.0	2.0
12	3.0	1.0	5.0	5.0	4.0	5.0	5.0	4.0	4.0	4.0	5.0
13	4.0	3.0	4.0	3.0	5.0	3.0	5.0	2.0	2.0	4.0	3.0
14	5.0	3.0	4.0	4.0	5.0	4.0	5.0	5.0	5.0	4.0	4.0
15	3.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0
16	5.0	3.0	3.0	4.0	5.0	2.0	3.0	4.0	5.0	3.0	5.0
17	2.0	1.0	2.0	1.0	2.0	2.0	3.0	3.0	2.0	2.0	2.0
18	5.0	3.0	4.0	3.0	2.0	4.0	3.0	5.0	4.0	3.0	2.0
19	4.0	4.0	4.0	3.0	3.0	4.0	5.0	5.0	5.0	4.0	4.0
20	4.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.0
21	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	1.0	1.0
22	4.0	4.0	5.0	2.0	3.0	4.0	4.0	5.0	2.0	3.0	5.0
23	2.0	2.0	2.0	2.0	2.0	3.0	1.0	2.0	2.0	2.0	1.0
24	3.0	2.0	2.0	2.0	2.0	3.0	2.0	4.0	2.0	3.0	3.0
25	4.0	4.0	4.0	4.0	4.0	4.0	3.0	4.0	4.0	4.0	4.0
26	4.0	2.0	3.0	3.0	4.0	4.0	4.0	3.0	4.0	4.0	4.0
27	2.0	2.0	1.0	2.0	5.0	2.0	4.0	3.0	5.0	4.0	5.0
28	3.0	3.0	5.0	3.0	4.0	4.0	3.0	5.0	5.0	4.0	5.0
29	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0	3.0	2.0
30	4.0	2.0	3.0	4.0	2.0	2.0	5.0	4.0	2.0	4.0	4.0
31	5.0	4.0	4.0	4.0	4.0	4.0	2.0	4.0	4.0	4.0	4.0
32	3.0	3.0	3.0	4.0	4.0	3.0	4.0	4.0	3.0	4.0	3.0
33	4.0	4.0	4.0	4.0	1.0	5.0	3.0	5.0	4.0	5.0	4.0
34	5.0	5.0	5.0	4.0	3.0	2.0	4.0	4.0	3.0	5.0	3.0
35	1.0	1.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
36	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
37	5.0	5.0	5.0	5.0	3.0	3.0	3.0	3.0	5.0	3.0	3.0
38	5.0	4.0	5.0	4.0	4.0	3.0	4.0	4.0	4.0	3.0	4.0
39	4.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0	4.0	4.0
40	4.0	3.0	4.0	4.0	4.0	3.0	4.0	3.0	3.0	3.0	4.0
41	4.0	5.0	5.0	5.0	5.0	4.0	3.0	3.0	5.0	5.0	4.0
42	5.0	5.0	5.0	5.0	4.0	5.0	4.0	5.0	5.0	5.0	4.0
43	5.0	3.0	3.0	2.0	4.0	4.0	5.0	4.0	4.0	3.0	4.0
44	3.0	3.0	3.0	3.0	5.0	4.0	3.0	4.0	4.0	4.0	4.0

Fig 5.18 Dataset (Actual Responses) for C3 – HDCM Source - Author Self Made

Abbreviated form of each risk feature (as in Category-1, is not done here. Full form is used.

Feature Selection & Extraction: The results of the Variance Threshold feature selection and the Fisher Score method is as follows:

Feature Selection & Extraction (variance threshold)

Find Constant and Non-Constant Features:

[True True True True True True True True True True True]

Number of Non-Constant Features: 11

Correlation Matrix Raw

Fig 5. 19 Correlation matrix heat map for C3 – HDCM

	The lack of skilled experts on HSR technology on client's side	The lack of skilled experts in consultant's side	Risks due to lack of skilled executive teams with construction companies	Failure to understand the project and activities associated with it by client/ contractors	Absence of standard specifications for High Speed Rail in India for components like signaling, safety, Rolling Stock and interface issues	Risk related to possible sub-optimal designs, both in a concept design or a detailed design	Failure to identify the optimal location of stations in the cities to ensure ideal multi-modal connectivity	Failure to identify the executive processes of the project, particularly regarding management of interface among different systems and establish intra-organizational communication	Restrictions on use of professional consultation and alternative designs by foreign / Indian companies, particularly related to possible conditions in the bilateral financing arrangement.	Risks related to successful long-term operations due to lack of an appropriate management structure, particularly regarding separation of ownership of Infrastructure and Operations	Lack of optimum work culture (in India) required to construct and operate such complex large infra projects
The lack of skilled experts on HSR technology on client's side	1.000000	0.737220	0.726251	0.591608	0.281281	0.548052	0.583353	0.676978	0.313572	0.530017	0.518999
The lack of skilled experts in consultant's side	0.737220	1.000000	0.509510	0.282295	0.068537	0.404611	0.239180	0.569083	0.281036	0.494917	0.403620
Risks due to lack of skilled executive teams with construction companies	0.726251	0.509510	1.000000	0.722544	0.206747	0.760274	0.610682	0.655918	0.128450	0.435341	0.543313

Fig 5.20 Correlation matrix for C3 – HDCM Source - Author Self Made

As per the above correlation matrix, number of most correlation features are: 8

1. Failure to identify the processes involved in the project, particularly regarding management of interface among different systems and establish intra-organizational communication
2. Failure to identify the optimal location of stations in the cities to ensure ideal multi-modal connectivity
3. Failure to understand the process associated with the project by contractors
4. Lack of optimum work culture (in India) required to construct and operate such complex large infra projects
5. Risk related to possible sub- optimal designs, both in a concept design or a detailed design
6. Risks due to lack of skilled executive teams with construction companies
7. Risks related to successful long-term operations due to lack of an appropriate management structure, particularly regarding separation of ownership of Infrastructure and Operations
8. The lack of skilled experts in consultant's side

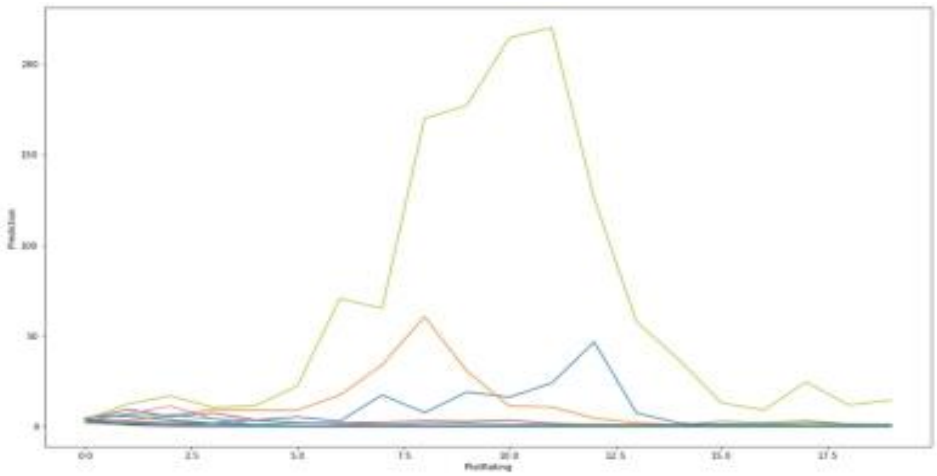


Fig 5. 21 Analysis results obtained from Monte Carlo for C3 –HDCM

Source - Author Self Made

RISK FACTOR	MARKS (Risk probability-prediction as per MCS)
The lack of skilled experts on HSR technology on client's side	3.223391
The lack of skilled experts in consultant's side	3.0104947
Risks due to lack of skilled executive teams with construction companies	3.0405304
Failure to understand the process associated with the project by contractors	2.9115124
Absence of standard specifications for High-Speed Rail in India for components like signaling, safety, Rolling Stock and interface issues	2.8727067
Risk related to possible sub- optimal designs, both in a concept design or a detailed design	2.5884066
Failure to identify the optimal location of stations in the cities to ensure ideal multi-modal connectivity	2.7143824
Failure to identify the processes involved in the project, particularly regarding management of interface among different systems and establish intra-organizational communication	2.356628
Restrictions on use of professional consultation and alternative designs by foreign / Indian companies, particularly related to possible conditions in the bilateral financing arrangement.	1.9810879

Risks related to successful long-term operations due to lack of an appropriate management structure, particularly regarding separation of ownership of Infrastructure and Operations	2.4630654 2.366098
Lack of optimum work culture (in India) required to construct and operate such complex large infra projects	2.48729

Source - Author Self Made

From the above results oof the Monte Carlo Analysis, we can conclude that the *Risk of the lack of skilled experts on HSR technology on client's side* is most likely to happen whereas *the Restrictions on use of professional consultation and alternative designs* are least likely to affect the project.

Table 5. 10 Statistical analysis output of each variable for C3 – HDCM

AttributeName	Rank	Consensus	Verdict
Lack of optimum work culture (in India) required to construct and operate such complex large infra projects	15.360	0.325521	Retained
Risks related to successful long-term operations due to lack of an appropriate management structure, particularly regarding separation of ownership of Infrastructure and Operations	7.680	0.651042	Retained
Restrictions on use of professional consultation and alternative designs by foreign / Indian companies, particularly related to possible conditions in the bilateral financing arrangement.	3.840	1.302083	Retained
Failure to identify the executive processes of the project, particularly regarding management of interface among different systems and establish intra-organizational communication	1.920	2.604167	Retained
Failure to identify the optimal location of stations in the cities to ensure ideal multi-modal connectivity	0.960	5.208333	Retained
Risk related to possible sub- optimal designs, both in a concept design or a detailed design	0.480	10.416667	Retained
Absence of standard specifications for High Speed Rail in India for components like signaling, safety, Rolling Stock and interface issues	0.240	20.833333	Retained
Failure to understand the project and activities associated with it by client/ contractors	0.120	41.666667	Retained
Risks due to lack of skilled executive teams with construction companies	0.060	83.333333	Retained
The lack of skilled experts in consultant's side	0.030	166.666667	Retained
The lack of skilled experts on HSR technology on client's side	0.015	333.333333	Retained

Table 5.11 Ranking table for analyzed data using Monte Carlo for C3 - HDCM

Source - Author Self Made

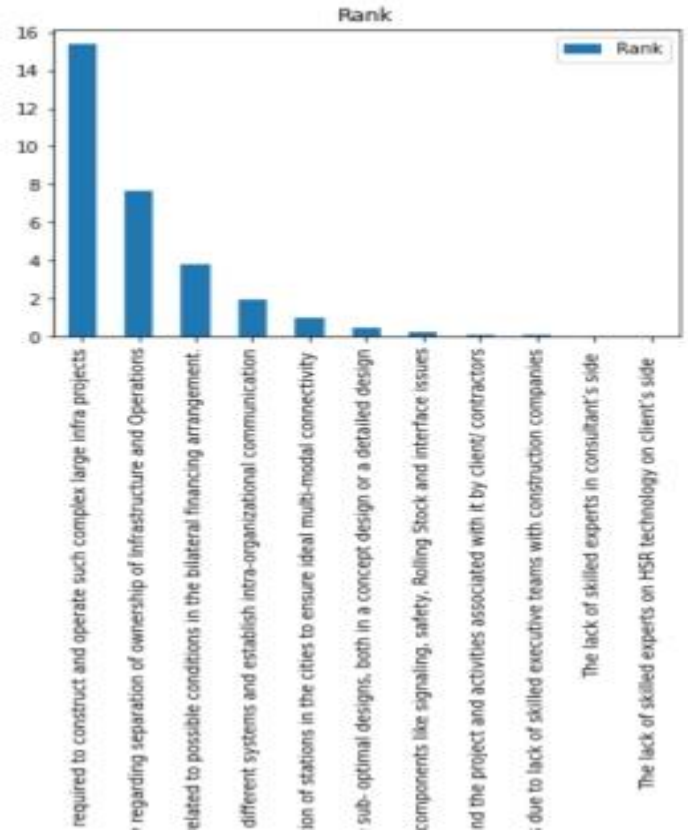


Fig 5. 22 Ranking Table in graphical form for C3 –HDCM **Source - Author Self Made**

AttributeName	Rank	Consensus	Verdict
The lack of skilled experts on HSR technology on client's side	0.07500	66.666667	Retained
The lack of skilled experts in consultant's side	0.07475	66.889632	Retained
Risks due to lack of skilled executive teams with construction companies	0.07450	67.114094	Retained
Failure to understand the project and activities associated with it by client/ contractors	0.07425	67.340067	Retained
Absence of standard specifications for High Speed Rail in India for components like signaling, safety, Rolling Stock and interface issues	0.07400	67.567568	Retained
Risk related to possible sub- optimal designs, both in a concept design or a detailed design	0.07375	67.796610	Retained
Failure to identify the optimal location of stations in the cities to ensure ideal multi-modal connectivity	0.07350	68.027211	Retained
Failure to identify the executive processes of the project, particularly regarding management of interface among different systems and establish intra-organizational communication	0.07325	68.259386	Retained
Restrictions on use of professional consultation and alternative designs by foreign / Indian companies, particularly related to possible conditions in the bilateral financing arrangement.	0.07300	68.493151	Retained
Risks related to successful long-term operations due to lack of an appropriate management structure, particularly regarding separation of ownership of Infrastructure and Operations	0.07275	68.728522	Retained
Lack of optimum work culture (in India) required to construct and operate such complex large infra projects	0.07250	68.965517	Retained

Table 5. 12 Consensus table for analyzed data using Monte Carlo for C3 –HDCM

Source - Author Self Made

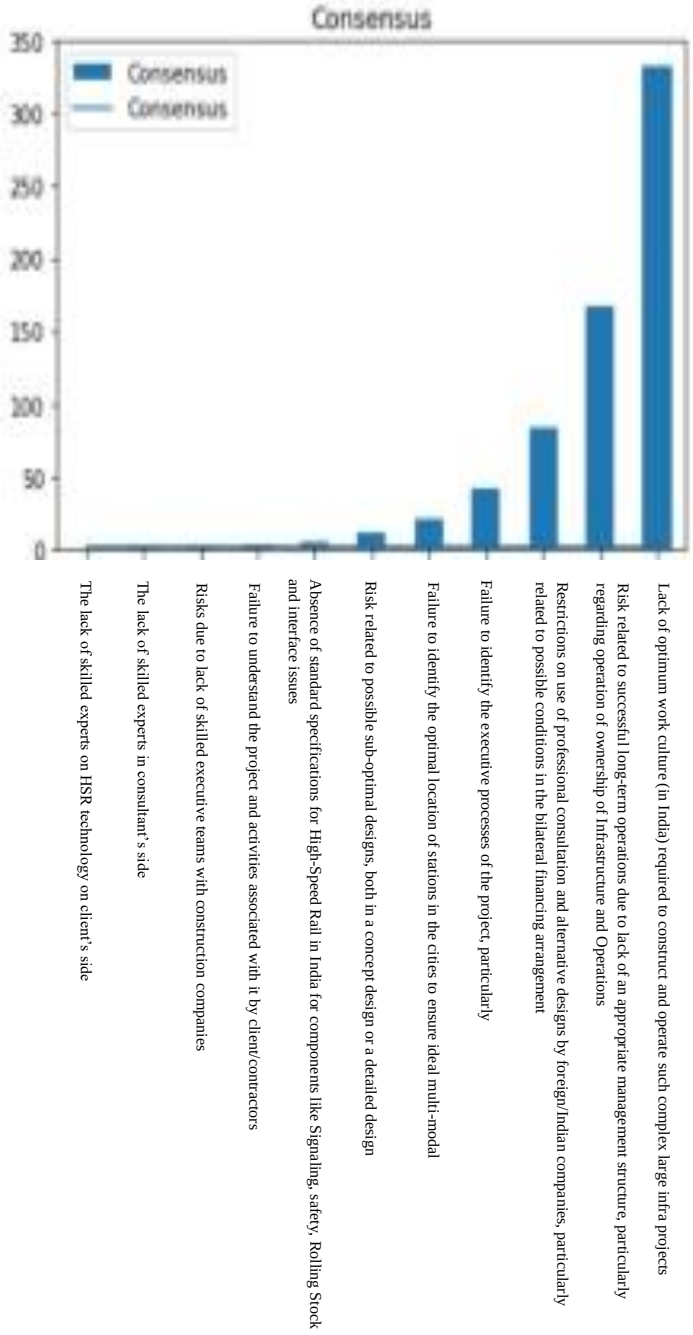


Fig 5. 23 Consensus Table in graphical format for C3 – HDCM

Source - Author Self Made

AttributeName	Rank	Consensus
Absence of standard specifications for High Speed Rail in India for components like signaling, safety, Rolling Stock and interface issues	0.31400	88.400901
Failure to identify the executive processes of the project, particularly regarding management of interface among different systems and establish intra-organizational communication	1.99325	70.863552
Failure to identify the optimal location of stations in the cities to ensure ideal multi-modal connectivity	1.03350	73.235544
Failure to understand the project and activities associated with it by client/ contractors	0.19425	109.006734
Lack of optimum work culture (in India) required to construct and operate such complex large infra projects	15.43250	69.291038
Restrictions on use of professional consultation and alternative designs by foreign / Indian companies, particularly related to possible conditions in the bilateral financing arrangement.	3.91300	69.795234
Risk related to possible sub- optimal designs, both in a concept design or a detailed design	0.55375	78.213277
Risks due to lack of skilled executive teams with construction companies	0.13450	150.447427
Risks related to successful long-term operations due to lack of an appropriate management structure, particularly regarding separation of ownership of Infrastructure and Operations	7.75275	69.379564
The lack of skilled experts in consultant's side	0.10475	233.556299
The lack of skilled experts on HSR technology on client's side	0.09000	400.000000

Table 5.13 Prominence table for C3 – HDCM Source - Author Self Made

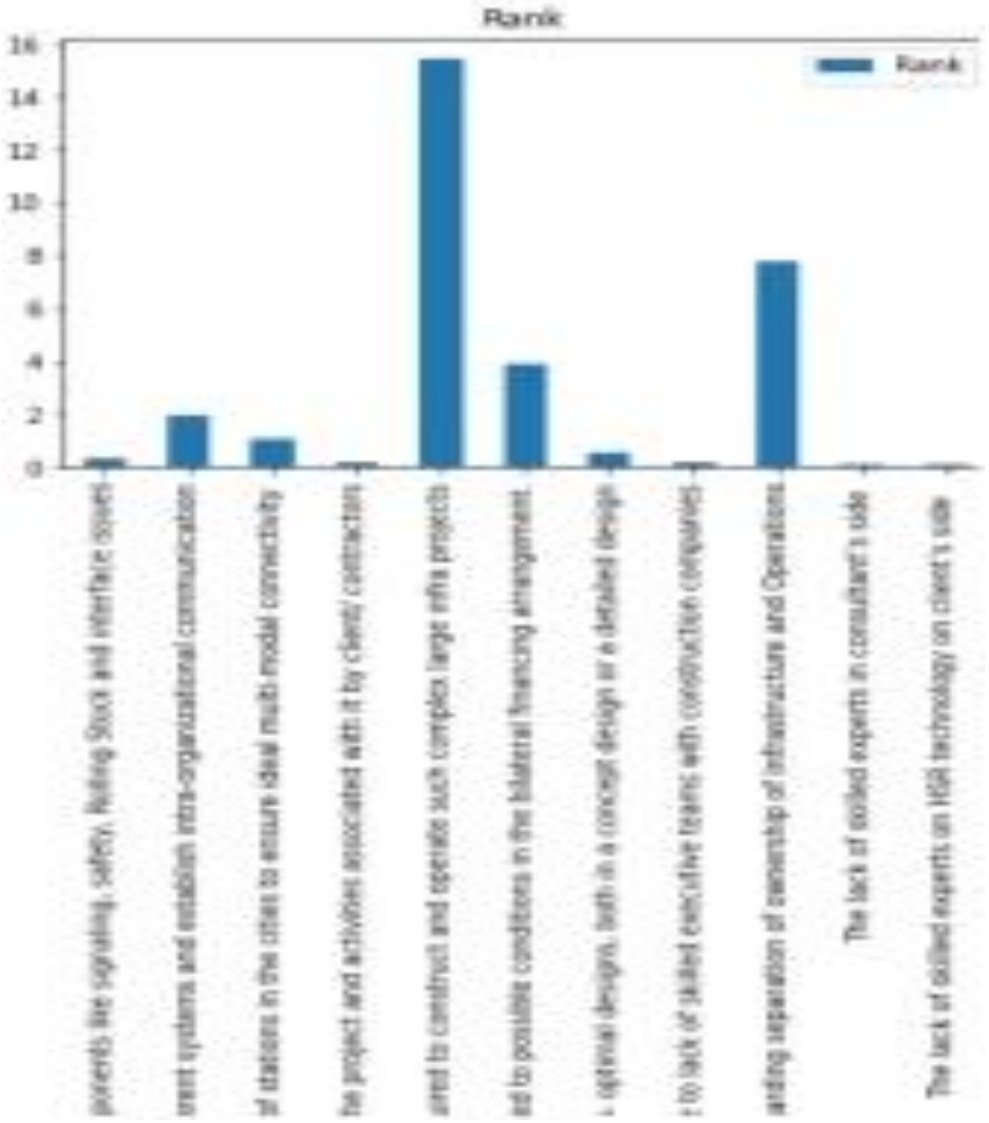


Fig 5. 24 Prominence analysis in graphical format for C3 – HDCM Source - Author Self Made

AttributeName	Rank	Consensus
Absence of standard specifications for High Speed Rail in India for components like signaling, safety, Rolling Stock and interface issues	0.16600	-46.734234
Failure to identify the executive processes of the project, particularly regarding management of interface among different systems and establish intra-organizational communication	1.84675	-65.655219
Failure to identify the optimal location of stations in the cities to ensure ideal multi-modal connectivity	0.88650	-62.818878
Failure to understand the project and activities associated with it by client/ contractors	0.04575	-25.673401
Lack of optimum work culture (in India) required to construct and operate such complex large infra projects	15.28750	-68.639996
Restrictions on use of professional consultation and alternative designs by foreign / Indian companies, particularly related to possible conditions in the bilateral financing arrangement.	3.76700	-67.191067
Risk related to possible sub- optimal designs, both in a concept design or a detailed design	0.40625	-57.379944
Risks due to lack of skilled executive teams with construction companies	-0.01450	16.219239
Risks related to successful long-term operations due to lack of an appropriate management structure, particularly regarding separation of ownership of Infrastructure and Operations	7.60725	-68.077481
The lack of skilled experts in consultant's side	-0.04475	99.777035
The lack of skilled experts on HSR technology on client's side	-0.06000	266.666667

Table 5. 14 Relation Table for C3 – HDCM Source - Author Self Made

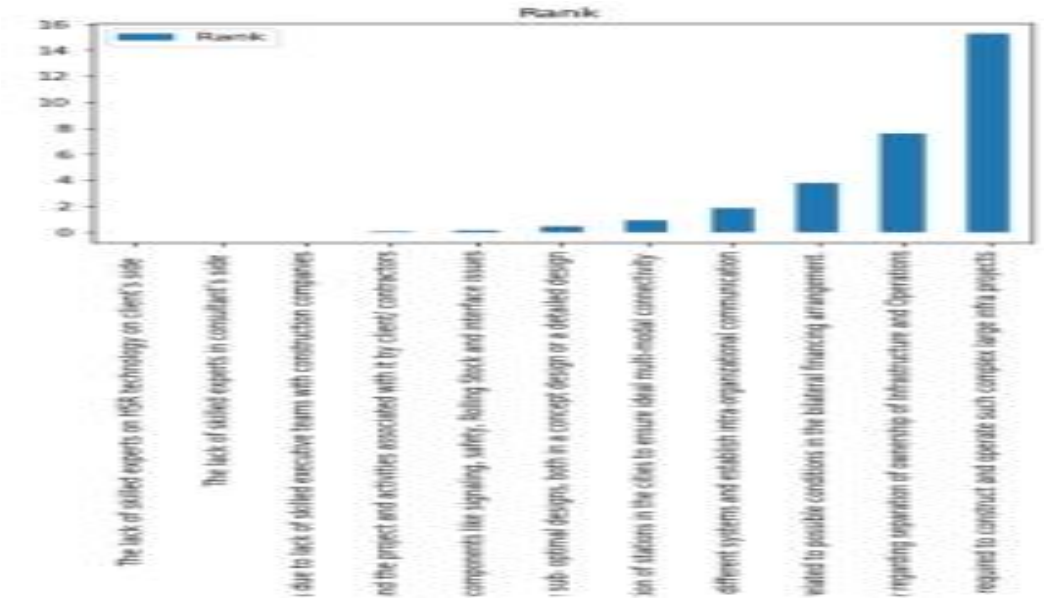


Fig 5. 25 Relation table in graphical format for C3 – HDCM Source - Author Self Made

5.2.2 Result: From the above Prominence and Relation analysis, it is observed that ***the lack of skilled experts on HSR technology on client's side*** has the highest effect over all others features in this category and also receives the most effect from all risk features in the category. Thus, from the management perspective, this risk feature needs to be mitigated on high priority and the ***the lack of skilled experts on HSR technology on client's side*** and ***the lack of skilled experts in consultant's side*** have the highest probability of occurrence and have to be monitored.

5.4 C4-CTLQC Construction, Technology, Land acquisition, Quality, Contract Risks: Dataset Attributes

	Right of way (Land) acquisition delays due to poor record and disputed ownership	Right of way (Land) acquisition delays due to inadequate /unsatisfactory compensation leading to litigation	Preventing implementation of the project in agricultural lands by the farmers post formal acquisition	Preventing implementation of project in the government-owned lands by the Department of Environment	Lack of proper implementation plan including swift decisions to contractors	Lack of appropriate advanced of material /equipment including poor quality and adequate safety arrangements at construction sites	The failure of contractors and consultants to consider the project final cost and estimate profit and loss i.e., low bids	Lack of adequate capital/ cash flow difficulties with construction companies	Lack of technical knowledge and trained manpower	Lack of aptitude in using proper digital MIS platforms leading to such management tools under-utilized	Risks related to delay in government approvals, traffic diversions etc.
1	5.0	5.0	5.0	3.0	5.0	4.0	5.0	5.0	4.0	4.0	5.0
2	5.0	2.0	3.0	3.0	3.0	5.0	5.0	5.0	5.0	3.0	4.0
3	4.0	5.0	4.0	2.0	3.0	2.0	2.0	4.0	3.0	2.0	4.0
4	5.0	5.0	5.0	3.0	4.0	3.0	5.0	4.0	4.0	3.0	4.0
5	5.0	5.0	5.0	5.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0
6	4.0	4.0	3.0	2.0	5.0	4.0	4.0	4.0	5.0	3.0	5.0
7	5.0	4.0	5.0	3.0	3.0	3.0	4.0	3.0	1.0	2.0	4.0
8	5.0	5.0	5.0	4.0	4.0	2.0	2.0	2.0	3.0	3.0	4.0
9	5.0	4.0	5.0	3.0	2.0	3.0	4.0	3.0	3.0	2.0	2.0
10	5.0	5.0	3.0	3.0	3.0	5.0	5.0	4.0	5.0	3.0	3.0
11	5.0	5.0	5.0	5.0	4.0	4.0	3.0	5.0	4.0	3.0	4.0
12	5.0	5.0	5.0	4.0	5.0	5.0	5.0	5.0	5.0	2.0	5.0
13	4.0	4.0	4.0	2.0	4.0	3.0	4.0	3.0	4.0	4.0	4.0
14	5.0	4.0	4.0	5.0	3.0	4.0	5.0	4.0	3.0	3.0	5.0
15	3.0	3.0	4.0	4.0	4.0	3.0	2.0	3.0	4.0	3.0	4.0
16	5.0	5.0	5.0	5.0	5.0	4.0	5.0	4.0	5.0	3.0	5.0
17	3.0	4.0	4.0	3.0	3.0	2.0	4.0	4.0	3.0	3.0	4.0
18	4.0	3.0	2.0	4.0	3.0	3.0	4.0	4.0	5.0	5.0	3.0
19	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
20	4.0	4.0	5.0	4.0	3.0	3.0	3.0	4.0	4.0	4.0	3.0
21	5.0	2.0	2.0	2.0	4.0	2.0	4.0	4.0	4.0	4.0	4.0
22	5.0	4.0	4.0	2.0	4.0	4.0	4.0	4.0	5.0	2.0	5.0
23	4.0	4.0	4.0	4.0	3.0	2.0	3.0	3.0	2.0	2.0	4.0
24	4.0	4.0	3.0	2.0	3.0	2.0	3.0	4.0	3.0	2.0	4.0
25	5.0	5.0	3.0	3.0	4.0	4.0	5.0	4.0	4.0	3.0	4.0
26	4.0	3.0	3.0	2.0	3.0	2.0	3.0	3.0	4.0	3.0	3.0
27	4.0	4.0	5.0	5.0	5.0	4.0	5.0	5.0	4.0	4.0	5.0
28	5.0	5.0	5.0	3.0	4.0	4.0	5.0	5.0	4.0	4.0	5.0
29	2.0	3.0	2.0	2.0	2.0	2.0	4.0	3.0	3.0	1.0	2.0
30	4.0	2.0	2.0	2.0	4.0	4.0	2.0	3.0	3.0	4.0	3.0
31	5.0	4.0	4.0	2.0	4.0	2.0	3.0	2.0	2.0	1.0	4.0
32	5.0	5.0	2.0	3.0	4.0	4.0	3.0	4.0	3.0	3.0	5.0
33	5.0	5.0	5.0	3.0	4.0	4.0	4.0	4.0	4.0	5.0	5.0
34	5.0	5.0	4.0	4.0	5.0	4.0	4.0	3.0	4.0	3.0	5.0
35	4.0	4.0	4.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	2.0
36	1.0	2.0	3.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0
37	4.0	4.0	4.0	3.0	5.0	5.0	5.0	5.0	5.0	4.0	5.0
38	5.0	4.0	3.0	3.0	3.0	4.0	5.0	4.0	4.0	4.0	5.0
39	5.0	4.0	2.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
40	5.0	5.0	4.0	4.0	4.0	4.0	3.0	4.0	4.0	3.0	4.0
41	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0
42	5.0	5.0	3.0	4.0	5.0	5.0	4.0	5.0	5.0	5.0	5.0
43	3.0	5.0	3.0	4.0	5.0	2.0	5.0	3.0	3.0	5.0	4.0
44	5.0	5.0	5.0	3.0	4.0	4.0	4.0	4.0	4.0	2.0	4.0

Fig 5. 26 Dataset (Actual Responses) for C4-CTLQC Source - Author Self Made

Abbreviated form of each risk feature (as in Category-1, is not done here. Full form is used. *Feature Selection & Extraction: The results of the Variance Threshold feature selection and the Fisher Score method is as follows:*

Find Constant and Non-Constant Features:

[True True True True True True True True True True True True True]

Number of Non-Constant Features: **13**

Fig 5. 27 Correlation matrix heat map for C4-CTLQC **Source - Author Self Made**

	Right of way (Land) acquisition delays due to poor record and disputed ownership	Right of way (Land) acquisition delays due to inadequate /unsatisfactory compensation leading to litigation	Preventing implementation of the project in agricultural lands by the farmers post formal acquisition	Preventing implementation of project in the government-owned lands by the Department of Environment	Lack of proper implementation plan including swift decisions to contractors	Lack of appropriate advanced of material /equipment including poor quality and adequate safety arrangements at construction sites	The failure of contractors and consultants to consider the project final cost and estimate profit and loss i.e., low bids	Lack of adequate capital/ cash flow difficulties with construction companies	Lack of technical knowledge and trained manpower	Lack of aptitude in using proper digital MIS platforms leading to such management tools under-utilized	Risks related to delay in government approvals, traffic diversions etc.
Right of way (Land) acquisition delays due to poor record and disputed ownership	1.000000	0.806562	0.566718	0.291748	0.500185	0.662685	0.347735	0.361735	0.439516	0.401742	0.569020
Right of way (Land) acquisition delays due to inadequate /unsatisfactory compensation leading to litigation	0.806562	1.000000	0.594909	0.201318	0.515166	0.576719	0.409614	0.414633	0.432735	0.492833	0.409614
Preventing implementation of the project in agricultural											

Fig 5. 28 Correlation matrix for C4-CTLQC Source - Author Self Made

As per the above correlation matrix, number of most correlation features are: 7

1. Lack of adequate capital/ cash flow difficulties with construction companies
2. Lack of technical knowledge and trained manpower
3. Right of way (Land) acquisition delays due to inadequate / unsatisfactory compensation leading to litigation
4. Risks relate to inadequate project management, changes in design, Price variation, extra works, extension of time, insufficient documentation etc. leading to disputes and arbitrations
5. Risks related to delay in government approvals, traffic diversions etc.
6. Risks related to comply with failure aspects of HSE standards, insurance and Labour regulations
7. The failure of understand profitable portion of the project including arriving final cost of the project

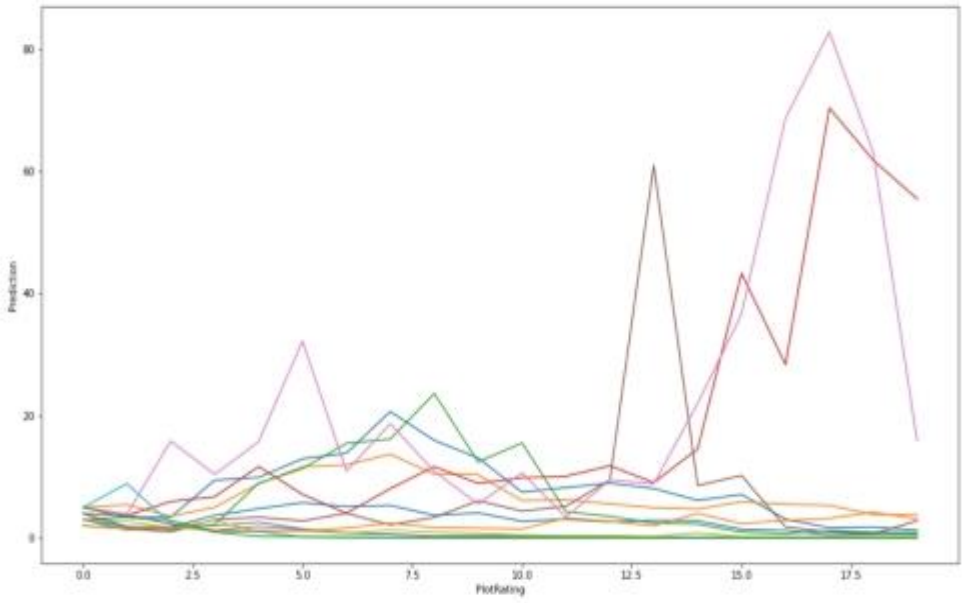


Fig 5.29 Analysis results obtained from Monte Carlo for C4-CTLQC Source - Author Self Made

RISK FACTOR	MARKS (Risk probability-prediction as per MCS)
Right of way (Land) acquisition delays due to poor record and disputed ownership	3.1080706
Right of way (Land) acquisition delays due to inadequate /unsatisfactory compensation leading to litigation	3.0306234
Preventing implementation of the project in agricultural lands by the farmers post formal acquisition	2.9444401
Preventing implementation of project in the government-owned lands	2.867475
Lack of proper implementation plan including swift decisions to contractors	2.7935164
Lack of appropriate advanced of material /equipment including poor quality and adequate safety arrangements at construction sites	2.6543248
The failure of understand profitable portion of the project including arriving fi cost of the project	2.620482 2.5330935
Lack of adequate capital/ cash flow difficulties with construction companies	2.413249
Lack of technical knowledge and trained manpower	2.3846033
Risks related to delay in government approvals, traffic diversions etc.	2.30167
Risks relate to inadequate project management, changes in design, Price variation, extra works, extension of time, insufficient documentation etc. leading to disputes and arbitrations	3.7933977
Inadequate provision of Risk Management in contract document including poor risk allocation	3.7920554

Table 5.15 Statistical analysis output of each variable for C4-CTLQC Source – Author

Result: From the above results from the Monte Carlo analysis, it is observed that the ***Risks related to inadequate project management, changes in design, Price variation, extra works, extension of time, insufficient documentation etc. leading to disputes and arbitrations*** are most likely to affect the project whereas *the* ***Risks related to delay in government approvals, traffic diversions etc.,*** will most likely be of least problem to the HSR project.

AttributeName	Rank	Consensus	Verdict
Risks relate to inadequate project management, changes in design, Price variation, extra works, extension of time, insufficient documentation etc. leading to disputes and arbitrations	61.440	0.081380	Retained
Risks related to failure to comply with HSE standards, insurance and labour regulations	30.720	0.162760	Retained
Risks related to delay in government approvals, traffic diversions etc.	15.360	0.325521	Retained
Lack of aptitude in using proper digital MIS platforms leading to such management tools under-utilized	7.680	0.651042	Retained
Lack of technical knowledge and trained manpower	3.840	1.302083	Retained
Lack of adequate capital/ cash flow difficulties with construction companies	1.920	2.604167	Retained
The failure of contractors and consultants to consider the project final cost and estimate profit and loss i.e., low bids	0.960	5.208333	Retained
Lack of appropriate advanced of material /equipment including poor quality and adequate safety arrangements at construction sites	0.480	10.416667	Retained
Lack of proper implementation plan including swift decisions to contractors	0.240	20.833333	Retained
Preventing implementation of project in the government-owned lands by the Department of Environment	0.120	41.666667	Retained
Preventing implementation of the project in agricultural lands by the farmers post formal acquisition	0.060	83.333333	Retained
Right of way (Land) acquisition delays due to inadequate /unsatisfactory compensation leading to litigation	0.030	166.666667	Retained
Right of way (Land) acquisition delays due to poor record and disputed ownership	0.015	333.333333	Retained

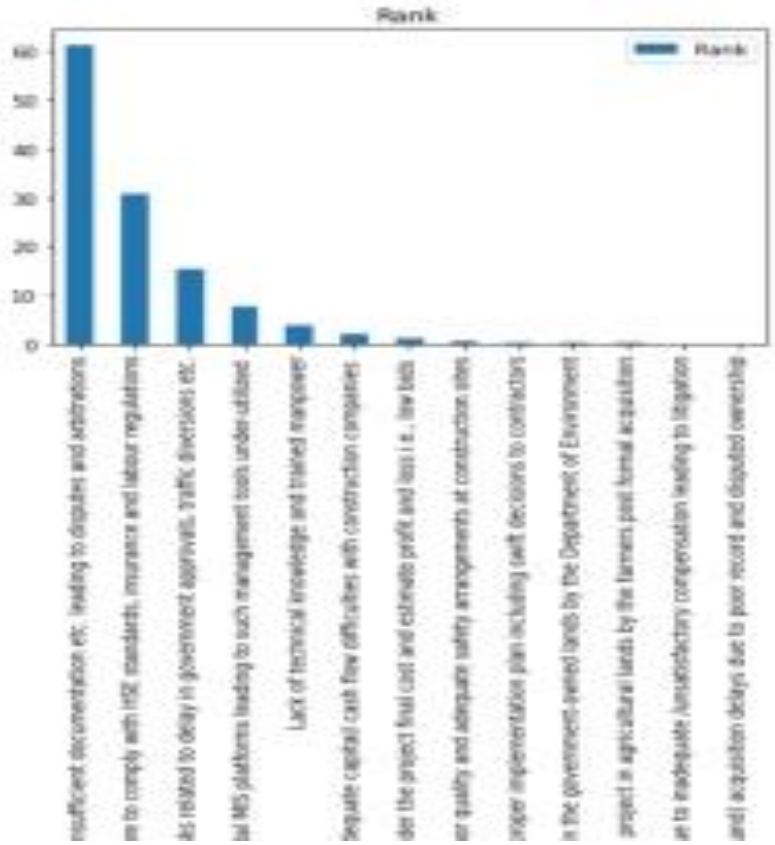


Fig 5. 30 Ranking Table in graphical form for C4-CTLQC Source - Author Self Made

AttributeName	Rank	Consensus	Verdict
Right of way (Land) acquisition delays due to poor record and disputed ownership	0.07500	66.666667	Retained
Right of way (Land) acquisition delays due to inadequate /unsatisfactory compensation leading to litigation	0.07475	66.889632	Retained
Preventing implementation of the project in agricultural lands by the farmers post formal acquisition	0.07450	67.114094	Retained
Preventing implementation of project in the government-owned lands by the Department of Environment	0.07425	67.340067	Retained
Lack of proper implementation plan including swift decisions to contractors	0.07400	67.567568	Retained
Lack of appropriate advanced of material /equipment including poor quality and adequate safety arrangements at construction sites	0.07375	67.796610	Retained
The failure of contractors and consultants to consider the project final cost and estimate profit and loss i.e., low bids	0.07350	68.027211	Retained
Lack of adequate capital/ cash flow difficulties with construction companies	0.07325	68.259386	Retained
Lack of technical knowledge and trained manpower	0.07300	68.493151	Retained
Lack of aptitude in using proper digital MIS platforms leading to such management tools under-utilized	0.07275	68.728522	Retained
Risks related to delay in government approvals, traffic diversions etc.	0.07250	68.965517	Retained
Risks related to failure to comply with HSE standards, insurance and labour regulations	0.07225	69.204152	Retained
Risks relate to inadequate project management, changes in design, Price variation, extra works, extension of time, insufficient documentation etc. leading to disputes and arbitrations	0.07200	69.444444	Retained

Table 5.16 Consensus table for analyzed data using Monte Carlo for C4-CTLQC

Source - Author Self Made

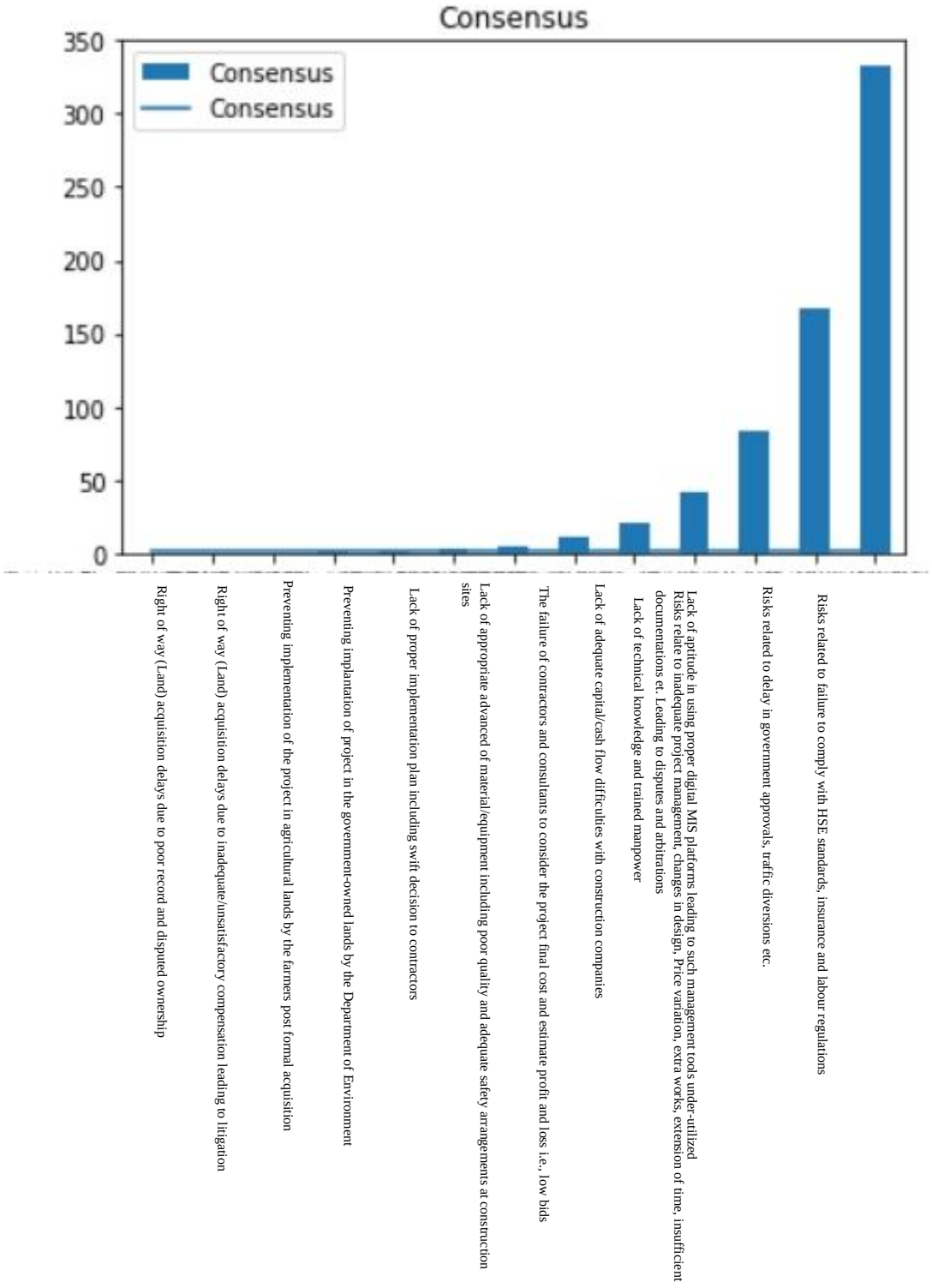


Fig 5. 31 Consensus Table in graphical format for C4 – CTLQC **Source - Author Self Made**

AttributeName	Rank	Consensus
Lack of adequate capital/ cash flow difficulties with construction companies	1.99325	70.863552
Lack of appropriate advanced of material /equipment including poor quality and adequate safety arrangements at construction sites	0.55375	78.213277
Lack of aptitude in using proper digital MIS platforms leading to such management tools under-utilized	7.75275	69.379564
Lack of proper implementation plan including swift decisions to contractors	0.31400	88.400901
Lack of technical knowledge and trained manpower	3.91300	69.795234
Preventing implementation of project in the government-owned lands by the Department of Environment	0.19425	109.006734
Preventing implementation of the project in agricultural lands by the farmers post formal acquisition	0.13450	150.447427
Right of way (Land) acquisition delays due to inadequate /unsatisfactory compensation leading to litigation	0.10475	233.556299
Right of way (Land) acquisition delays due to poor record and disputed ownership	0.09000	400.000000
Risks relate to inadequate project management, changes in design, Price variation, extra works, extension of time, insufficient documentation etc. leading to disputes and arbitrations	61.51200	69.525825
Risks related to delay in government approvals, traffic diversions etc.	15.43250	69.291038
Risks related to failure to comply with HSE standards, insurance and labour regulations	30.79225	69.366913
The failure of contractors and consultants to consider the project final cost and estimate profit and loss i.e., low bids	1.03350	73.235544

Table 5. 17 Prominence table for C4-CTLQC

Source - Author Self Made

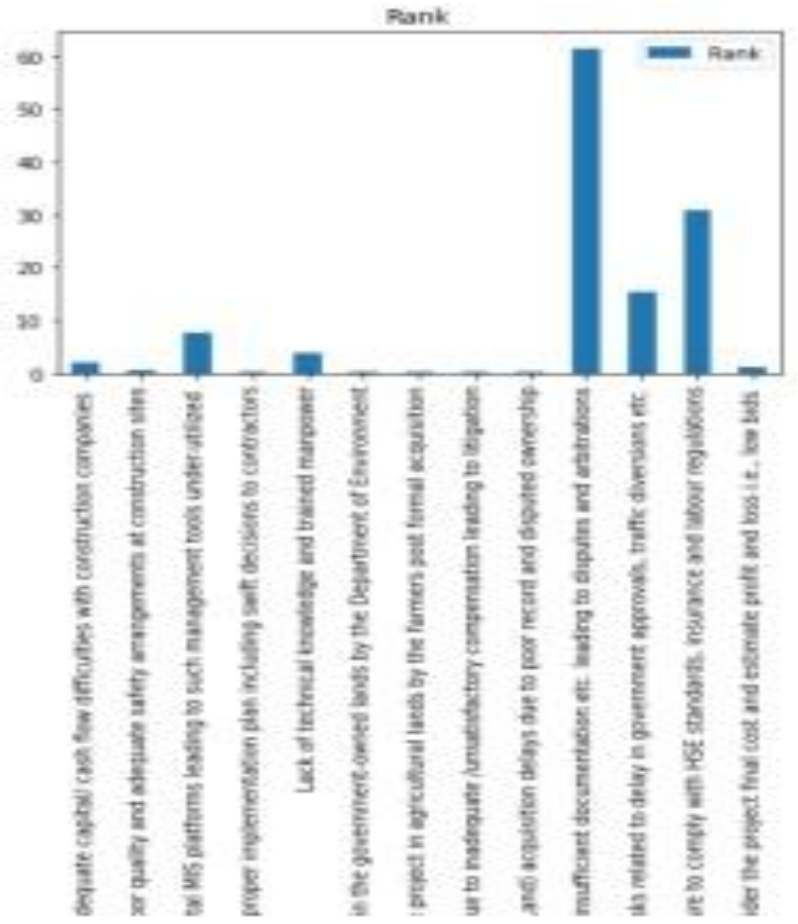


Fig 5. 32 Prominence analysis for C4-CTLQC

Source - Author Self Made

AttributeName	Rank	Consensus
Lack of adequate capital/ cash flow difficulties with construction companies	1.84675	-65.655219
Lack of appropriate advanced of material /equipment including poor quality and adequate safety arrangements at construction sites	0.40625	-57.379944
Lack of aptitude in using proper digital MIS platforms leading to such management tools under-utilized	7.60725	-68.077481
Lack of proper implementation plan including swift decisions to contractors	0.16600	-46.734234
Lack of technical knowledge and trained manpower	3.76700	-67.191067
Preventing implementation of project in the government-owned lands by the Department of Environment	0.04575	-25.673401
Preventing implementation of the project in agricultural lands by the farmers post formal acquisition	-0.01450	16.219239
Right of way (Land) acquisition delays due to inadequate /unsatisfactory compensation leading to litigation	-0.04475	99.777035
Right of way (Land) acquisition delays due to poor record and disputed ownership	-0.06000	266.666667
Risks relate to inadequate project management, changes in design, Price variation, extra works, extension of time, insufficient documentation etc. leading to disputes and arbitrations	61.36800	-69.363064
Risks related to delay in government approvals, traffic diversions etc.	15.28750	-68.639996
Risks related to failure to comply with HSE standards, insurance and labour regulations	30.64775	-69.041392
The failure of contractors and consultants to consider the project final cost and estimate profit and loss i.e., low bids	0.88650	-62.818878

Table 5. 18 Relation Table for C4-CTLQC

Source - Author Self Made

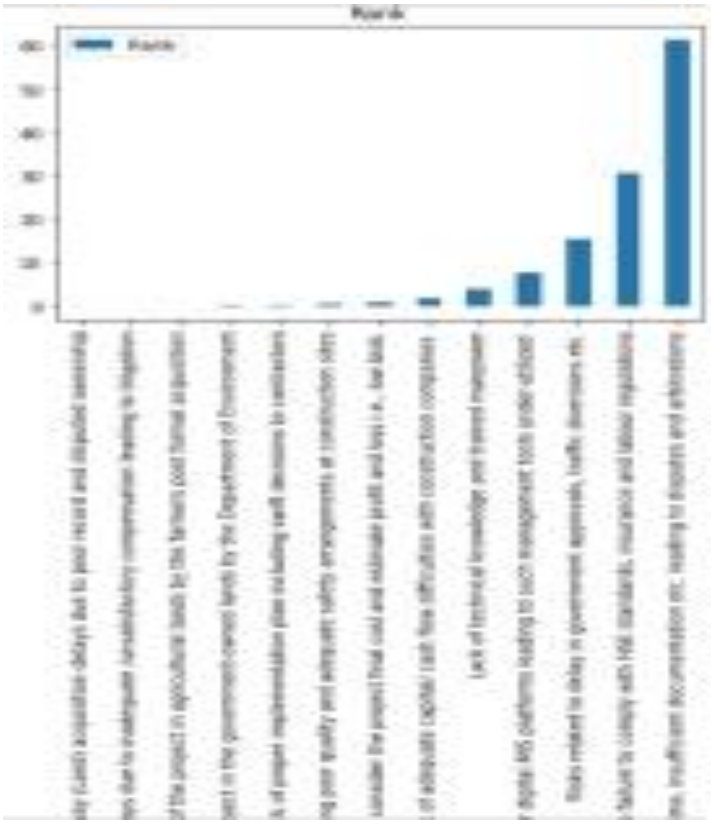


Fig 5. 33 Relation table in graphical format for C4-CTLQC

Source – Author Self Made

5.4.2 Result: From the above Prominence and Relation analysis, it is observed that **Right of way (Land) acquisition delays due to poor record and disputed ownership** has the highest effect over all others features in this category and also receives the most effect from all risk features in the category. Thus, from the management perspective, this risk feature needs to be mitigated on high priority. The risk parameters **Risks relate to inadequate project management, changes in design, Price variation, extra works, extension of time, insufficient documentation etc., leading to disputes and arbitrations** and **Inadequate provision of Risk Management in contract document including poor risk allocation** have the highest probability of occurrence and have to be monitored.

5.5 C5-CCHO Completion, Commissioning and Handing Over Risks: Dataset Attributes

	Risks related to Testing and Commissioning of the HSR system- inadequate experience	Risks related to final Approvals/Permits	Risks related to inadequate repository of knowledge with the Public Authority granting approvals	Change of Control or Transition Risk on completion of the project
1	5.0	4.0	5.0	5.0
2	4.0	2.0	3.0	4.0
3	4.0	4.0	4.0	4.0
4	4.0	4.0	4.0	3.0
5	3.0	5.0	5.0	4.0
6	3.0	3.0	4.0	3.0
7	2.0	2.0	2.0	2.0
8	3.0	4.0	4.0	5.0
9	4.0	3.0	2.0	2.0
10	5.0	5.0	5.0	5.0
11	4.0	3.0	4.0	3.0
12	4.0	4.0	5.0	5.0
13	3.0	2.0	3.0	3.0
14	4.0	5.0	5.0	5.0
15	3.0	3.0	2.0	2.0
16	5.0	4.0	5.0	3.0
17	3.0	2.0	2.0	3.0
18	2.0	1.0	2.0	3.0
19	4.0	3.0	4.0	4.0
20	3.0	3.0	4.0	4.0
21	2.0	2.0	4.0	3.0
22	3.0	3.0	4.0	4.0
23	2.0	2.0	1.0	1.0
24	2.0	3.0	4.0	3.0
25	4.0	3.0	3.0	3.0
26	3.0	4.0	3.0	3.0
27	5.0	5.0	4.0	5.0
28	3.0	4.0	5.0	5.0
29	3.0	3.0	3.0	2.0
30	2.0	4.0	4.0	2.0
31	4.0	5.0	5.0	4.0
32	3.0	3.0	3.0	3.0
33	5.0	5.0	4.0	3.0
34	5.0	5.0	5.0	4.0
35	1.0	1.0	1.0	1.0
36	1.0	1.0	1.0	1.0
37	3.0	4.0	4.0	3.0
38	5.0	4.0	3.0	4.0
39	4.0	4.0	5.0	4.0
40	3.0	2.0	2.0	2.0
41	4.0	4.0	4.0	4.0
42	5.0	5.0	5.0	4.0
43	2.0	3.0	4.0	5.0
44	4.0	4.0	4.0	4.0

Fig 5. 34 Dataset (Actual Responses) for C5-CCHO Source - Author Self Made

Abbreviated rom of each risk feature (as in Category-1, is not done here. Full form is used. *Feature Selection & Extraction: The results of the Variance Threshold feature selection and the Fisher Score method is as follows:*

Find Constant and Non-Constant Features:

[True TrueTrue True]

Number of Non-Constant Features: **4**

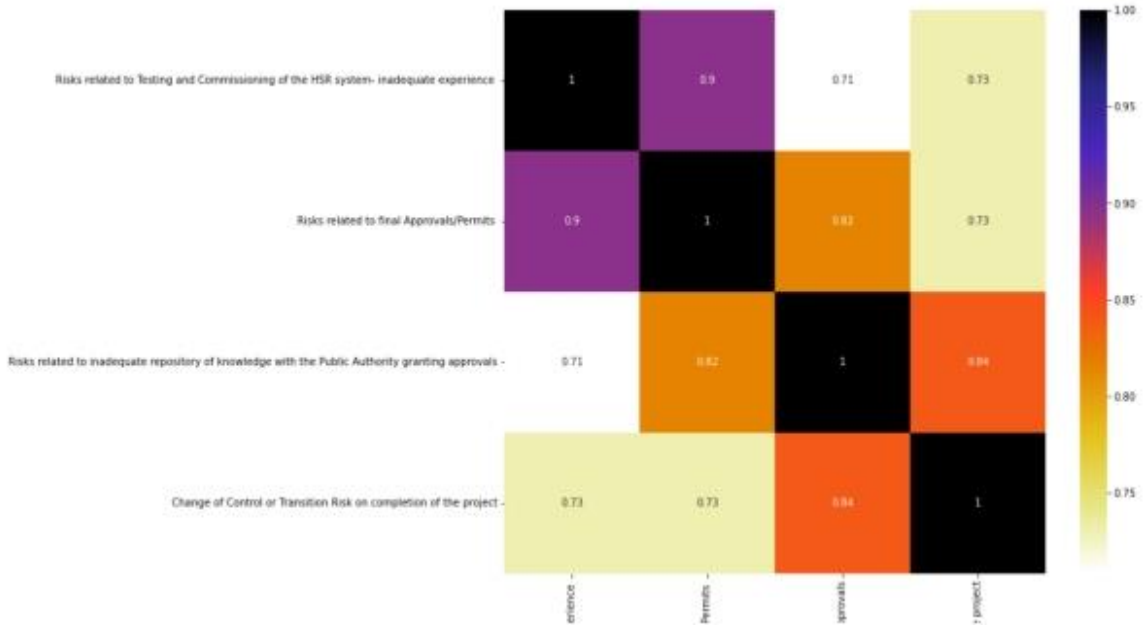


Fig 5. 35 Correlation matrix heat map for C5-CCHO

Source - Author Self Made

	Risks related to Testing and Commissioning of the HSR system- inadequate experience	Risks related to final Approvals/Permits	Risks related to inadequate repository of knowledge with the Public Authority granting approvals	Change of Control or Transition Risk on completion of the project
Risks related to Testing and Commissioning of the HSR system- inadequate experience	1.000000	0.897059	0.708447	0.731814
Risks related to final Approvals/Permits	0.897059	1.000000	0.816254	0.731814
Risks related to inadequate repository of knowledge with the Public Authority granting approvals	0.708447	0.816254	1.000000	0.840100
Change of Control or Transition Risk on completion of the project	0.731814	0.731814	0.840100	1.000000

Fig 5. 36 Correlation matrix for C5-CCHO

As per the above correlation matrix, number of most correlation features: 3

1. Change of Control or Transition Risk on completion of the project
2. Risks related to final Approvals/Permits
3. Risks related to inadequate repository of knowledge with the Public Au thority granting
   approvals

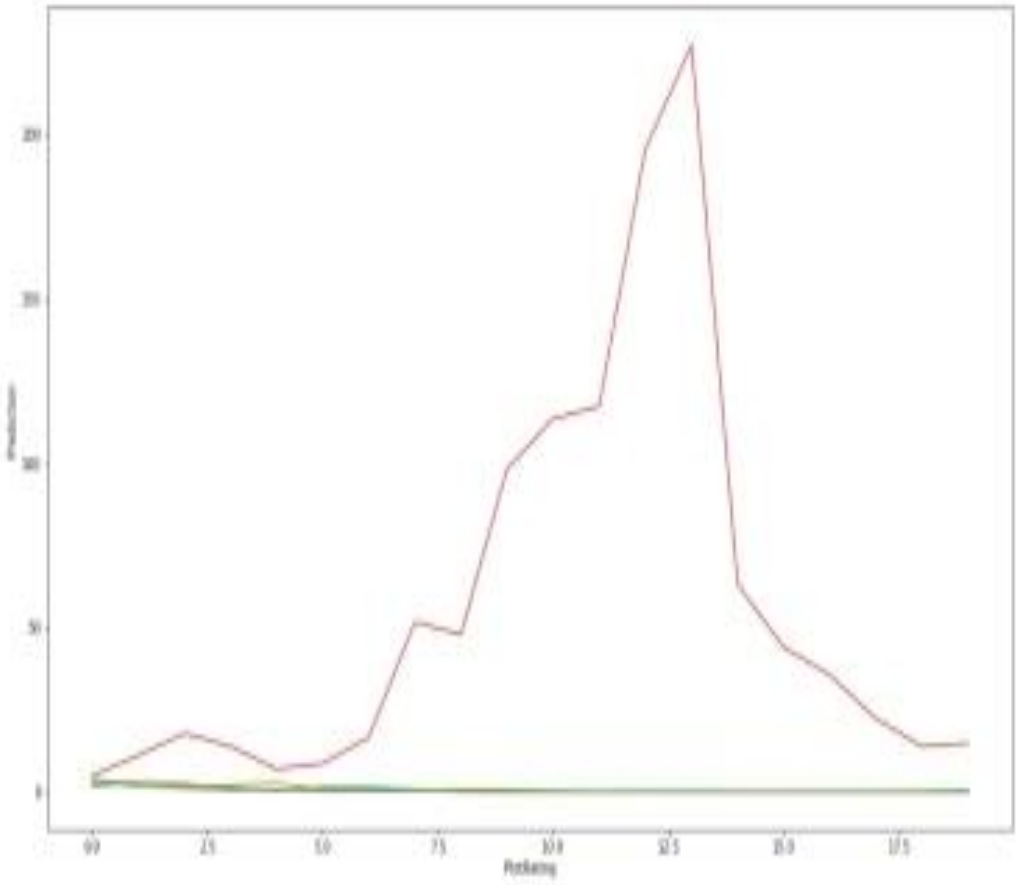


Fig 5. 37 Analysis results obtained from Monte Carlo for C5-CCHO

Source - Author Self Made

RISK FACTOR	MARKS
Risks related to Testing and Commissioning of the HSR system- inadequate experience	3.7653077
Risks related to final Approvals/Permits	3.8263307
Risks related to inadequate repository of knowledge with the Public Authority granting approvals	3.7961984
Change of Control or Transition Risk on completion of the project.	3.5751438

Table 5. 19 Statistical analysis o/p of each variable (C5-CCHO)

Source - Author Self Made

5.5.1 Result: From the results of the Monte Carlo Simulation method, after performing the risk factor probability analysis, the MARKS as shown in the table above signify how much probability of occurrence each of the above features have in the Indian HSR project. From the above analysis of results, it is observed that *Risks related to final Approvals/Permits* are the highest in this category whereas the *Change of Control or Transition Risk on completion of the project* has the least likelihood of occurrence.

AttributeName	Rank	Consensus	Verdict
Change of Control or Transition Risk on completion of the project	0.120	41.666667	Retained
Risks related to inadequate repository of knowledge with the Public Authority granting approvals	0.060	83.333333	Retained
Risks related to final Approvals/Permits	0.030	166.666667	Retained
Risks related to Testing and Commissioning of the HSR system- inadequate experience	0.015	333.333333	Retained

Table 5. 20 Ranking table for analyzed data using Monte Carlo for C5-CCHO

Source - Author Self Made

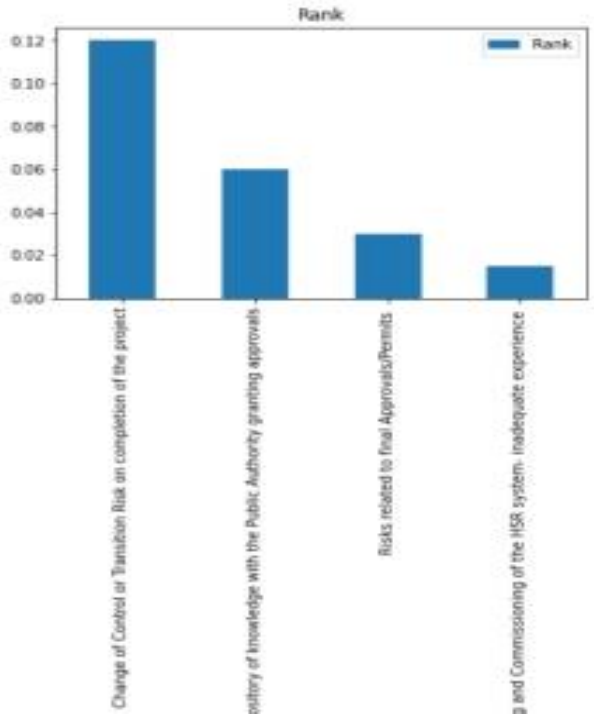


Fig 5. 38 Ranking Table in graphical form for C5-CCHO

Source - Author Self Made

AttributeName		Rank	Consensus	Verdict
Risks related to Testing and Commissioning of the HSR system- inadequate experience	0.07500	66.666667	Retained
Risks related to final Approvals/Permits	0.07475	66.889632	Retained
Risks related to inadequate repository of knowledge with the Public Authority granting approvals	0.07450	67.114094	Retained
Change of Control or Transition Risk on completion of the project	0.07425	67.340067	Retained

Table 5. 21 Consensus table for analysed data using Monte Carlo method for C5-CCHO

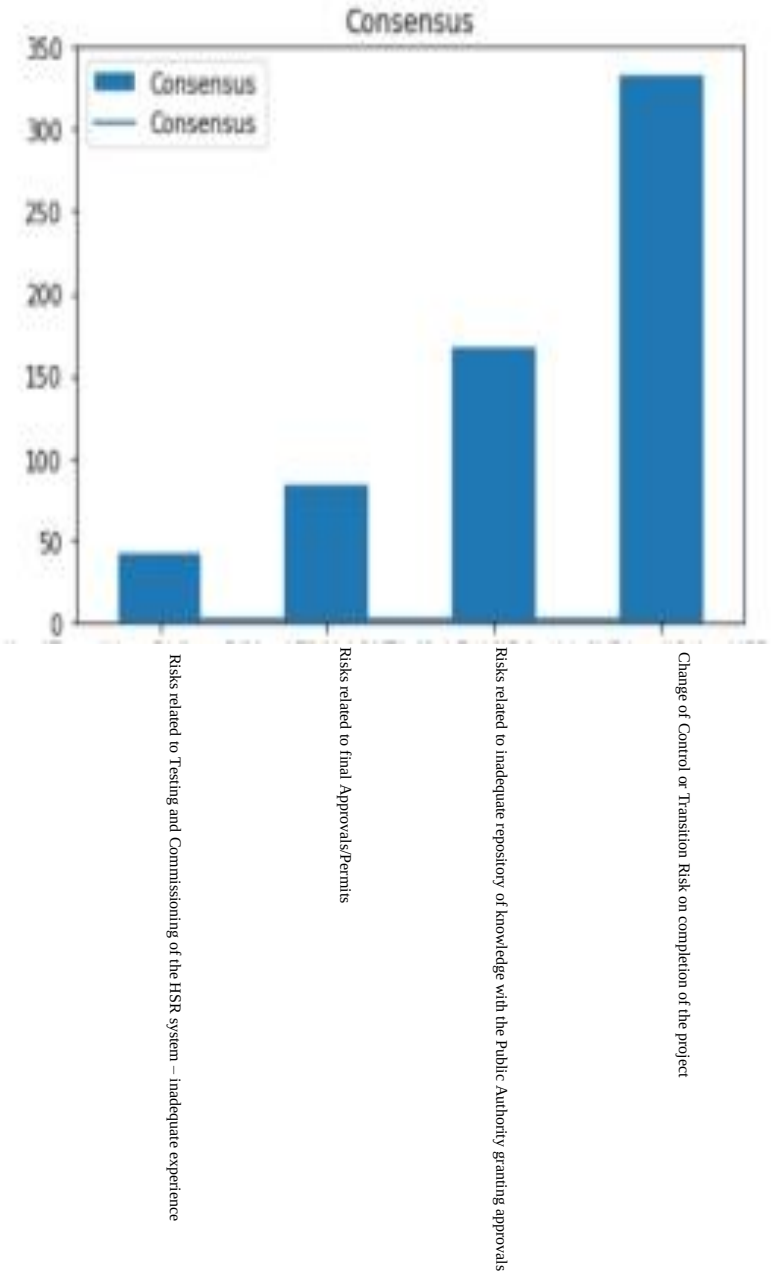


Fig 5. 39 Consensus Table in graphical format for C5-CCHO **Source - Author Self Made**

AttributeName	Rank	Consensus
Change of Control or Transition Risk on completion of the project	0.19425	109.006734
Risks related to Testing and Commissioning of the HSR system- inadequate experience	0.09000	400.000000
Risks related to final Approvals/Permits	0.10475	233.556299
Risks related to inadequate repository of knowledge with the Public Authority granting approvals	0.13450	150.447427

Table 5. 22 Prominence table for C5-CCHO

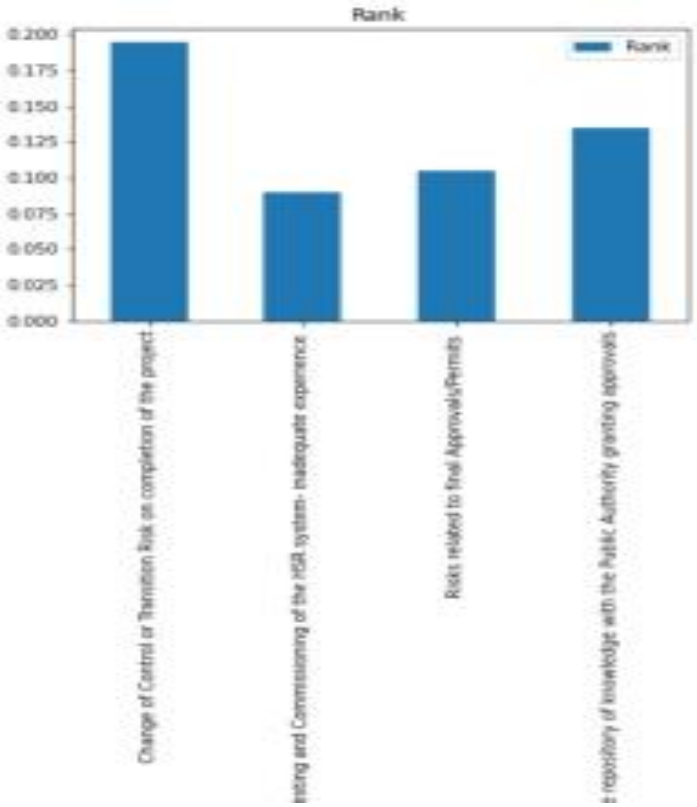


Fig 5. 40 Prominence analysis for C5-CCHO **Source** - Author Self Made

AttributeName	Rank	Consensus
Change of Control or Transition Risk on completion of the project	0.04575	-25.673401
Risks related to Testing and Commissioning of the HSR system- inadequate experience	-0.06000	266.666667
Risks related to final Approvals/Permits	-0.04475	99.777035
Risks related to inadequate repository of knowledge with the Public Authority granting approvals	-0.01450	16.219239

Table 5. 23 Relation Table for C5-CCHO

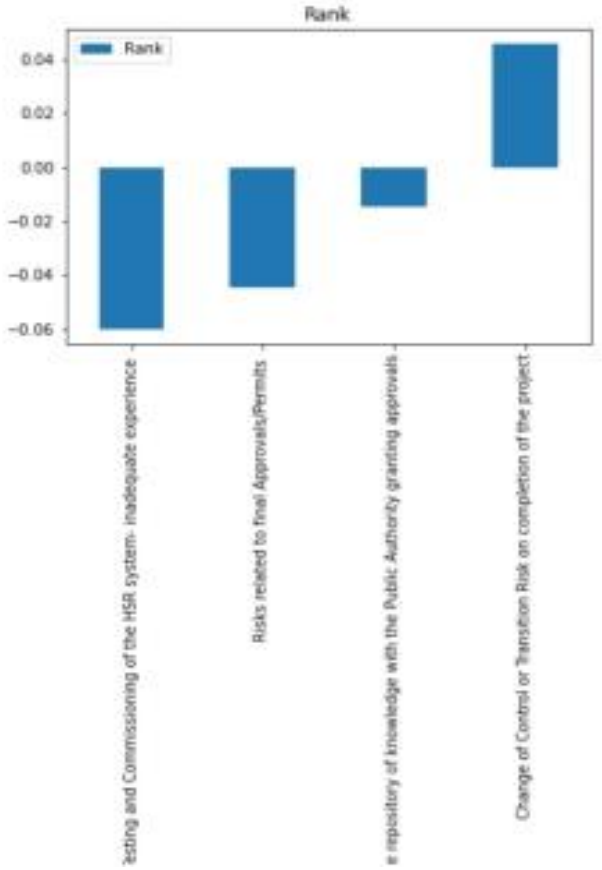


Fig 5. 41 Relation table in graphical format for C5-CCHO Source – Author Self Made

5.5.3 Result: From the above Prominence and Relation analysis, it is observed that *Risks related to Testing and Commissioning of the HSR systems-Inadequate experience* has the highest effect over all the others features in this category and also receives the most effect from all the risk features in the category. Thus, from the management perspective, this risk feature needs to be mitigated on high priority. The risk *Risks related to final Approvals/Permits* have the highest probability of occurrence and have to be monitored.

5.6. C-6 RORNR - Revenue, O&M Costs, Ridership, Non fare revenue, Replacement costs

Risk: Dataset Attributes

	Risks in Contractual robustness/ enforceability in regard to Operation contracts	Risks of inflated ridership estimates leading to reduced fare revenues	Risks of inflated non-fare revenues like advertisements etc.	Reduced success in commercial exploitation of station area real estate due to complicated processing and uncertainty in lease/ownership rights	Time and cost escalation of the project due to various risks discussed earlier	Risk of lower O&M costs at estimation stage and higher O&M costs during operation	Risk of increased costs of replacement of capital assets like track and rolling stock then that estimated	Risk in insufficient attention to development of stations as commercial profit centers	Risks of dispute in sharing of revenues among shareholders and the SPV	Risks of refinancing or change in concession agreements in case of reduced ridership
1	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	3.0	3.0
2	3.0	3.0	4.0	5.0	3.0	4.0	5.0	3.0	3.0	2.0
3	3.0	2.0	2.0	2.0	4.0	4.0	4.0	2.0	4.0	3.0
4	4.0	4.0	3.0	4.0	5.0	4.0	4.0	3.0	3.0	4.0
5	4.0	5.0	4.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0
6	4.0	4.0	2.0	2.0	3.0	4.0	3.0	2.0	2.0	4.0
7	4.0	4.0	2.0	4.0	5.0	4.0	3.0	4.0	3.0	3.0
8	3.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
9	2.0	4.0	4.0	2.0	4.0	4.0	4.0	3.0	2.0	4.0
10	5.0	4.0	2.0	2.0	4.0	5.0	5.0	3.0	3.0	5.0
11	2.0	5.0	5.0	5.0	5.0	4.0	4.0	4.0	3.0	5.0
12	5.0	5.0	4.0	5.0	5.0	5.0	4.0	4.0	5.0	5.0
13	2.0	5.0	3.0	3.0	5.0	5.0	3.0	3.0	3.0	3.0
14	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
15	2.0	3.0	3.0	3.0	4.0	2.0	4.0	3.0	5.0	4.0
16	5.0	5.0	4.0	5.0	5.0	4.0	4.0	5.0	3.0	5.0
17	4.0	5.0	4.0	4.0	5.0	4.0	4.0	3.0	4.0	4.0
18	2.0	4.0	5.0	4.0	4.0	2.0	3.0	4.0	2.0	3.0
19	4.0	4.0	2.0	5.0	5.0	5.0	5.0	4.0	4.0	4.0
20	3.0	3.0	4.0	4.0	4.0	3.0	4.0	3.0	4.0	3.0
21	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.0	2.0
22	5.0	3.0	3.0	4.0	4.0	4.0	2.0	5.0	3.0	3.0
23	1.0	2.0	2.0	2.0	3.0	3.0	3.0	3.0	3.0	2.0
24	3.0	2.0	2.0	2.0	3.0	4.0	3.0	2.0	4.0	3.0
25	4.0	4.0	3.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0
26	4.0	3.0	3.0	4.0	3.0	4.0	3.0	3.0	3.0	3.0
27	4.0	4.0	2.0	4.0	5.0	4.0	3.0	5.0	2.0	3.0
28	4.0	5.0	5.0	5.0	5.0	4.0	5.0	3.0	3.0	5.0
29	3.0	3.0	3.0	1.0	3.0	3.0	2.0	2.0	2.0	3.0
30	2.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0	4.0	2.0
31	5.0	5.0	5.0	4.0	5.0	5.0	4.0	2.0	4.0	5.0
32	3.0	4.0	3.0	4.0	NaN	4.0	4.0	3.0	2.0	4.0
33	4.0	5.0	4.0	4.0	5.0	4.0	2.0	4.0	3.0	4.0
34	4.0	5.0	4.0	3.0	5.0	4.0	4.0	5.0	4.0	4.0
35	1.0	2.0	1.0	3.0	2.0	1.0	1.0	1.0	1.0	1.0
36	1.0	2.0	2.0	2.0	3.0	2.0	2.0	2.0	2.0	2.0
37	4.0	5.0	5.0	4.0	5.0	4.0	5.0	4.0	3.0	3.0
38	3.0	5.0	4.0	3.0	5.0	4.0	3.0	4.0	3.0	4.0
39	4.0	3.0	4.0	4.0	4.0	4.0	4.0	2.0	2.0	5.0
40	4.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	4.0	4.0
41	4.0	5.0	4.0	4.0	4.0	4.0	5.0	4.0	4.0	4.0
42	5.0	4.0	3.0	5.0	4.0	5.0	3.0	4.0	5.0	4.0
43	4.0	5.0	4.0	5.0	4.0	4.0	5.0	4.0	3.0	4.0
44	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	NaN

Fig 5. 42 Dataset (Actual Responses) for C6-RORNR Source - Author

Self Made

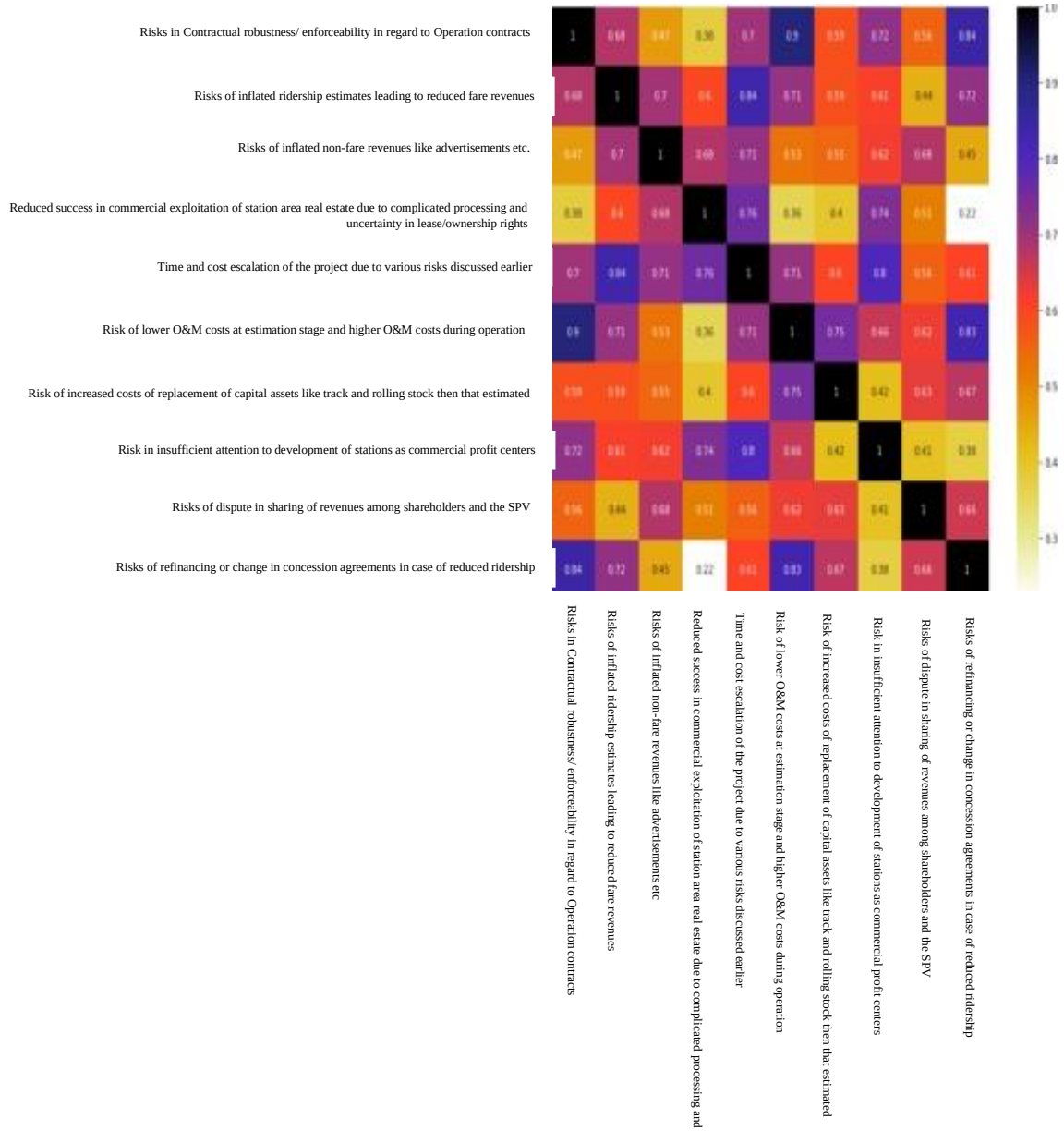
Abbreviated form of each risk feature (as in Category-1), is not done here. Full form is used. *Feature and Selection & Extraction: The results of the Variance Threshold feature selection and the Fisher Score method is as follows:*

Find Constant and Non-Constant Features:

[True True True True True True True True True True]

Number of Non-Constant Features: **10**

Fig 5. 43 Correlation matrix heat map for C6-RORNR **Source - Author Self Made**



	Risks in Contractual robustness/ enforceability in regard to Operation contracts	Risks of inflated ridership estimates leading to reduced fare revenues	Risks of inflated non-fare revenues like advertisements etc.	Reduced success in commercial exploitation of station area real estate due to complicated processing and uncertainty in lease/ownership rights	Time and cost escalation of the project due to various risks discussed earlier	Risk of lower O&M costs at estimation stage and higher O&M costs during operation	Risk of increased costs of replacement of capital assets like track and rolling stock then that estimated	Risk in insufficient attention to development of stations as commercial profit centers	Risks of dispute in sharing of revenues among shareholders and the SPV	Risks of refinancing or change in concession agreements in case of reduced ridership
Risks in Contractual robustness/ enforceability in regard to Operation contracts	1.000000	0.681818	0.470752	0.380830	0.700649	0.904726	0.586816	0.718039	0.556553	0.844072
Risks of inflated ridership estimates leading to reduced fare revenues	0.681818	1.000000	0.698011	0.598448	0.836886	0.708858	0.586816	0.613325	0.436680	0.715626
Risks of inflated non-fare revenues like advertisements etc.	0.470752	0.698011	1.000000	0.680015	0.712424	0.532945	0.551854	0.621036	0.680361	0.450517
Reduced success in commercial exploitation of station area real estate due to complicated processing and uncertainty in lease/ownership rights	0.380830	0.598448	0.680015	1.000000	0.757073	0.362815	0.398002	0.738562	0.512412	0.219623

Fig 5.44 Correlation matrix for C6-RORNR Source - Author Self Made

Number of most correlation features: 5

1. Risk in insufficient attention to development of stations as commercial profit centers
2. Risk of increased costs of replacement of capital assets like track and r olling stock then
   that estimated
3. Risk of lower O&M costs at estimation stage and higher O&M costs d uring operation
4. Risks of refinancing or change in concession agreements in case of red uced ridership
5. Time and cost escalation of the project due to various risks discussed e arlier

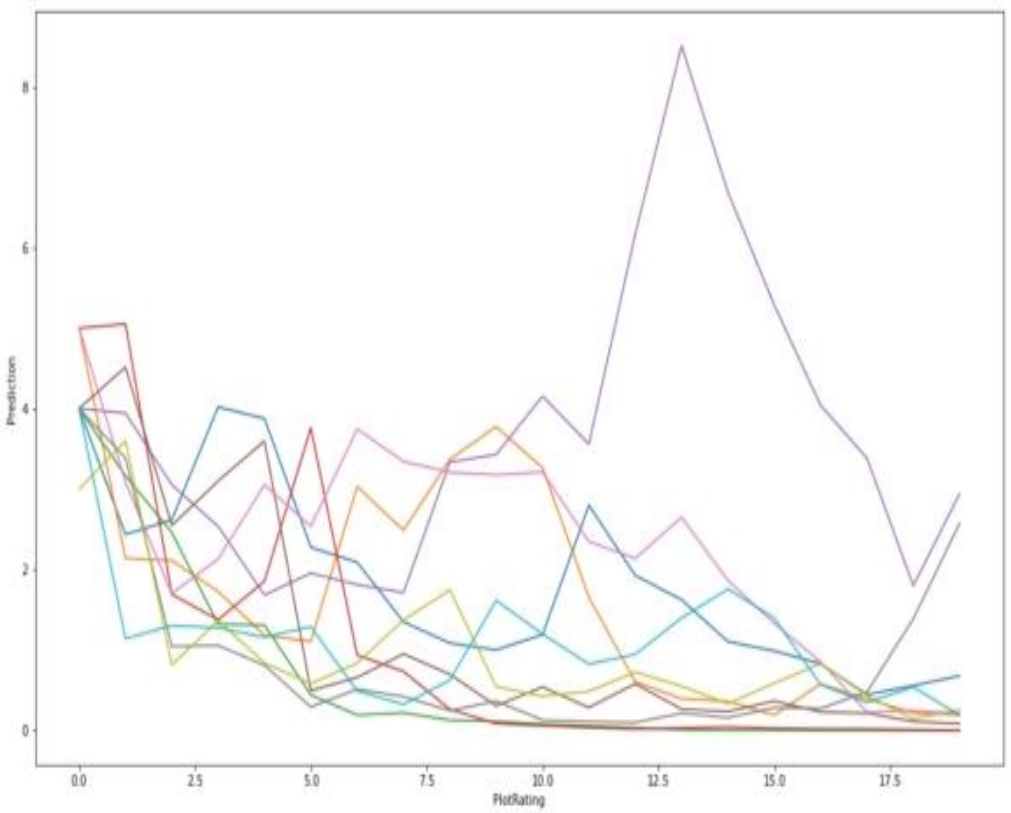


Fig 5. 45 Analysis results obtained from Monte Carlo for C6 RORNR

Source - Author Self Made

RISK FACTOR	MARKS (Risk probability-prediction as per MCS)
Risks in Contractual robustness/ enforceability in regard to Operation contracts	3.6395779
Risks of inflated ridership estimates leading to reduced fare revenues	3.458889
Risks of inflated non-fare revenues like advertisements etc.	3.4201596
Reduced success in commercial exploitation of station area real estate due to complicated processing and uncertainty in lease/ownership rights	3.4073203
Time and cost escalation of the project due to various risks discussed earlier	3.4597344

Risk of lower O&M costs at estimation stage and higher O&M costs during operation	3.0359452
Risk of increased costs of replacement of capital assets like track and rolling stock then that estimated	3.2270257
Risk in insufficient attention to development of stations as commercial profit centers	3.2908053
Risks of dispute in sharing of revenues among shareholders and the SPV	2.2824194
Risks of refinancing or change in concession agreements in case of reduced ridership	3.1463702

Table 5. 24 Statistical analysis output of each variable for C6 RORNR

Source - Author Self Made

5.6.1 Result: From the results of the Monte Carlo Simulation method, after performing the risk factor probability analysis, the MARKS as shown in the table above signify how much probability of occurrence each of the above features have in the Indian HSR project. From the above analysis of results, it is observed that *Risks in Contractual robustness/ enforceability in regard to Operation contracts* have the highest likelihood of occurrence in this category whereas the *Risks of dispute in sharing of revenues among shareholders and the SPV* has the least likelihood of occurrence.

AttributeName	Rank	Consensus	Verdict
Risks of refinancing or change in concession agreements in case of reduced ridership	7.680	0.651042	Retained
Risks of dispute in sharing of revenues among shareholders and the SPV	3.840	1.302083	Retained
Risk in insufficient attention to development of stations as commercial profit centers	1.920	2.604167	Retained
Risk of increased costs of replacement of capital assets like track and rolling stock then that estimated	0.960	5.208333	Retained
Risk of lower O&M costs at estimation stage and higher O&M costs during operation	0.480	10.416667	Retained
Time and cost escalation of the project due to various risks discussed earlier	0.240	20.833333	Retained
Reduced success in commercial exploitation of station area real estate due to complicated processing and uncertainty in lease/ownership rights	0.120	41.666667	Retained
Risks of inflated non-fare revenues like advertisements etc.	0.060	83.333333	Retained
Risks of inflated ridership estimates leading to reduced fare revenues	0.030	166.666667	Retained
Risks in Contractual robustness/ enforceability in regard to Operation contracts	0.015	333.333333	Retained

Table 5. 25 Ranking table for analyzed data using Monte Carlo for C6-RORNR

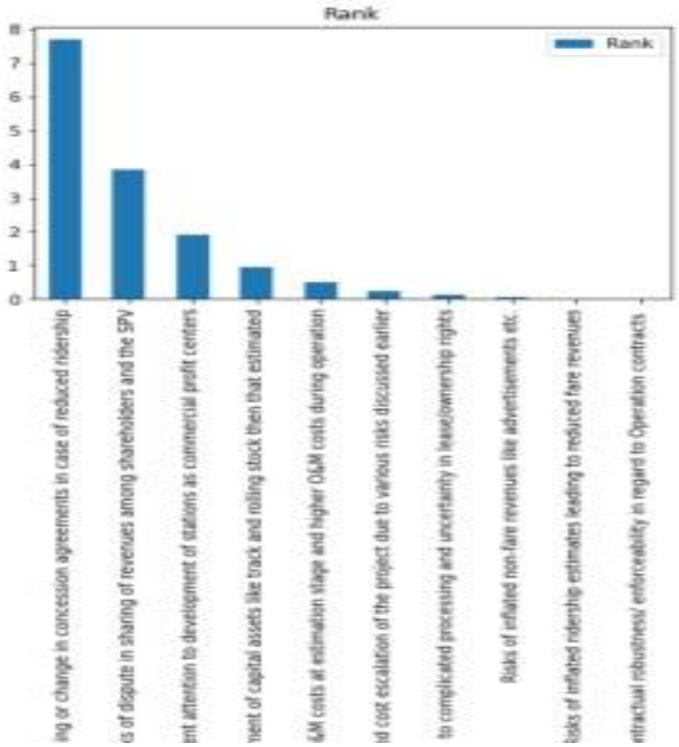


Fig 5. 46 Ranking Table in graphical form for C6-RORNR

Source - Author Self Made

AttributeName	Rank	Consensus	Verdict
Risks in Contractual robustness/ enforceability in regard to Operation contracts	0.07500	66.666667	Retained
Risks of inflated ridership estimates leading to reduced fare revenues	0.07475	66.889632	Retained
Risks of inflated non-fare revenues like advertisements etc.	0.07450	67.114094	Retained
Reduced success in commercial exploitation of station area real estate due to complicated processing and uncertainty in lease/ownership rights	0.07425	67.340067	Retained
Time and cost escalation of the project due to various risks discussed earlier	0.07400	67.567568	Retained
Risk of lower O&M costs at estimation stage and higher O&M costs during operation	0.07375	67.796610	Retained
Risk of increased costs of replacement of capital assets like track and rolling stock then that estimated	0.07350	68.027211	Retained
Risk in insufficient attention to development of stations as commercial profit centers	0.07325	68.259386	Retained
Risks of dispute in sharing of revenues among shareholders and the SPV	0.07300	68.493151	Retained
Risks of refinancing or change in concession agreements in case of reduced ridership	0.07275	68.728522	Retained

Table 5.26 Consensus table for analyzed data using Monte Carlo for C6-RORNR

Source - Author Self Made

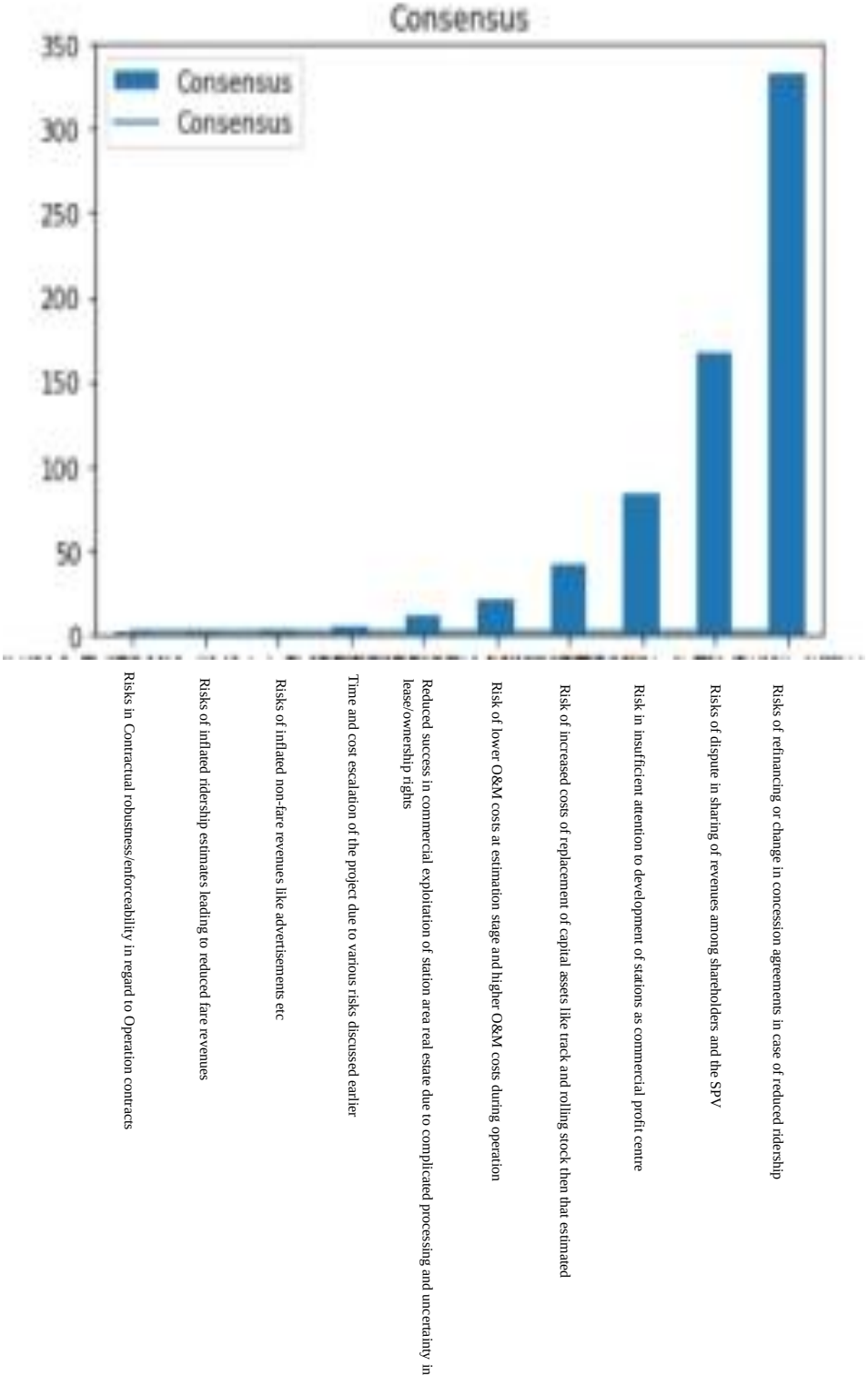


Fig 5. 47 Consensus Table in graphical format for C6 RORNR **Source - Author Self Made**

AttributeName	Rank	Consensus
Reduced success in commercial exploitation of station area real estate due to complicated processing and uncertainty in lease/ownership rights	0.19425	109.006734
Risk in insufficient attention to development of stations as commercial profit centers	1.99325	70.863552
Risk of increased costs of replacement of capital assets like track and rolling stock then that estimated	1.03350	73.235544
Risk of lower O&M costs at estimation stage and higher O&M costs during operation	0.55375	78.213277
Risks in Contractual robustness/ enforceability in regard to Operation contracts	0.09000	400.000000
Risks of dispute in sharing of revenues among shareholders and the SPV	3.91300	69.795234
Risks of inflated non-fare revenues like advertisements etc.	0.13450	150.447427
Risks of inflated ridership estimates leading to reduced fare revenues	0.10475	233.556299
Risks of refinancing or change in concession agreements in case of reduced ridership	7.75275	69.379564
Time and cost escalation of the project due to various risks discussed earlier	0.31400	88.400901

Table 5.27 Prominence table for C6 RORNR Source - Author Self Made

AttributeName	Rank	Consensus
Reduced success in commercial exploitation of station area real estate due to complicated processing and uncertainty in lease/ownership rights	0.04575	-25.673401
Risk in insufficient attention to development of stations as commercial profit centers	1.84675	-65.655219
Risk of increased costs of replacement of capital assets like track and rolling stock then that estimated	0.88650	-62.818878
Risk of lower O&M costs at estimation stage and higher O&M costs during operation	0.40625	-57.379944
Risks in Contractual robustness/ enforceability in regard to Operation contracts	-0.06000	266.666667
Risks of dispute in sharing of revenues among shareholders and the SPV	3.76700	-67.191067
Risks of inflated non-fare revenues like advertisements etc.	-0.01450	16.219239
Risks of inflated ridership estimates leading to reduced fare revenues	-0.04475	99.777035
Risks of refinancing or change in concession agreements in case of reduced ridership	7.60725	-68.077481
Time and cost escalation of the project due to various risks discussed earlier	0.16600	-46.734234

Table 5. 28 Relation Table C6 RORNR Source - Author Self Made

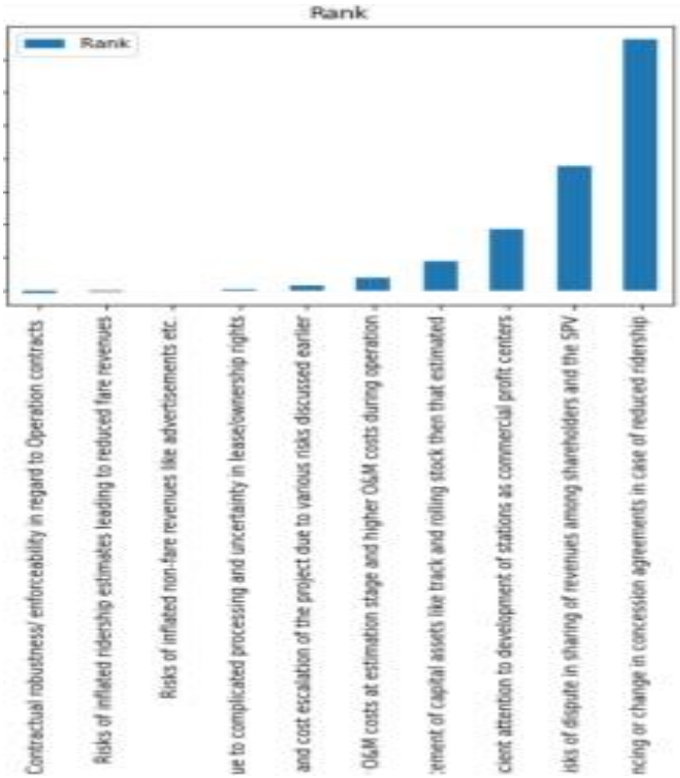


Fig 5. 48 Relation table in graphical format C6-RORNR Source – Author Self Made

5.6.3 Result: From the above Prominence and Relation analysis, it is observed that *Risks in Contractual robustness/enforceability in regard to Operation contracts* has the highest effect over all the others features in this category and also receives the most effect from all the risk features in the category. Thus, from the management perspective, this risk feature needs to be mitigated on high priority. This risk also has the highest probability of occurrence. The risk which has the least probability of occurrence in this category is *Risks of dispute in sharing of revenues among shareholders and the SPV.*

5.7 Preparation of Risk Management Model (Research Objective 2) adopting the Monte Carlo Simulation analysis for all categories of risks:

The interrelationships between the specified risk dimensions within each of the six categories and their relative probability of occurrence were investigated and analyzed in the previous section. In this ensuing section, we will attempt to build a Risk Management Model taking the six risk categories as a whole adopting the process flow chart outlined earlier and as done for individual categories. The six risk categories will be our input features in this case and the input data set is

the risk probability factor (Marks) identified for each individual risk feature by the Monte Carlo Simulation analysis.

Correlation Comparison and distribution:

After the feature selection and extraction, we will calculate the correlation coefficient using the formula :

Correlation Coefficient = Covariance (rank(X), rank(Y)) / (SD(rank(X))

using a different function in the software library using the *ri* data of all features calculated individually earlier and SD of all the features.

	PREM	FFR	HDCM	CTLQC	CCHO	RORNR
0	3.756576	4.005019	3.223391	3.108071	3.765308	3.639578
1	3.647517	3.450192	3.010495	3.030623	3.826331	3.458889
2	2.523037	3.421810	3.040530	2.944440	3.796198	3.420160
3	2.405954	3.416651	2.911512	2.867475	3.575144	3.407320
4	2.288501	3.227192	2.872707	2.793516	1.000000	3.459734
5	2.148818	3.151596	2.588407	2.654325	1.000000	3.035945

Fig 5. 49 Monte Carlo Analysis Dataset

Source - Author Self Made

Feature and Selection & Extraction: The results of the Variance Threshold feature selection and the Fisher Score method is as follows:

Find Constant and Non-Constant Features:

[True True True True True True]

Number of Non-Constant Features: **6**

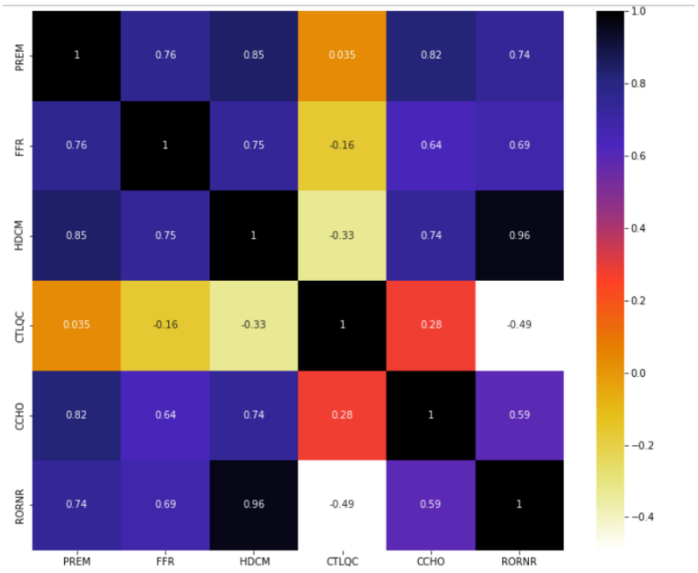


Fig 5.50 Graphical representation of Correlation Matrix

Source - Author Self Made

	PREM	FFR	HDCM	CTLQC	CCHO	RORNR
PREM	1.000000	0.762213	0.845253	0.034600	0.821023	0.743756
FFR	0.762213	1.000000	0.746771	-0.162143	0.640271	0.685894
HDCM	0.845253	0.746771	1.000000	-0.332752	0.743418	0.961857
CTLQC	0.034600	-0.162143	-0.332752	1.000000	0.283230	-0.491507
CCHO	0.821023	0.640271	0.743418	0.283230	1.000000	0.587947
RORNR	0.743756	0.685894	0.961857	-0.491507	0.587947	1.000000

Table 5. 29 Correlation Coefficient Matrix

(This provides the dependency analysis of all risk categories presented in this study).

Source - Author Self Made

5.7.1 Result: The results of the above model, where the correlation coefficient reflects the degree of inter-dependency between the risk categories, reveal that the highest correlation exists between the RORNR (Revenue related risks) and HDCM (Human resource related risks) (0.96) whereas the least correlation exist between the RORNR and CTLQC (Construction related risks) (-0.49) stating thereby that they are virtually independent.

PREM (Political/Environmental related risks) is highly linked to HDCM and CCHO (Commissioning and Handing over risks) but has least affinity for CTLQC.

FFR (Funding related risks) has a high correlation with PREM but least with CTLQC.

CTLQC, as a risk dimension has least correlation with any other category.

CCHO is closely related to PREM and the rest too whereas RORNR has most correlation with HDCM and significant correlation with PREM.

The relationship equations between the 6 risk categories, as derived from the correlation matrix, are as follows:

Eq. 1:
PREM = 0.76 FFR+ 0.84 HDCM + 0.034 CTLQC + 0.82 CCHO + 0.74 RORNR

Eq. 2:
FFR = 0.76 PREM+ 0.74 HDCM – 0.16 CTLQC + 0.64 CCHO + 0.68 RORNR

Eq. 3:
HDCM = 0.84 PREM + 0.74 FFR- 0.33CTLQC +0.74 CCHO + 0.96 RORNR

Eq. 4:
CTLQC = 0.03PREM -0.16FFR -0.33HDCM + 0.28 CCHO – 0.49 RORNR

Eq. 5:
CCHO = 0.82 PREM + 0.64FFR + 0.74 HDCM + 0.28 CTLQC + 0.58RORNR

Eq. 6:
RORNR = 0.74 PREM + 0.68 FFR+ 0.96 HDCM – 0.49 CTLQC + 0.58 CCHO

RISK FACTOR	**MARKS**
PREM	2.4222858
FFR	2.8833048
HDCM	3.397533
CTLQC	2.8556528
CCHO	3.0706413
RORNR	2.6592636

Table 5. 30 Predicted Data for each attribute From Monte Carlo Risk Analysis (This provides the prediction analysis of all dimensions presented in this study).

Here **Monte-Carlo** Simulation analysis results predict that the Risks related to Human Resource, Design, Consultancy and Management risks has prediction value 3.397533 are most likely to affect the HSR project.

The (Political, Regulatory, Environmental and Macroeconomic Risks) has prediction value 2.4222858 which is the least among all the six categories and is therefore likely to have the least effect over the HSR project.

Financing/ Funding risks has prediction value 2.8833048, Construction, Technology, Land acquisition, Quality, Contract Risks has prediction value 2.8556528, Completion, Commissioning and Handing Over Risks has prediction value 3.0706413 and Revenue, O&M Costs, Ridership, non fare revenue, Replacement costs Risk has prediction value 2.6592636.

Thus, the Risk management Model, as generated successfully by this research through the above analysis, consists of two parts: table 5.31 as the Predictive Model and Table 5.30 as the Dependency Model.

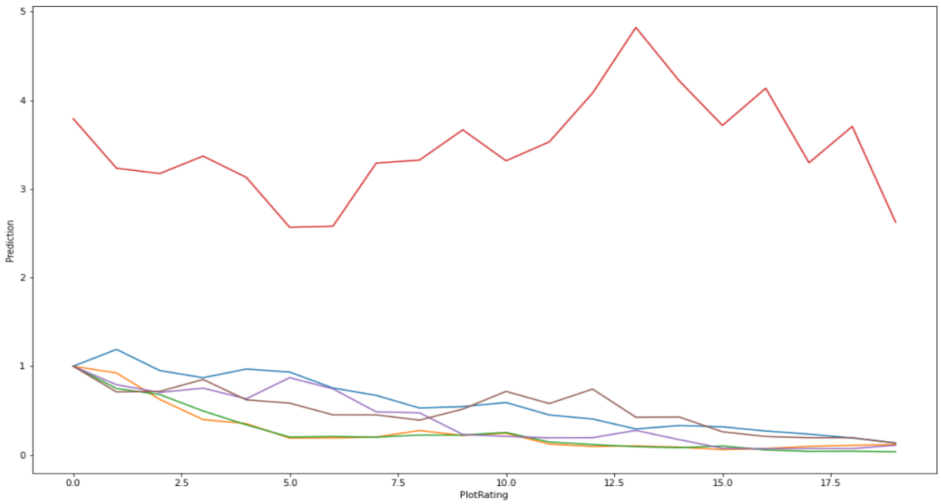


Fig 5.51 Result of the Data Analysis Monte Carlo Simulation for all Categories

Source - Author Self Made

We continue to proceed for calculation of the Prominence and Relations parameters for the Categories of risks as a whole, as done earlier for individual risk categories.

AttributeName	Rank	Consensus	Verdict
RORNR	9.85736	10.196424	Retained
CCHO	4.95368	20.392848	Retained
CTLQC	2.50184	40.785696	Retained
HDCM	1.27592	81.571391	Retained
FFR	0.66296	163.142783	Retained
PREM	0.35648	326.285565	Retained

Table 5.31 Total effect given by each risk to other risks (ri)

Source - Author Self Made

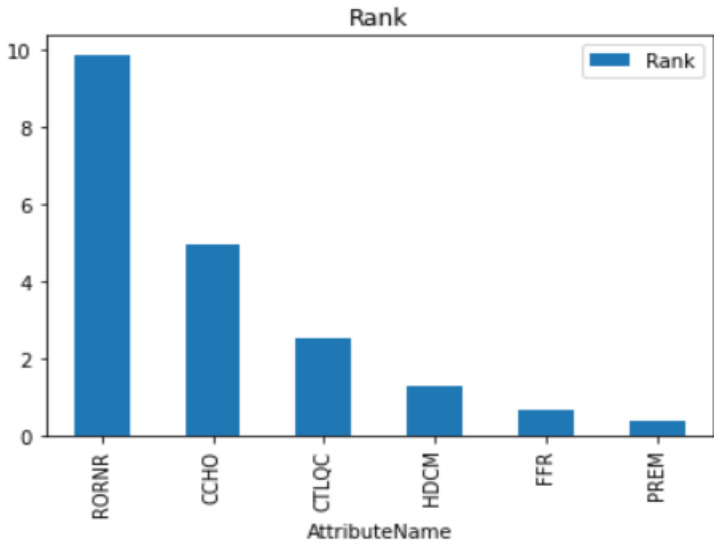


Fig 5. 52 Ranks of all dimension on the basis of ri

Source - Author Self Made

Based on the findings in Table 5.32, (Revenue, O&M Costs, Ridership, Non-fare revenue, Replacement costs Risk) has given the highest effect to other risks. It is followed by (Completion, Commissioning and Handing over Risks), (Construction, Technology, Land acquisition, Quality, Contract Risks), (Human Resource, Design, Consultancy and Management risks), (Financing/ Funding risks), and Political, Regulatory, Environmental and Macroeconomic Risks.

AttributeName	Rank	Consensus	Verdict
PREM	3.550000	28.571429	Retained
FFR	3.076316	33.043478	Retained
HDCM	2.602632	39.175258	Retained
CTLQC	2.128947	48.101266	Retained
CCHO	1.655263	62.295082	Retained
RORNR	1.181579	88.372093	Retained

Table 5. 32 Total effect received by each risk from other risks (*ci*)

Source - Author Self Made

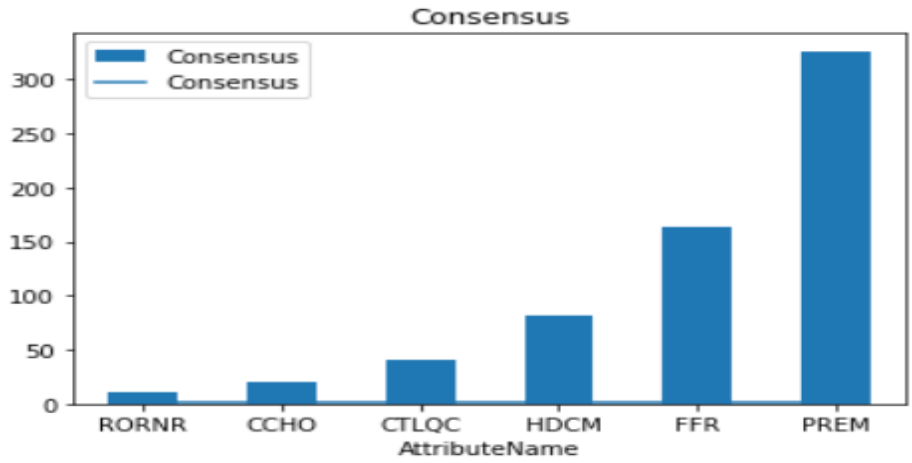


Fig 5. 53 Ranks of all dimension on the basis of *ci*

Source - Author Self Made

In terms of c_i, (Political, Regulatory, Environmental and Macroeconomic Risks) has received the highest effect from other risks. Risk dimensions, (Financing/ Funding risks), (Human Resource, Design, Consultancy and Management risks), (Construction, Technology, Land acquisition, Quality, Contract Risks),(Completion, Commissioning and Handing Over Risks), and (Revenue, O&M Costs, Ridership, Non-fare revenue, Replacement costs Risk) stand in other ranks after (Political, Regulatory, Environmental and Macroeconomic Risks), respectively in the prominence list.

AttributeName	Rank	Consensus
HDCM	3.878552	120.746649
CCHO	6.608943	82.687930
CTLQC	4.630787	88.886961
FFR	3.739276	196.186261
PREM	3.906480	354.856994
RORNR	11.038939	98.568517

Table 5. 33 Prominence (ri+ci)

Source - Author Self Made

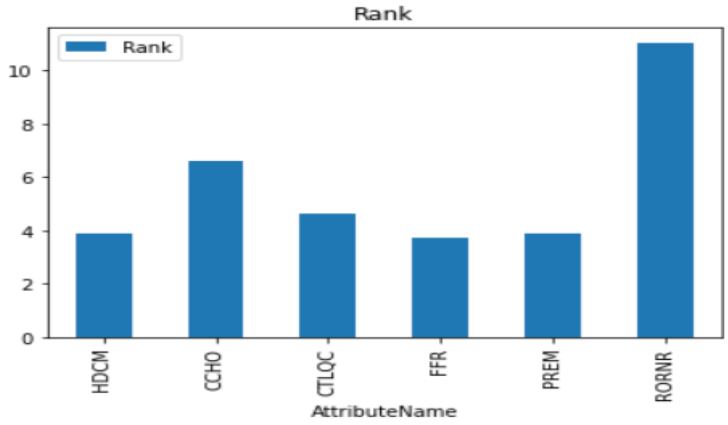


Fig 5. 54 Ranks of all dimension on the basis of Prominence (ri+ci)

Source - Author Self Made

In terms of Prominence, (Revenue, O&M Costs, Ridership, Non fare revenue, Replacement costs Risk) this factor has the highest total effect. (Completion, Commissioning and Handing Over Risks), (Construction, Technology, Land acquisition, Quality, Contract Risks), (Political, Regulatory, Environmental and Macroeconomic Risks), (Human Resource, Design, Consultancy and Management risks) , and Financing/ Funding risks stand in other ranks after (Revenue, O&M Costs, Ridership, Non fare revenue, Replacement costs Risk) , respectively in the prominence list.

AttributeName	Rank	Consensus
HDCM	-1.326712	42.396134
CCHO	3.298417	-41.902234
CTLQC	0.372893	-7.315570
FFR	-2.413356	130.099304
PREM	-3.193520	297.714137
RORNR	8.675781	-78.175669

Table 5. 34 Relation (*ri−ci*)

Source - Author Self Made

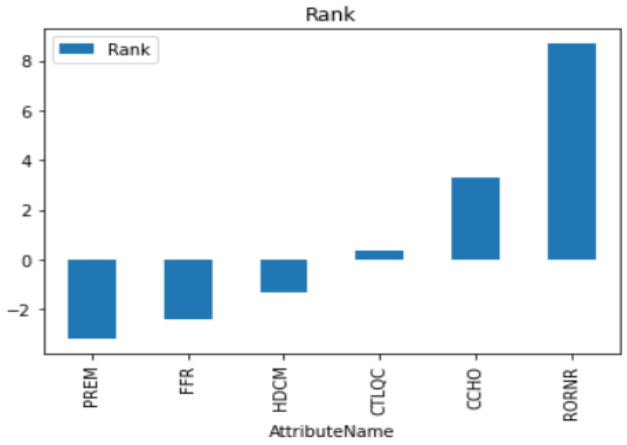


Fig 5. 55 Ranks of all dimension on the basis of Prominence (*ri−ci*)

Source - Author Self Made

Based on the findings in above Table 5.36 (Revenue, O&M Costs, Ridership, Non fare revenue, Replacement costs Risk) has the highest relational value and have great impact on the system. It is followed by (Completion, Commissioning and Handing Over Risks), (Construction, Technology, Land acquisition, Quality, Contract Risks), (Human Resource, Design, Consultancy and Management risks), and Financing/ Funding risks stand in other ranks after (Revenue, O&M Costs, Ridership, Non fare revenue, Replacement costs Risk) and the lowest factor in the relation category is (Political, Regulatory, Environmental and Macroeconomic Risks).

CHAPTER-6

CONCLUSION

In order to reduce the risk of HSR in India being interrupted, it is critical to identify the main risks. Risks seldom arise on their own; rather, the occurrence of one risk may lead to the emergence of another. This research has highlighted the interdependencies and relationships of various risks in the Indian HSR for the first time, and has also shed light on which risks should be prioritized in order to reduce the likelihood of others. Risk mitigation strategies that focus on the interconnected dangers may be developed using this analysis and results.

Analytical results and how they are perceived depend on whether risk analysis perspective is used, which might be proactive or reactive. Risks that have the potential to transfer from one threat to another over the long term are prioritized in a proactive approach because of the greater damage they may do. Reactive risk management tries to reduce the damage of potential threats and speed an organization's recovery from them, but assumes that those threats will happen eventually. Proactive risk management identifies threats and aims to prevent those events from ever happening in the first place. Proactive approaches take into consideration the system's net causers in order to predict its future state (i.e., Relation) with a focus on current system state rather than the potential problems that may arise. It focuses on coping with current and immediate threats. (i.e., Prominence). A reactive approach focuses on correcting existing system failures while minimizing the potential for new ones that may arise as a result of current risks.

The Monte Carlo simulation enables us to examine all possible outcomes of our decisions and to estimate their risk impact, enabling us to make more informed decisions in the face of uncertainty.

The resilient paradigm begins with a characterization of the risks associated with the infrastructure and the services that operate on it, taking into account each risk's occurrence, vulnerability, and exposure. From the risk formulation, the development of the resilient paradigm necessitates an in-depth examination of the relationship between risks and events and, consequently, the possibility of mitigating the effects through action on the various components and restoration of the state prior to the event.

The resilient paradigm must be examined both in terms of the infrastructure itself and the economic role it plays in integrating restarts, which traditional infrastructures frequently fail to do. Additionally, the resilient paradigm must be built in terms of operation, by examining all components that are at risk, both for safety and security, as well as for the regularity of the traffic control service. Regularity requires investigation since it is badly harmed by heterotactic regimes created by the intermixture of high-speed passenger trains and heavy freight trains, as well as intercity and regional trains.

In this research, out of the 60 risk dimensions that were identified from secondary data as a result of extensive literature review, primary data was collected in the form of responses from experts in the field of High-Speed Railways. After an incisive analytical process using the Mote Carlo Simulation method, prominent risks are identified and interesting conclusions have emerged regarding their influence/relationships with other risk factors. Chapter 5 deals with these conclusions in detail. A summarized version is as below:

The top 10 risks (of the 55 risks identified) that have the most likelihood of occurrence are:

1. Risks related to decline in stakeholder support (Sovereign- at the Central government level)
2. Risks related to decline in stakeholder support (Sub-Sovereign- a regional or local government body)

3. Risks related to arrangement of finances from foreign Multilateral/ Bilateral conditional/ tied loans
4. The lack of skilled experts on HSR technology on client's side
5. Right of way (Land) acquisition delays due to poor record and disputed ownership
6. Risks relate to inadequate project management, changes in design, Price variation, extra works, extension of time, insufficient documentation etc. leading to disputes and arbitrations
7. Inadequate provision of Risk Management in contract document including poor risk allocation
8. Risks related to final Approvals/Permits
9. Risks related to inadequate repository of knowledge with the Public Authority granting approvals
10. Risks in Contractual robustness/ enforceability in regard to Operation contracts

In this research, an attempt has been made to create a Risk management Model for the new High Speed Rail project in India. The same has been created in 2 parts: table 5.31 as the Predictive Model and Table 5.30 as the Dependency Model.

Table 5.35 Correlation Coefficient Matrix

	PREM	FFR	HDCM	CTLQC	CCHO	RORNR
PREM	1.000000	0.762213	0.845253	0.034600	0.821023	0.743756
FFR	0.762213	1.000000	0.746771	-0.162143	0.640271	0.685894
HDCM	0.845253	0.746771	1.000000	-0.332752	0.743418	0.961857
CTLQC	0.034600	-0.162143	-0.332752	1.000000	0.283230	-0.491507
CCHO	0.821023	0.640271	0.743418	0.283230	1.000000	0.587947
RORNR	0.743756	0.685894	0.961857	-0.491507	0.587947	1.000000

This provides the dependency analysis of all risk categories presented in this study.

The results of the above model, where the correlation coefficient reflects the degree of inter-dependency between the risk categories, reveal that the highest correlation exists between the RORNR (Revenue related risks) and HDCM (Human resource related risks) (0.96) whereas the least correlation exist between the RORNR and CTLQC (Construction related risks) (-0.49) stating thereby that they are virtually independent.

PREM (Political/Environmental related risks) is highly linked to HDCM and CCHO (Commissioning and Handing over risks) but has least affinity for CTLQC.

FFR (Funding related risks) has a high correlation with PREM but least with CTLQC.

CTLQC, as a risk dimension has least correlation with any other category. CCHO is closely related to PREM and the other categories also whereas RORNR has most correlation with HDCM and significant correlation with PREM.

Table 5. 36 Prediction Data for each attribute from Monte Carlo Risk Analysis

RISK FACTOR	MARKS
PREM	2.4222858
FFR	2.8833048
HDCM	3.397533
CTLQC	2.8556528
CCHO	3.0706413
RORNR	2.6592636

This provides the prediction analysis of all dimensions presented in this study.

Here **Monte-Carlo** Simulation analysis results predict that the Risks related to Human Resource, Design, Consultancy and Management risks have a prediction value 3.397533 and are most likely to affect the HSR project.

The Political, Regulatory, Environmental and Macroeconomic Risks have prediction value 2.4222858 which is the least among all the six categories and are therefore likely to have the least effect over the HSR project.

Financing/ Funding risks have a prediction value 2.8833048, Construction, Technology, Land acquisition, Quality, Contract Risks have prediction value 2.8556528, Completion, Commissioning and Handing Over Risks have a prediction value 3.0706413 and Revenue, O&M Costs, Ridership, Non-fare revenue, Replacement costs Risks have a prediction value 2.6592636.

Based on the findings, the factor of the Revenue, O&M Costs, Ridership, Non-fare revenue, Replacement costs Risks lie at first position of Relation list. In other words, in the risk factor has highest impact on the system compared to others in-particular the Political, Regulatory, Environmental and Macroeconomic Risks have received the highest effect from other risks (ci value). It implies, when Revenue, O&M Costs, Ridership, non-fare revenue, Replacement costs Risk arise, it might result in adding numerous risks in the system. It may impact other risks since it has the greatest Relation value, whereas Political, Regulatory, Environmental and Macroeconomic Risks can be influenced by other owing to high ci value.

It indicates that Political, Regulatory, Environmental and Macroeconomic Risks have the capacity to produce other associated risk in near future. There must be a greater emphasis on mitigation of Political, Regulatory, Environmental, and Macroeconomic Risks than mitigation of these dangers as a response to an incident.

A risk analysis can't be complete if it only takes into account one factor, such as Relation or Prominence, and it needs to take into account a variety of other factors, such as causers and recipients. Net causers and causers are distinct from net receivers, and vice versa.

This study can be generalized for High-Speed railway projects in a developing nation where the economic, political and social ecosystem and environment is similar to that in India. For example, if a country like Sri Lanka, Bangladesh or Pakistan (our neighbors in South East Asia) wish to implement a similar project,

the analysis can help them in highlighting the risks that have to be prominently managed. However, the results of this study have a good potential to provide a framework of prominent risks and their inter-relationships with each other and can serve as a good guide for the risk mitigation efforts of the project authorities.

Way forward: The study has attempted to go into great detail in the philosophy, technology, management and background contexts of most the HSR systems in the world. Some linkages and prominences between possible risk categories and features have been successfully established, which were not done earlier. It will be a good idea to study how well these results compare with those in advanced countries where the HSR systems are already in operation.

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