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Maritime sector has always been influencing the global economy. Shipping facilitates the bulk transportation of raw material, oil and gas products, food and manufactured goods across international borders. Shipping is truly global in nature and it can easily be said that without shipping, the intercontinental trade of commodities would come to a standstill.

Recognizing the importance of research in various aspects of maritime and logistic sector, IIRE through its Journal of Maritime Research and Development (IJMRD) encourages research work and provides a platform for publication of articles, manuscripts, technical notes, papers, *etc.* on a wide range of relevant topics listed below:

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- Multimodal Transport
- Inland Waterways Transport
- Maritime Statistics
- Port Management, Port Pricing and Privatization
- Economic and Environmental Impact of Shipping and Ports
- Other Current Topics of Interest in Shipping

Editorial

This issue contains a potpourri of research topics ranging from Reliability of Propulsion systems to the dilemmas of the fishing industry, effects of the pandemic and a re-look at safety to philosophical connect of sustainability.

Indeed, as is well said, shipping is an amalgamation of diverse disciplines and an integration of various knowledge streams, after all it is a highly internationalized industry working in an increasingly globalized environment with the ship at its core. Pluralistic epistemology and multidisciplinary understanding underpin the study of shipping. Carrying 80-90% of international trade, it is today an indispensable tool that integrates world economies. So also comes with it the pressures of growing demand on efficiency, like reduction of cost, time compression, reliability, just-in-time delivery, flexibility, and customization. Discrete as it may be, this international trade is supported by 98,140 ships served by over 1.5 million seafarers, operating geographically remotely and in a high-risk environment. So, concerns of human safety and environmentally safe operations co-exist with service quality, in as much as digitalization and decarbonization pressures.

As a cauldron of multidisciplinary approaches, the practice of shipping opens possibilities that are only limited by one’s imagination!

Happy reading!

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THE IMPACT OF PANDEMIC ON GLOBAL SHIPPING-AWARENESS FOR SEAFARERS

Mihir Chandra [1]

Abstract

The world is no more the same. It has witnessed one of the worst humanitarian crises due to the Pandemic-Covid-19. Just few months from its detection, by July 2020, over 14.8 million people had been infected, with the numbers increasing. The evident erosions were in the loss of trade volumes and financial recovery for all economies has become a challenge. Effect on global shipping got sighted immediately due to lockdowns, shutdown of manufacturing hubs, port congestions/shut down, crew change and pending crew repatriation, restricted landing ashore by seafarers, certification of ships/seafarers. The effects are still showing as challenges are being met and overcome. The vulnerability to such situations for the existing education models and management of supply chain logistics are couple of aspects, which is analyzed in the backdrop of the pandemic. The paper attempts to provide a view on the need of change in existing protocols and maritime education models, economics enterprises and e-business modules for an innovative and recalibrated dynamics towards what may be called as 'Sea the future', post covid-19. This paper reviews the available literature while comparing the existing models with the innovative work plans for crew change, hybrid marine education and digitized breakthroughs for cargo documentation certification of ships and crew. Shipping has been adopting newer technologies in a slow manner yet has made noticeable improvements in fuel efficiency, emission reductions and port operations. Further studies with post-covid perspectives will provide impetus to the efforts.

Keywords: Impact of pandemic, Maritime education, Port congestions.

1. INTRODUCTION:

Charles Darwin said, 'It is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change'. Today when the humanity is facing second wave of Covid-19, those words are so prophetic now. World is going through 'VUCA' times, volatility, uncertainty, complexity, and ambiguity. This acronym of 1987 on leadership theories needs to be seen now as Vision, Understanding, Clarity, and Agility for making us responsive to change as the need of time. Blue economy has suffered hugely during this pandemic affecting the various human activities at sea that are enormous due to the abundance of ecosystem services and resources. There is plethora of opportunities at different levels of innovations and economic globalization. There was crowding in traditional marine sectors such as shipping, fishing, dredging, recreation, and conventional energy (oil and gas), while the emerging economic sectors such as alternate sources of energy by wave and wind, aquaculture and even blue biotechnology were taking shapes; but suddenly all activities got challenged for sustainability. The problem has been seen that awareness of the effect of pandemic for economy

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has not been made available to seafarers in simplistic manner. This paper reviews to make seafarers aware about economy and shipping scenario in the wake of pandemic.

2. SOME LITERATURE NOTINGS:

The literature 'Impact of COVID-19 On the Shipping and Maritime Industry' (EMSA,2021) has dealt deep into the chaos created for manufacturing industry and so to the shipping industry–STALAWFIRM(2020). INDIA'INDIAN EXPRESSES has on its print about the queuing up of cruise liner on the shores of recycling yard at 'ALANG' in India as the cruise industry got severely hit due to tourism got suspended in lock-downs and port congestions.

In December 2020 Hellenic shipping news showed data of various commodity freight going through downward curve. Low demand of cargo and so the shipping has led to bankruptcy of various small shipping companies, though the revival is seen for corporate sectors having stronger balance sheet as seen in 'K' shape of economy.

EMSA report says that the total number of calls (at all ports in the world) by vessels flying the flags of EU Member States (UK excluded) in 2020 decreased by 3.5% in comparison to2019; similarly, the related total gross tonnage decreased by 11.1%. A significant decrease started in mid-March 2020, as an impact of the COVID-19 outbreak escalation across Europe and precipitated lockdown.

EMSA report further says that the shipping routes from Europe to China and from Europe to the US have been affected. As per the report, the ship traffic from Europe to China and the US has declined in 2020, when compared to same periods in 2019. This negative trend continues to be observed with traffic to and from China for March 2021(EMSA-2021)[4].

3. DISCUSSION:

3.1 IMPACT ON ECONOMY:

Covid-19 resulted in the bleeding of world economy. In the year 2020 growth of shipping industry shrunk after a quantum leap of year 2019 which was due to new orders. Pandemic is one major issue which got wedded with minors like trade-wars, cyber threats, and climate regulations. With the new virus, freight rates of dry bulk section dropped by more than 70% for crude tankers it dropped by 36%.Product tanker market suffered a drop of 30%

(globenewswire.com). The volatility part is going to be associated with containerized sector. Container ports have experienced a 'V' shape[1], falling demand for container transport'. The lockdown and quarantine needs were the major cause of port congestions for the first quarter of 2020 and so it registered a fall of 5.1% in global container shipping volumes.

EXIM cargo declined worldwide in a bid to avoid hazard of spread of COVID. Waiting periods, 'Blank sailings' have resulted in many disputes between owners and charterers. It is recorded as 188 number of blank sailings[2], in first quarter of 2020. Therefore, the economic recovery of V-shape, is doubtful for developing countries; to some trades there may be 'K' shape[3], of revival. Economists say that there may be 'W' shape[4], of economy in vicinity due to other variants of pandemic now hitting many developing countries. In November2020, UNCTADSECRETARY GENERAL said, "The industry must be a key stakeholder helping adapt 'JUSTIN TIME EFFICIENCY' logistics to 'JUST IN CASE PREPAREDNESS'.

The shipbuilding industry also got affected. China has a share of about 40% in the industry. In January 2020, China showed decline in this trend and it does not augur well for the world economy. One of the biggest forums of world trade the maritime industry faced challenges due to border restrictions, travel bans, Visa restrictions. The real problem faced by shipping industry now is work-chain and supply-chain disruptions, closure of manufacturing facilities and logistic bottlenecks. This industry breathes oxygen of labor and supply resource; both got in short supply by lockdown and caused asphyxia to industry. Uncertainty made labor migration from industrial hubs to countryside due to loss of jobs and for survival of soul and kin. Reverse migration did happen but it was lower than expected- the case in context is India about port dynamics.

Ship recycling industry which has inverse relationships with freight market has got some gain and the cruise ship owners, who are queuing up for demolition are getting affected with offers to the tune of U.S. dollars 100 per ton because of high demand of recycling. Ship survey and certification as a process is also in web of problems. Even the seafarers' certification is being extended so that the ship keeps sailing.

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[1] *V-Shape – Economy slumps down sharply in recession and recovers sharply.*
[2] *Blank sailing- It means operator decides to cancel/ skip port call or region.*
[3] *K-Shape- Following a recession, different parts of economy recover at different rates, times, or magnitude-larger companies recover fast but smaller firms suffer in indebtedness/ poverty-example is present state of economic trend.*
[4] *W-Shape- When economy passes through recession into recovery and the immediately turns down into another recession example may be as predicted if third wave of pandemic hits back.*

Pandemic thus has underscored global interdependency of nations, particularly in three sectors: health, education, and supply chain. There is a need for supply chain shortening mechanism with less dependence on lean inventory models. Never it was considered to have greater visibility and agility for door-to-door transport operation. Last mile connectivity to be more in focus. Ports connectivity to hinterland to reach to shipper must increase as innovative model for future ambiguities to be clearer. South Asia to have full-fledged regional integration for economics and politics.

3.2 IMPACT ON MARITIME EDUCATION:

COVID 19 hit maritime education as a bolt from the blue. Lockdown sealed the conventional pedagogy of offline mode a new player came into field from every frontier; 'MOOCS' and 'LMS[5]'- online tools to be resilient with the circumstances. Though in subcontinent physical location, the non-availability of the internet, and a lack of prior expertise with internet technologies may be the key barriers to online education. However, Internet, Smart phones became the tools to educate instantly and COVID-19 forced turn into innovator through disruption. Learning became a must for teachers and learners in equal proportions Maritime education needs reinforcement through hybrid-learning-learning, exit-examination system, cloud-based simulator exercises for asynchronous and synchronous models. The blended learning model adopted by institutions across the world has revealed a framework for inculcating technology in regular classroom teaching and highlighted the fact that the quantum of blending accepted by the pupils has a positive correlation with their learning gain[7]. Intent to innovate and ideate for implementation of the new mantra for education which will traverse from school to laboratory and laboratory to industry. Industry, then will get smart seafarers. During the pandemic the challenge has also been to maintain mental equilibrium as longer period of learning through screen times has affected not only the vision but also the mental wellbeing. Privacy boundary has been breached as in the subcontinent because of small dwelling area learner and worker both are placed in confined spaces but for different objectives with interference of software noise and family interactions. This has led to a different level of mental stress.

Physical immunity has indeed been taken care of but mental toughness needs to be checked too for ambience limitations. Universities, Schools and Laboratories need to reskill and upgrade

[5] *MOOCS/LMS- 'Massive open online courses' like Lynda, Google primer, Tree-house and common examples are 'Coursera', 'Udacity', 'edX'. LMS-'Learning management system' like 'Moodle', 'Blackboard' 'Desire2learn' as software's for digital learning environment.*

themselves for future and to scan the horizon beyond local limits. New frontiers need to access with collaborative education patterns. Emphasis is required to be on innovation, entrepreneurship in marine disciplines to be a catalyst of growth for BLUE-ECONOMY.

3.3 SEAFARER-THE UNSUNG HERO OVER THE SEAS:

It is proverbial that the winds and waves are always on the side of ablest mariners. Factually it is worth reminding the global community that seafarer is suffering the worst during the pandemic caused problems of crew change and their family felt the need of seafarers' wellbeing the most. The unmet needs got compounded with complexity of processes involved in repatriation and quarantine related isolation. IMO issued various circulars after the outbreak of this pandemic as guidance to all stake holders for wellbeing of industry. Many organizations signed the Neptune declaration[6], which has four main actions for ameliorating the concerns of seafarers like, vaccination on priority for seafarers as being key workers, establishment, and implementation of gold standard health protocols, ensuring air connectivity between key maritime hubs for seafarers and increased collaboration between ship operators and charterers to facilitate crew change. This will alleviate mental agony of families of seafarers as some cades of bereavement due to Covid has impacted psychosocial problems for seafarers. Even the workload without relief to seafarers has caused fatigue to such an extent that errors in taking actions have compounded.

4. CONCLUSION:

Sars-Covid-19, being the worst public health and humanitarian crisis of century has shown the drivers of civilization the days of great depression of 1930s in the rear-view mirror and at the same time has shown the era of post-world war and days of Spanish-flue in the other side mirror. Ebola and few other viruses did give us some nightmares but humanity was never at VUCA times like this. In India Unemployment is increased from 6.7% on 15 March to 26% on 19 April 2020 (Mondal V-2020). After the lockdown, almost 14 crore (140 million) people is lost their employment while salaries were cut for many others-so a real impact on economy for India's GDP is looming. Winston Churchill had said at the end of World War II "Never let a good crisis go to waste". And it is in context the most motivating sentence. Many lessons are to be learnt such as safety to be non-negotiable, contactless automation, digital solutions, more communication during crisis, design thinking to be in education models, soft skills to be made

[6] *Neptune declaration- It aims to promote and protect welfare of seafarers. It came in reckoning in response to crew change for around 40000 seafarers who were stranded because of pandemic travel band and emphasized for recognition of seafarers as 'keyworkers.'*

accessible for up skilling, re skilling for diversified job opportunities in wake of job losses. With these critical thoughts, it comes to mind whether Covid is a maritime obstruction or an innovative disruption? Covid had taught us to see beyond visibility and to invest time, wealth, and space in doing research and development, and our schools should upgrade to this paradigm for marine education to be the haven of innovative solutions to critical problems. IMO Secretary General said, 'Seafarers deliver so much for us; we have to deliver for them'. The lessons learnt also include the need to give greater recognition to seafarer. Neptune declaration[6] is one step towards this and time has come to treat seafarers as key workers.

Many frontiers like software, autonomous ships, drone supply tools, medicines and green solutions for climate are rising on the horizon as pandemic will sooner set on other horizon. The awareness level of any problem gives windows of solutions and starts up more research work to deal with pandemic like situations in better manner for sustainability.

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[6] *Neptune declaration- It aims to promote and protect welfare of seafarers. It came in reckoning in response to crew change for around 40000 seafarers who were stranded because of pandemic travel band and also emphasized for recognition of seafarers as 'keyworkers.'*

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Capt. Mihir Chandra is Associate Professor in Indian Maritime University, Chennai, India for the discipline of Nautical Studies. He has sailed for 20 years and is teaching for the last 21years. He is a research scholar and my broad subject of research is on seafarers' wellbeing. He had contributed with papers in international seminars and few of papers are published in E-Journals of INDIA. He is a life member of INDIAN METEOROLOGICAL SOCIETY. He is also a lead auditor of LRQS–ISO.

MARINE FISHING – A MARITIME ACTIVITY

Capt, S. Viswanathan [1]
Capt. (Dr.). Ashutosh Apandkar [2]

Abstract

The sea is a very large water body occupying 71% of the planet. It is home to various kinds of creatures and hold large number of resources. It is subjected to various weather patterns such as strong winds, high waves, tropical cyclones, and squally weather. The sea is being used for various activities such as transportation, tourism, sports, and offshore activities and for fishing. These activities are being carried out with the help of various types and sizes of vessels. Marine fishing is one of such activities carried out at sea. The fishing activities are carried out with the help of various types and sizes of fishing vessels from coastal waters to the high seas. Even though the fishing activities are carried out with different kinds of nets and methods, there are influencing components, which play major role in carrying out fishing safely and efficiently. The influencing components on marine fishing are the sea, the vessel and the crew. To efficiently carry out the fishing operation, the crew and the skipper need to have a sound knowledge of the sea conditions, navigation on the seas and vessel operations like, maneuvering, safety of the vessel and crew, and the wellbeing of the fishermen. It is suggested that if the vessel's activities are grouped into various job-functions, then that would enable proper planning for teaching, training of the fishermen and addressing issues to the governments on the safe and efficient operation of the vessels at sea. Furthermore, it is noted that marine fishing is presently administered under the Ministry of Fisheries, Animal husbandry and Dairying, where the exposure to the maritime nature of fishing is limited. It is hence perceived that the risks and perils to which the fishermen and the fishing vessel are exposed to out at sea are not very well addressed. This paper identifies and highlights the risks and perils associated with the sea, the vessel and the crew and groups them into job-functions. It also brings out the importance of bringing the function of marine fishing under a new ministry such as The Ministry of Maritime Affairs along with the other maritime activities such as shipping, offshore activities, maritime tourism, and maritime sports.

Keywords: Marine fishing, The sea, The vessel, The crew, Navigation, Marine engineering, Safety, Marine pollution, Maritime governance.

1. INTRODUCTION:

The sea has been used by various types of vessels such as power-driven vessels, sailing vessels, dynamically positioning vessel, semi-submersible vessels, and fishing vessels, for different purposes like, transportation, oil exploration, renewable energy production, tourism, recreation, and fishing. These vessels are fitted with different types of equipment and gears and operated in various marine environment based on their operation. All these vessels get exposed

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to ordinary perils at sea like, wind and waves, wear and tear of the vessel and damages to the fish catch while transporting back to port.

These vessels are registered with the coastal states and comply with the rules and regulations of the coastal states. As per the United Nations Law of the sea 1982, under article 87, the coastal state or land locked states, have rights of freedom of fishing at high seas (Sharma, 1995). Hence the fishing vessels have rights to engage in fishing at the territorial waters[3], contiguous zones[4], Exclusive Economic Zones (EEZ)[5]of the coastal states and high seas[6].

As per International Labor Organization, work in the fishing sector has many characteristics that set it apart from work in other sectors. The harvesting of fish and of marine resources takes place in the often-challenging marine environment. When the weather conditions are harsh, as they often are, or when the catch itself presents a risk, the rate of accidents and fatalities can be quite high; in fact, in many countries, fishing is the most hazardous occupation (ILO Study, 2010). Fishing is an activity carried out at sea, where the sea is seldom calm. So, the fishermen involved in fishing are to ensure their safety, good health, and vessel's good condition always. To understand the sea and its conditions, and the vessel and its operations, are primarily important for the efficient fishing operation at sea. These fishing vessels carry out fishing from coastal water to EEZ and Area Beyond National Jurisdiction (ABNJ) (Das, 2017). These vessels are equipped with fishing gears appropriately for fishing, depending on the area of operation and depth of the sea.

There are numerous tasks performed by these fishing vessels when fishing near the coast and in deep waters. The primary tasks include, the safe navigation of the fishing vessel from the home port to the fishing ground and back, planning passage based on the potential fishing ground, shooting and hauling of nets for fishing operations, fish catch handling on-board the vessels with or without the assistance of deck machineries, storing them in fishing holds properly, operate and maintain the engines and other machineries, maintenance of electrical wiring system, working safely on-board the fishing vessel, looking after the health and hygiene of the entire crew on-board the vessel, complying with the coastal and international rules and

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[3]*The limit of the territorial waters is the line every point of which is at twelve nautical miles from the nearest point of the appropriate baseline.*

[4]*The contiguous zone may not extend beyond 24 nautical miles from the baselines from which the breadth of the territorial sea is measured*

[5]*The exclusive economic zone shall not extend beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured*

[6] *All parts of the sea those are not included in the exclusive economic zone, in the territorial sea or in the internal waters of a State, or in the archipelagic waters of an archipelagic State.*

regulations, communicating with other vessels and rendering assistance to other vessels during difficult times. All these tasks are hazardous in nature and the risk is further elevated when the sea condition becomes worst. Moreover, the vessel when fishing at sea encounters maritime perils[3] at sea where the vessel and is crew must be expert in handling such situations.

Shore based supports are necessary for the efficient operation of the vessels and at the time of distress when encountered maritime perils. The fishing vessels are registered, inspected regularly for its seaworthiness, and monitored for their locations when at sea by the authorities from department of fisheries. The fishing vessel's personnel are provided with necessary training and when at sea the vessels are provided with weather reports, weather warnings, high wave alerts and potential fisheries zones by the shore authorities for on-board decision-making. When the vessel is in distress situation, they are assisted or rescued by the authorities and coast guards as required. Moreover, in coordination with the shore authorities, the fishing vessel also assists during search and rescue operation of any other distress crafts. These hazards are exposed during various tasks performed by the vessel at sea. These hazards and risks are to be managed well to carry out fishing operation efficiently. Hence, the crew of the fishing vessel must have sound knowledge on the tasks and hazards and be able to face the maritime perils at sea and skillfully operate the fishing vessel for carrying out the marine fishing. The department of fisheries under the Ministry of Fisheries, Animal husbandries and Dairying, makes policies, acts, rules, regulation, and various schemes to support the marine fishing industry and fishing community. It is however observed that this Ministry has limited exposure to the core nature of maritime exposure that has its own nuances and peculiarities. Hence, by discussing the maritime risks involved in marine fishing, and highlighting the various components which play major roles in fishing operations at sea, an attempt is made to appreciate the importance of bringing the subject of marine fishing under a common ministry for all the maritime activities. This will enable maritime professionals to be part of the ministry and their presence in the administration will fill the gap for supporting the fishing industries adequately in making policies, acts and welfare schemes.

2. THE SEA:

The sea is the primary component which influences fishing at sea. The sea is a vast area of salty waters which is subject to the wind, waves, currents, and tides always. The hazard associated

[3] *Perils of the Sea refers to extraordinary forces of nature that maritime ventures might encounter during a voyage which includes incidental to the navigation of the sea, fire, war, piracy attack, captures, seizures, restraints, jettisons, barratry, and any other perils of the like kind.*

with the sea is to get lost at sea when the vessel loses the sight of the land. Navigating the vessel in the proper direction and appropriate distance into the sea is important for the fishing at sea. The sea may get rough at times and subjected to cyclones, squally weathers, heavy swells, high waves, strong tide and current.

Thus, the tasks related to the influencing the component “Sea” is grouped into job - functions:
Navigation
Marine Meteorology and Oceanography.

3. NAVIGATION:

Navigation is the primary function of any vessel that is put into sea for services. When a fishing vessel is at sea, the function of navigation is being carried out all the times from departing port, during fishing operations and returning to port from the fishing grounds. Navigation of the vessel is carried out with the help of a group of skilled crew members. Watch keeping duties and keeping a look out are the major functions which are carried out to ensure the vessel’s location and the direction of movement of the vessel. When keeping a navigational watch, compliance with the International regulations for prevention of collision at sea-1972(COLREG, 1972) and ensuring the vessel’s safe navigation is the prime duty of the watch keepers and the skipper. Moreover, the watch keepers must be able to operate the available navigational equipment such as Global Positioning System, echo sounder, chart plotters, for vessels in and near the Indian coast, ISRO developed NavIC (Navigation in Indian Constellation) and GEMINI (Gagan Enabled Mariner Instrument for Navigation and Information) instruments efficiently for the safe navigation of the vessel throughout the voyage. Hence, sound knowledge on the navigational procedures, knowing the operation and limitations of the navigational equipment, planning of the voyage and movement of the vessel at sea, are necessary to support the fishing operations at sea.

3.1 MARINE METEOROLOGY AND OCEANOGRAPHY:

The air over sea is always in motion. The movement of the wind causes disturbance to the sea and increases the wave height as the wind speed increases. The wave and wind cause the condition of the vessel for fishing very difficult. Moreover, with the severe weather condition, the vessel may capsize at sea. The vessel regularly gets updates on weather conditions and weather warnings from the shore station and plans the voyage of the vessel as required. When receiving cyclonic weather warning the vessel takes necessary avoiding action to keep well clear of the cyclone. The fishes at sea are migratory in nature. The ocean current and temperature plays a major role in movement of the fishes. Based on the oceanographic condition, potential fisheries zones (PFZ) are identified by the shore laboratories and the PFZ details are sent to the fishing vessel. The shore authorities support the fishing vessel by providing weather warnings, high wave alerts and potential fisheries zone alerts for on-board decision making for the efficient operation of the fishing vessel.

4. THE VESSEL:

The second influencing component in fishing at sea is the vessel. The vessel used for fishing at sea is made of steel or fiber or wood depending on the area of operation and type of fishing operation they are involved. The fishing vessel which is well constructed and equipped accommodates the entire crew and helps them to carry out fishing operation safely and efficiently over the dynamic sea. The vessel must be constructed strong enough to remain seaworthy throughout its voyage and all its equipment and machineries well fit and working to tackle the ordinary perils at sea. The shore authorities support the fishing vessel operators by inspecting the vessel’s hull and machineries during the initial stages and then after regularly to ensures its seaworthiness and issues necessary certificates. The tasks related to the influencing component “Vessel” are grouped into job-functions as: Vessel Construction and Marine Engineering.

4.1. VESSEL CONSTRUCTION:

The fishing vessels are constructed by using steel, fiber, or wood. Mechanized boats are constructed by using steel or fiber or combination of both. The vessel crew need to have a good knowledge of the parts of the vessel and its construction to efficiently identify the fault in the construction and repair when damaged. A sound knowledge on the vessel construction helps the crew to efficiently use the space within the vessel. Moreover, the need for the maintenance and carrying out of the maintenance are done with ease. The fish hold and refer system must be well constructed and operated to store the catch of fish in good quality until it reaches the landing station.

4.2 MARINE ENGINEERING:

Main engines, generators, electrical equipment and wiring system on-board the fishing vessel are essential for operation of the fishing vessel. The main engine propels the vessel and generator powers the equipment, winches, lights, and other electronic equipment. Battery is fitted for powering essential equipment in event of generator failure. In case of failure occurs at the engines, generators, lights or wiring system, the engineers and crew carry out necessary repair and ensure the vessel's operation is being carried out as planned. A good knowledge on these machineries, their operations, inspection, and maintenance are necessary for the smooth operation and proper functioning of the machineries. The crew who are responsible for the running of the machineries need to be competent enough to do regular maintenance and break down maintenance of the machineries when required.

5. THE CREW:

The influencing component "Crew" are the personnel working on-board the vessel. The crew ensures the vessel is operated safely and efficiently at sea. The crew carry out many tasks at sea for the efficient and safe fishing. The stability of the fishing vessel needs to remain positive throughout the vessel's operation at sea. The crew's health and vessel's hygiene condition must be maintained in good condition thorough out the voyage. The tasks related to the influencing component "Crew" are grouped into job-function as:(a) Vessel Operation, (b) Care of Crew and their Welfare and (c) Marine Communication.

5.1 VESSEL OPERATION:

Vessel operation at sea primarily gives a stable and good condition at sea for carrying out fishing operation safely and efficiently. Stability of the fishing vessel shall be kept sufficiently positively always. The fishing vessel loses its stability when lifting loaded fishing nets with the help of derrick, reduces its reserve buoyancy when water is shipped on deck and increases free surface effect when the shipped water stays on deck for longer period(Lapa, 2018). The stability issue is further aggravated during the rough weather conditions. During rough weather conditions, the vessel is subject to surfing, Pooping, and broaching (Mata-Álvarez-Santullano & Souto-Iglesias, 2013). This may lead the vessel to capsize at sea. So, the vessel needs to be manoeuvred through the water knowing the effects of the wind and waves on the vessel. Thus, the skipper and the winch operator are to be very skillful and must have good knowledge on the stability of the vessel(STCW-F, 1995). Fishing vessel generates various garbage during stay at sea. To ensure better marine environment, this garbage should not be thrown into sea, instead they must be stored on-board the vessel and disposed ashore safely. They also use the fuel for the engine and generator. The oil spilled into the sea causes pollution. A good knowledge on the environmental pollution and sustainable fishing is vital for the personnel working on the fishing vessel. The skipper and crew must be well versed with the security at sea, rights of fishing at exclusive economic zones and high seas.

5.2 CREW CARE AND WELFARE:

Safety of the crew is an important issue as the fishing activities are carried out within the length and breadth of the vessel and involves high risks at sea(Union, 2016). The on-board crew is going to live at sea during the entire voyage and must have sufficient knowledge on occupational safety and health and carefully work on-board the vessel particularly when doing lifting operation. They must wear appropriate personnel protective equipment wherever necessary(FAO/Government Cooperative Programme, 2010). These risks also get elevated when the weather condition goes bad. Sufficient rest period for the crew working on-board the vessel, recreational facilities, good communication to the shore is necessary for efficient fishing operation at sea.

5.3 MARINE COMMUNICATION:

The fishing vessels are provided with communication equipment for communicating with other vessels. The communications are carried out during the routine operation or in emergency condition requesting assistance from other vessels. Calling on VHF and talking to the other vessel is an ordinary practice at sea. Standard Marine Communication Phrases are used by the crew of the vessels for efficient communication. The vessel receives information regarding weather forecast, weather warnings and navigational warnings. The skipper and mate interpret the meteorological information received and plan their fishing activities accordingly. The communication during the distress situation is carried out for requesting assistance from other vessels and rendering assistance to other vessels.

6. THE FISHING:

Fishing at sea is the primary function of the fishing vessel as this brings the crew their earning and profit to the owner. The fishing vessel catches the fishes with the help of the fishing nets. There are different types of fishing methods, trawling; gillnetting, pole and lining, long lining, purse seining is few. The entire fishing operation involves many hazards and needs good seamanship practices to identify the potential fishing areas, school of the fish, bring the net covering the entire school of fish and get the fishes trapped into the fishing net. The fish catch can be enhanced when modern electronic equipment such as fish finder, sonar, net-sonde are used efficiently for catching fish. Moreover, the necessary information on the potential fishery zones on Indian coast are received through electronic communication equipment such as NavIC (Navigation in Indian Constellation) and GEMINI (Gagan Enabled Mariner's Instrument for Navigation and Information) and the skipper and crew interpret the received information and take decision on fishing operation. The onboard crew of the fishing vessel must handle all the influencing components to the advantage for safe and efficient fishing at sea.

7. DISCUSSION:

Fishing is being carried out at sea for livelihood and profit. The fishing operation at sea is a hazardous operation where the sea conditions, vessel conditions, crew, and their operational capacities create the hazards. The crew must be able to safely handle and mitigate the hazards associated with the sea and the vessel and minimize the risk involved for carrying out fishing at sea. Presently marine fishing is administered under the Ministry of Fisheries, Animal Husbandry and Dairying and the necessary governance and policymaking is rendered through this ministry. The fishing activity is also considered as an agricultural activity where the fish is harvested from the sea. This outlook severely hampers the appreciation of the hazards and perils experienced from inherent nature of the sea and the vessel. Furthermore, the risk involved to the crew and maritime nature of the fishing activity are not well addressed. Unlike fishing at the pond or fish farming, the fishing at sea involves many hazards.

The fishing vessel must venture into sea for catching fish and the crew who are going to operate the vessel over the dynamic sea must be well skilled on all the tasks performed over the sea to support the fishing activities. The fishing will be efficient when the crew are well familiar with fishes, methods of fishing and fishing techniques. The influencing components play a major role in identifying the fish, catching the fish, and handling the fish catch. The crew is staying at sea for long period of time. So, they must be mentally and physically sound in staying at sea for long period of time and carrying out fishing operation efficiently.

Moreover, the shore officials need to support the vessel by providing weather updates, potential fisheries zones, and rescue operation. In addition, if personnel with maritime background become part of the administration, right policy decision on the development of the marine fishing can be made and they will be able to provide necessary shore support to the fishing vessel as and when required.

8. CONCLUSION:

For carrying out efficient and successful fishing at sea, the entire crew working on-board the fishing vessel must have a sound knowledge about the sea, its condition, weather patterns and its effect on the fishing vessel. The fishing vessel is where the entire team of fishermen are going to stay, work, eat and sleep if the vessel is at sea for catching fish. Moreover, the safety of the vessel and its crew play an important role in carrying out the fishing operations at sea efficiently. The tasks carried out by the fishing vessel at sea can be grouped into the following job-functions based on the influencing components on marine fishing.

<table>
<tr><th>Sr. No</th><th>Influencing Components</th><th>Function</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">The Sea</td><td>1. Navigation</td></tr>
<tr><td>2. Marine meteorology and Oceanography</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">The Vessel</td><td>1. Vessel construction</td></tr>
<tr><td>2. Marine Engineering</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">The Crew</td><td>1. Vessel operation</td></tr>
<tr><td>2. Crew care and welfare</td></tr>
<tr><td>3. Marine Communication</td></tr>
</table>

Table No. 1 Job function on fishing vessel

Hence, in conclusion, since the sea, the vessel and the crew play an influencing role in efficient fishing, the entire act of marine fishing should be primarily considered as a maritime activity rather than agricultural activity.

The formulation of necessary rules and regulations, policy making and assisting fishermen with welfare schemes, and any other government related act for the betterment of marine fishing and fishermen will thus be more meaningful, relevant, and pertinent. It will hence be appropriate to keep the marine fishing under a ministry which looks after the maritime activities like the Ministry of Shipping. Moreover, in addition to the marine fishing and shipping, there are other similar maritime activities such as offshore activities, maritime tourism, maritime sports and ocean engineering which are also influenced by the similar components and can be grouped together into one ministry named such as ‘Ministry of Maritime Affairs’. These activities too are presently part of Ministry of Tourism or Ministry of Earth Sciences etc. Which lack the maritime relevance that predominantly influences these activities.

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ENHANCING RELIABILITY OF SHIP PROPULSION PLANT USING MARKOV MODEL

Ulhas S. Kalghatgi [1]
A. Merceline Anita [2]

Abstract

Ships trade internationally, transporting cargo on a large scale, which is several thousand times more than the cargo carried through any other mode of transport from one destination to another, with unfailing operation of propulsion and essential machinery. This makes it imperative that propulsion as well as auxiliary machinery should be always available in a good condition. The availability in fact is a direct measure of how reliable the machinery is. This paper presents applicability of time-homogenous Markov processes to fuel oil systems, for marine diesel engines running on heavy fuel oils. We determine the limiting distribution of the process of the changes of technical states of fuel systems and hence calculate the reliability and availability of the System. The proposed study of this process includes eight components of fuel oil system, which constitutes eight states and a transition state model has been developed. Numerical study has been carried out to analyze the stationary probabilities and limiting distribution of the process.

Keywords: Markov model, Propulsion & Auxiliary machinery, Availability and Reliability.

1. INTRODUCTION:

Markov models are Stochastic processes that undergo transition from one state to another. They have found innumerable applications, especially for modeling processes and decision making in the field of Reliability, Physics, Queuing theory, Finance, Statistics, etc. A fundamental property of all Markov models is their memory-lessness. The basis of a Markov model is the assumption that the future is independent of the past, given the present. This arises from the study of Markov chains. Markov analysis looks at a sequence of events and analyses the tendency of one event to be followed by another. Using this analysis, it is possible to generate a new sequence of random but related events, which, appear like the original. A Markov Chain may be described as homogenous or non-homogenous. In this paper, a homogenous chain is used to carry out the analysis, i.e., the transition time between states is constant. The importance of Markov process is shown by analyzing the reliability function and availability of fuel oil system, which is essential for the operation of ship's propulsion machinery.

The Markov transition diagram indicating the system states is presented, as it gives availability function and leads to the expression for reliability function. The availability of machinery is very important factor in ensuring uninterrupted sailing of ships. The availability in fact is a direct measure of how reliable the machinery is, which will enable ships to fulfill the charter

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party obligations by reaching the destinations. The paper is organized as follows. In Sections 2 and 3, the basic definitions, Assumptions and notations are given, The Concept of Markov Model which is of prime importance in our study has been discussed in Section 4, Section 5 gives brief description of Ship's Propulsion System. In Section 6, two pump sea cooling water system is taken up to analyze using Markov method as a precursor and hence apply this method to Fuel Oil System. In Section 7, Semi-Markov process is applied to determine the limiting distribution of the process of changes of technical states of the heavy Fuel Oil System. The Results are tabulated and finally in Section 8, conclusion is drawn about effectiveness of Semi-Markov method in handling dynamic cases and its Superiority over Reliability Block Diagrams and Fault Tree Analysis in handling Complex Systems.

2. BASIC DEFINITIONS AND TERMINOLOGIE:

2.1. RELIABILITY R(T):

Reliability R(t) is the probability of performing a specific function under given condition for a specified period interval without failure [7] and is denoted by $R(t)$. It is pertinent to note that the reliability function being a probability, is dimensionless.

$$1 \geq R(t) \geq 0 \qquad (1)$$

Where $R(0) = 1$ and $R(\infty) = 0$

If the failure rate $\lambda(t)$ is constant, then we get equation,

$$\lambda(t) = \lambda \qquad (2)$$

$$R(t) = e^{-\int_0^t \lambda(t)dt} \qquad (3)$$

In many practical applications, failure rates of item/system are considered as constant by assuming the condition, as good as new for every repaired item or system.

2.2. MEANTIME TO FAILURE (MTTF):

Meantime to failure of a system is defined as the expected value of the random variable T denoting the times to failure. It is a basic measure of Reliability for non-repairable systems.

$$MTTF = \int_0^\infty R(t)dt \qquad (4)$$

2.3. AVAILABILITY A(T):

Availability is defined as the probability that a component or system is performing its required function at a given point of time when used under stated operating conditions and maintained in a prescribed manner [2]. Sometimes it becomes necessary to determine mission availability, which is the average availability over the interval $(0, T)$ and is expressed as

$$A(t) = (\frac{1}{T}) \int_0^T A(t)dt \quad (5)$$

3. ASSUMPTIONS AND NOTATIONS:

3.1. ASSUMPTIONS:

i. The basic assumption of a Markov process is that the behavior of a system in each state is memoryless.
ii. Stay time in the system states follows an exponential distribution, i.e., failure and repair rates are constant for all units during this process.
iii. The probability that the system changes its state depends only on the previous state.
iv. Finite state space and time homogenous Markov process is considered for our study.
v. The Markov Model assumes that the future is independent of the past given the present.

3.2. NOTATIONS:

λ - failure rate of the system
μ - repair rate for the system
0 - represents operative state
1 - represents failed state
$P_j(t)$ - represents the probability that the system is in state j at time t.

$P_{ij}(t)$ - represents transition probability from state i to state j at time t.

4. BASICS OF MARKOV MODEL[5]:

A Markov Model consists of list of possible states of the System, transition paths between these states and the rate parameters of these transitions. In Reliability Analysis, transitions usually consist of failures & repairs. The figure below gives the transition diagram for two states (good & failed) of a single component.

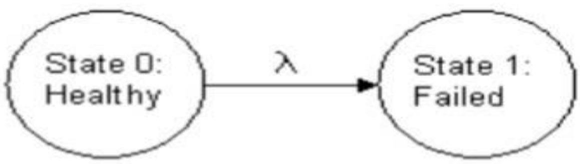

Figure 1: Transition path between two states

Here λ denotes the failure rate parameter from state 0 to state 1.and $P_j(t)$ denotes the Probability of the System being in state j at time t.

The incremental change in probability dP_0 of state 0 at any given time is given by the following fundamental relation

$$\frac{dP_0}{dt} = -\lambda P_0 \qquad (6)$$

Also, $P_0(t) + P_1(t) = 1$ (Total probability of the System at time t is P(t))

The solution of the above equation with the initial conditions $P_0(0) = 1 \& P_1(0) = 0$ is

$$P_0(t) = e^{-\lambda t} \;\&\; P_1(t) = 1 - e^{-\lambda t} \qquad (7)$$

The transitions with constant rates are called exponential transitions because the transition times are exponentially distributed.

5. PROPULSION PLANT DESCRIPTION

Ships are propelled by one or more combinations of following means of propulsive power/Prime movers

- Diesel engines
- Steam or gas turbines
- Electrical propulsion motors
- Hybrid, i.e., diesel/electric or diesel/gas, also known as CODAG

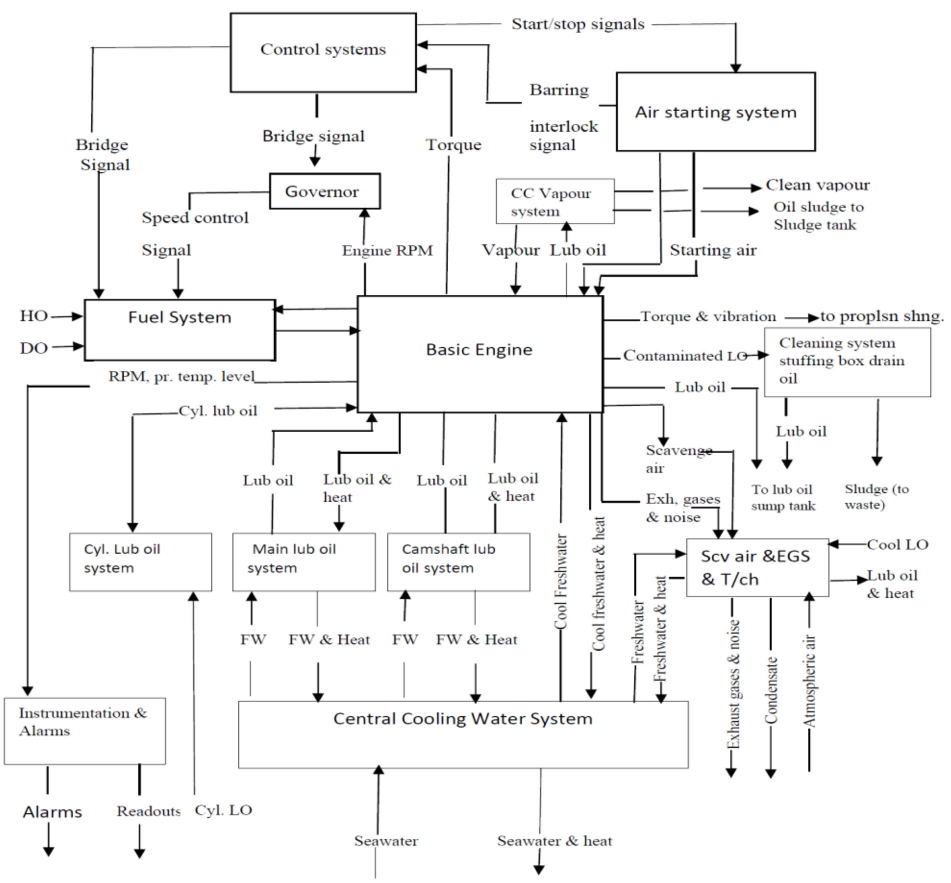

Figure 2: Marine Propulsion Diesel Engine with systems & sub-systems

Source: ABS guidance notes on RCM, Appendix 2, 2004

The propulsion machinery is made operational with the help of various auxiliary systems such as fuel oil, compressed air, cooling water, lubricating oil systems and many other support functions. Uninterrupted operation of a shipâ€™s propulsion machinery solely depends on satisfactory functioning of these auxiliary systems, whose reliability plays an important role to ensure availability of propulsion engine/s.

Figure 2 provides an insight as to how a marine propulsion engine and its systems and subsystems are interconnected.

Ship propulsion systems are very often, for maintenance purposes, overhauled earlier than scheduled, though not required, which may result in certain malfunctions during dismantling and re-assembly leading to the system breakdown. Obviously, many malfunctions cannot be foreseen, but by proper maintenance they can be reduced to the minimum. For easier monitoring and timely action, it is customary to subdivide the prime mover (diesel engine in this case) into subsystems as shown in figure 3.

Figure 3: Propulsion engine and its sub-systems

6. MODELING OF SEA COOLING WATER (SCW) SYSTEM

The function of Sea Cooling Water (SCW) System is to carry away heat generated due to combustion taking place in the internal combustion engine cylinders and is circulated through various coolers.

Sea Cooling Water System comprises of 2 pumps connected in parallel as shown in figure 4 below and the two pumps do not fail at the same time.

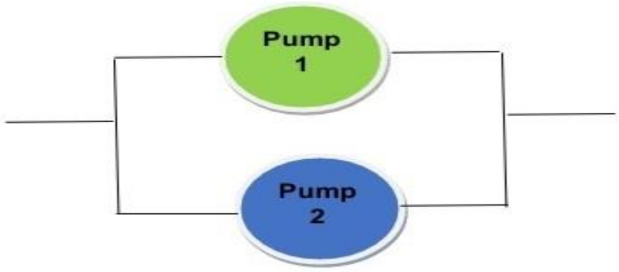

Figure 4: Sea Water Pumps connected in parallel

The individual pumps have been assumed to have constant failure rates of $\lambda_1 = 50 \times 10^{-6}$[6] failures per hour and $\lambda_2 = 20 \times 10^{-6}$[6] failures per hour respectively. When Markov analysis is used, a two-component system can be in one of the four possible states, presented in table 1, which shows the list of all possible states in terms of the element states.

State	Pump 1	Pump 2
0	Working	Working
1	Failed	Working
2	Working	Failed
3	Failed	Failed

Table 1: Possible system states

The two-pump transition state model for the simple two-unit system is shown in the figure 5 below with failure and repair rates.

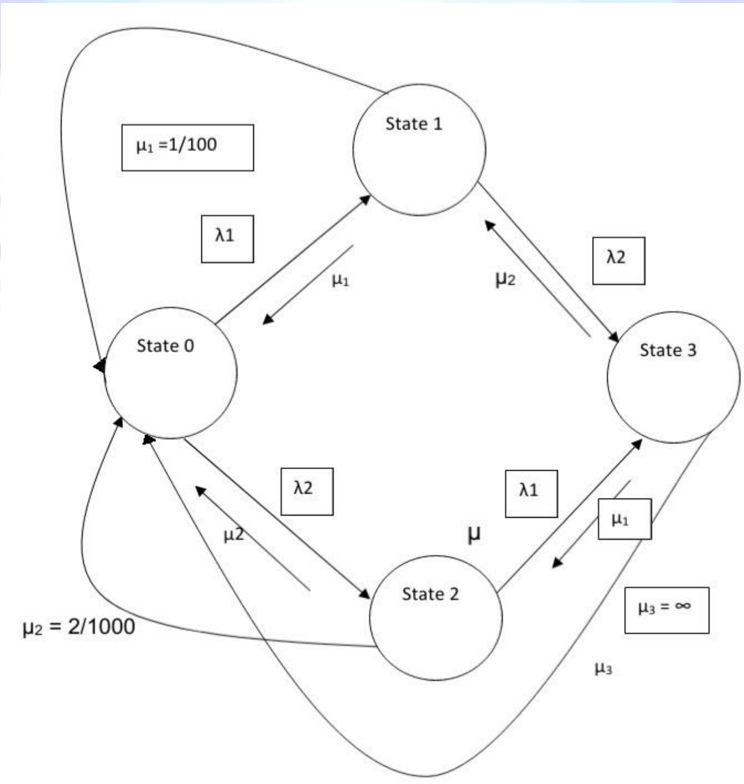

Figure 5: Two pump transition state model

Here, we consider the values of $\lambda_1, \lambda_2, \mu_1, \mu_2$ as

- $\lambda_1 = 50 \times 10^{-6}$ failures per hour.
- $\lambda_2 = 20 \times 10^{-6}$ failures per hour.
- $\mu_1 = 1/100$ per hour.
- $\mu_1 = 2/1000$ per hour.

The repair rate of the fully failed state (state 3) is close to infinity; hence the probability of that state will be zero. The total system failure rate is the total flow rate into that state $= \lambda_2 P_1 + \lambda_1 P_2$.

To determine the long-term usages system failure rate, we need to consider only the steady-state equations, at states 0, 1, 2 and 3 respectively as follows.

$$\text{AtState } 0,\ (\lambda_1 + \lambda_2)P_0 = \mu_1 P_1 + \mu_2 P_2 + \mu_3 P_3 \tag{8}$$

$$\text{AtState } 1,\ \lambda_1 P_0 = (\lambda_2 + \mu_1)P_1 \tag{9}$$

$$\text{AtState } 2,\ \lambda_2 P_1 = (\lambda_1 + \mu_2)P_2 \tag{10}$$

$$\text{AtState } 3,\ \lambda_2 P_1 + \lambda_1 P_2 = \mu_3 P_3 \tag{11}$$

Where P_j is the probability of the system at state $j,\ j = 0,1,2,3$.

The quantity $\mu_3 P_3$ represented by equation (11) is indeterminate. However, the left side of that equation defines the overall system failure rate.

Substituting equation (11) in equation (8), we eliminate the empty state P_3, and the system equations can be written as

$$(\lambda_1 + \lambda_2)P_0 = (\lambda_2 + \mu_1)P_1 + (\lambda_1 + \mu_2)P_2 \tag{12}$$

$$\lambda_1 P_0 = (\lambda_2 + \mu_1)P_1 \tag{13}$$

$$\lambda_2 P_0 = (\lambda_1 + \mu_2)P_2 \tag{14}$$

Solving Equations (13) and (14), gives

$$P_1 = \frac{\lambda_1}{\lambda_2 + \mu_1} P_0 \quad P_2 = \frac{\lambda_2}{\lambda_1 + \mu_2} P_0 \tag{15}$$

Since, sum of all the probabilities must always equal 1, and since $P_3 = 0$, the conservation equation is

$$P_0 + P_1 + P_2 = 1 \tag{16}$$

Substituting the values of P_1 and P_2 from equation (15) and solving for P_0, we get the steady-state value of P_0 as.

$$P_0 = \frac{1}{1+\frac{\lambda_1}{\lambda_2+\mu_1}+\frac{\lambda_2}{\lambda_1+\mu_2}} \qquad (17)$$

Therefore, by solving equations (8) to (11), corresponding probabilities at each of the states have been determined as shown in equation (17).

Using equations (15) and (17), we get

The overall average system failure is given by,

$$\lambda_{sys} = \lambda_2 P_1 + \lambda_1 P_2 = \frac{\lambda_2\frac{\lambda_1}{\lambda_2+\mu_1}+\lambda_1\frac{\lambda_2}{\lambda_1+\mu_2}}{1+\frac{\lambda_1}{\lambda_2+\mu_1}+\frac{\lambda_2}{\lambda_1+\mu_2}} \qquad (18)$$

Inserting the values $\lambda_1 = 50 \times 10^{-6}, \lambda_2 = 20 \times 10^{-6}, \mu_1 = 1/100$, and $\mu_2 = 2/1000$, gives the average total system failure rate $\lambda_{system} = 5.79 \times 10^{-7}$ per hour.

6.1. MATRIX NOTATION:

Since $P_0 + P_1 + P_2 = 1$, the resulting set of equations can be written in matrix form as:

$$CP = U \qquad (19)$$

Were

$$C = \begin{bmatrix} 1 & 1 & 1 \\ \lambda_1 & -(\lambda_2+\mu_1) & 0 \\ \lambda_2 & 0 & -(\lambda_1+\mu_2 \end{bmatrix} P = \begin{bmatrix} P_0 \\ P_1 \\ P_2 \end{bmatrix} U = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

The solution for this matrix equation is $P = C^{-1}U$.

The state equations for the two-pump Sea Cooling Water System were written down explicitly and solved using basic algebraic equations, but for larger and more complicated models it is often more convenient to write the equations in matrix form and solve them.

In general, there is a state equation for each state of the model, but these equations are not all independent, because the sum of all the state probabilities must always equal 1. This constraint must be imposed to determine the solution. For example, the steady-state equations for states of the two pumps Sea Cooling Water System are given as

$$(\lambda_1+\lambda_2)P_0 - (\lambda_2+\mu_1)P_1 - (\lambda_1+\mu_2)P_2 = 0$$
$$\lambda_1 P_0 - (\lambda_2+\mu_1)P_1 = 0$$
$$\lambda_2 P_0 - (\lambda_1+\mu_2)P_2 = 0 \qquad (20)$$

The above results are also applicable to lubricating oil system fitted with 2 pumps. In general, the system shutdown rate will be some linear combination of the state probabilities. In this 2-pumps Sea Cooling Water System, the system shutdown rate is $\lambda_2 P_1 + \lambda_1 P_2$, so we can define the row vector $L = [0 \;\; \lambda_2 \;\; \lambda_1]$. The average system failure rate is $\lambda_{system} = LC^{-1}U$.

7. MARKOV MODEL FOR FUEL OIL SYSTEM:

In this section, we consider applying Markov Model to Fuel Oil System with a rigorous approach. A trouble-free operation of marine internal combustion engine on board ship requires that all the sub-systems described in section 6 should have high degree of Reliability. Out of two systems, sea cooling water and lubricating oil systems, only one system was modeled using Markov analysis considering only two pumps. This analysis is less severe, because it involved only four possible states, such as, both the pumps operating, one is running and the other one is on standby, one pump failed, one operating, and finally both pumps in failed state. However, the simple algebraic equations used will prove inadequate if one must consider a complex system consisting of higher number of components with all components in ability state, for a system to be in operation.

This section deals with application of theory of Semi-Markov process to determine a limiting distribution of the process of changes of technical states of heavy fuel oil system consisting of eight components. For the fuel oil system to be always available, following key components need to be functioning.

- Injectors
- High pressure hoses
- Injection pump
- Low pressure hoses
- Fuel filters
- Fuel-feed pump
- Fuel heater
- Viscometer

A Markov Model comprising of the states of the fuel oil system including the states of the above components is developed defining the following states as

s_0 : Fuel Oil System fully functional, i.e. ability state of a fuel system.
s_1 : Failure State of the system due to injector failure.
s_2 : Failure State of the system due to high pressure hoses failure.
s_3 : State of the system due to Injection pump failure.
s_4 : State of the system due to low pressure hoses failure.
s_5 : State of the system due to filters failure.
s_6 : State of the system due to fuel-feed pump failure.
s_7 : State of the system due to fuel heater failure.

s_8 : State of the system due to Viscometer failure.

The fuel system considered herein has been investigated, applying following scientific hypothesis. **Hypothesis â€“(H)**: The process of changes of technical states of any fuel system (defined as a random function whose argument is time and the values are random variables denoting the current technical states) running under rational operation i.e., operation based on economic calculation. Further it is pertinent to emphasize that any state of the process investigated at any instant of time $\tau_n(n = 0,1,$ â€¦$, m; \tau_0 < \tau_1 <$ â€¦ $< \tau_m)$ depends significantly on the immediate previous state and not on the states that occurred earlier or the periods of their duration. The states are $\{s_i, i \in N\}$. For the application, we consider $N = \{0,1,2,\ldots 8\}$. The following assumptions are made for our study.

1. Probabilities $(p_{ij}; i \neq j; i,j \in N)$ of the process transition, i.e., changes of fuel system states from any state â€œs_iâ€ , which the process (system) is in, to the next (any) state "s_j", do not depend on the states which the process was earlier in.
2. Periods of unconditional duration of the states â€œs_iâ€ of the process of changes of fuel system states are stochastically independent random variables $(T_i; i \in N)$, where T_i is the time of the state.
3. Periods of duration of each of the possible-to-occur states â€œs_iâ€ of the process of changes of fuel system states, provided that the next state is one of the remaining process states â€œs_jâ€ , are stochastically independent random variables $(T_{ij}; i \neq j; i,j \in N)$.
4. Failure rates of the components of fuel system are exponentially distributed, with failure rates $f_1, f_2, \ldots, f_8$. Therefore, the duration at s_0 would be exponentially distributed with failure rate $f_1 + f_2 + \ldots + f_8$. The probability that the next state would be s_i is

$$= \frac{f_i}{f_1 + f_2 + \ldots + f_8} \tag{21}$$

Application of a semi-Markov model of the process of changes of technical states of a fuel system for a heavy fuel engine allows

- To consider preventive maintenance required to restore the system into operation upon completion of maintenance of system’s components and
- To investigate more than two Reliability states of an Engine Fuel System as well as its components.

This enables to investigate a semi-Markov model of changes of technical states of fuel systems for marine internal combustion engines with an eight-element set S. This means that the limiting distribution of the process of changes of ability and inability states of heavy fuel supply systems for marine diesel engines. It can be defined by using the model of the process of changes of the system states, which is developed in a form of a semi-Markov process $\{W(t): t \geq 0\}$ with a set of states $(S = s_i; \quad i = 1,2,\ldots,8)$. The graph showing state transitions for the process $\{W(t): t \geq 0\}$ is shown below in Figure 6. Transitions of the states $s_i(i = 1,2,\ldots,8)$ occur in succeeding times $t_n(n \in N)$, where at time $t_0 = 0$, the engine fuel system is in state s_0. The state s_0 lasts until a failure of any of the components of the engine fuel system occurs. However, the states $s_i(i = 1,2,\ldots,8)$ last until the damaged engine fuel system is restored.

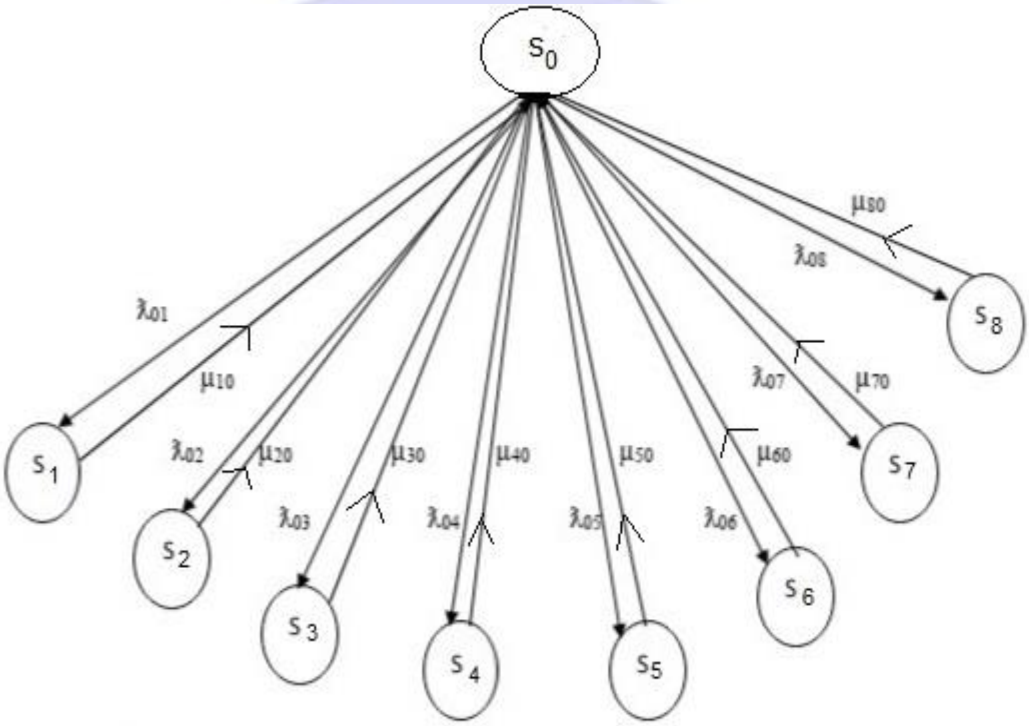

Figure 6: Graph of state transitions for the process $\{W(t): t \geq 0\}$

Obtaining the values of the probabilities $P_j(j = 0,1,2,3)$ that make a limiting distribution of the process of changes of ability and inability states of a heavy fuel supply system for a marine diesel engine requires determination of the initial distribution of the process $\{W(t): t \geq 0\}$ and its matrix function.

The initial distribution of the process $W(t)$ at time $t = 0$ is

$$W(0) = s_0 \text{ with probability } 1,$$
$$P\{W(0) = s_i\} = 1 \text{ for } i = 0,$$
$$= 0 \quad for \quad i = 1,2,\ldots,8$$

For $i = 0$, assuming exponential distribution as per assumption stated in section 4 above

$$\text{Matrix } P = [p_{ij}] \;\; i = 1,2,\ldots,8 \;\&\; j = 1,2,\ldots,8$$
$$p_{i,0} = 1, \;\; (i = 1,2,\ldots 8)$$

$$p_{i,0} = \frac{f_i}{\sum_{k=1}^{8} f_k} = \frac{f_i}{f}, \quad \text{where} \quad f = \sum_1^8 f_k$$

$$p_{i,j} = 0, \quad i = j, \quad i,j = 0,1,2\ldots8$$

$$p_{0,j} = 1, \quad j = 1,2\ldots8$$

The process $\{W(t): t \geq 0\}$is irreducible and the random variables, $T_{i,j}$ (i.e., duration of system being in states s_i and s_j respectively) take finite positive expected values. Therefore, its limiting distribution is of the following form

$$P_j = \frac{\pi_j E(T_j)}{\sum_{l=1}^{8} \pi E(T_l)} \tag{22}$$

Where E is the expected value of random variable of duration of the state.

The probabilities $\pi_j(j = 0,1,2,\ldots,8)$ in the equation (22) are limiting probabilities of the embedded Markov chain to the process $\{W(t): t \geq 0\}$. However, $E(T_j)$ and $E(T_k)$ are expected values of the random variables T_j and T_k respectively, which are the time periods of staying the system in states s_j and s_k respectively, regardless of which state will be the next. To determine the limiting distribution, it is required to solve the system of equations that comprise the said limiting probabilities $\pi_j(j = 0,1,\ldots,8)$ of the embedded Markov chain and the matrix P of the probabilities of transition from the state s_i to s_j,. Such a system takes the following form:

$$\pi = \pi P \qquad (23)$$

$(P - 1)\pi = 0$, where $P - 1$ is a matrix, whose elements are of the following form in the matrix given below.

$$\begin{bmatrix} -1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ \frac{f_1}{f} & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \frac{f_2}{f} & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ \frac{f_3}{f} & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ \frac{f_4}{f} & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \\ \frac{f_5}{f} & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \\ \frac{f_6}{f} & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 \\ \frac{f_7}{f} & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\ \frac{f_8}{f} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \end{bmatrix} \times \pi = 0$$

The above matrix is a model of changes of technical states of an engine fuel system. Non-zero elements of the matrix depend on the distribution of random variables which are the time intervals of staying the process $\{W(t): t \geq 0\}$ in the states $s_i \in S(i = 0,1,\ldots.8)$. The elements of the above matrix function are the probabilities of the process transitions from state s_i to state $s_j(s_i, s_j \in S)$ in time no longer than t.

$$\pi_0 = \sum_{i=1}^{8} \pi_i = 1 - \pi_0 \geq \pi_0 = \frac{1}{2} \quad (24)$$

$$\pi_i = \frac{f_i}{f} \pi_0 \quad \text{forall} \quad i = 1,2\ldots.8 \quad (25)$$

$$\geq \pi_0 = \frac{1}{2} \quad (26)$$

$$\pi_i = \frac{1}{2} \frac{f_i}{\sum_{i=1}^{8} f_i} \quad \text{forall} \quad i \neq 0 \quad (27)$$

from equations (22) and (23) the stationary probabilities(π) of embedded chain and limiting distribution P are estimated using excel sheet and tabulated in Table 2 shown below.

	FO System & Components	Failure Rates (per hour)	Repair Rates (per hour)	Average Time (hours)	Stationary Probability of Embedded Chain	Limiting Distribution
i	s_i	λ	μ	E(T)	π	P
1	Injectors	0.00000675	0.04166667	24	0.022520419	0.000161766
2	High Pressure Hoses	0.000000417	0.0625	16	0.001391261	6.66238×10^{-6}
3	Injection Pump	0.0000124	0.125	8	0.041370843	9.9057×10^{-5}
4	Low Pressure Hoses	0.00000957	0.05	20	0.031928949	0.000191124
5	Filters	0.000104	0.125	8	0.346981263	0.0008308
6	Fuel Feed Pump	0.000009	0.1	10	0.030027225	8.98702×10^{-5}
7	Fuel Heater	0.000000417	0.1	10	0.001391261	4.16399×10^{-6}
8	Viscometer	0.00000731	0.125	8	0.024388779	5.83957×10^{-5}
0	FO System Operational	0.000149864	-	6672.716596	0.5	0.99855816

Table 2: Stationary Probabilities(π) and Limiting Distribution (P)

8. CONCLUDING REMARKS:

- Combinatorial models such as Reliability Block Diagrams and Fault Trees are frequently used to predict the Reliability, Maintainability, and Safety (RMS) of Complex Systems. However, these methods cannot accurately model dynamic system behavior.
- Markov Analysis, with its unique ability to handle dynamic cases, is a powerful tool in the RMS analyses of dynamic systems.

- A Markov model breaks the system configuration into several states, each connected to all other states by transition rates.
- Using transition matrices and state transition diagrams, it represents various system states and the possible transition between these states. The state diagrams are more visual in nature than mathematical representations, thus they are much easier to interpret.
- Thus, Markov analysis can be a powerful RMS analysis tool. On that basis it has been used to model complex, dynamic, highly distributed, Fault Tolerant System, using Ship's Fuel Oil System as an example, or otherwise it would be very difficult or impossible to model with classical techniques.

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FROM SAFETY – I TO SAFETY – II
IS THERE A CASE FOR THE SHIPPING INDUSTRY?

Dr (Capt) Suresh Bhardwaj [1]

Abstract

Safety is usually defined as '*freedom from incidents and accidents*!

- Is it then a "*dynamic non-event*?" noted more in its *absence* - than its presence.
- If the measurement of safety is that *nothing happens*, then how do we understand how systems operate - to produce *nothing*?
- In other words, since accidents are only probabilistic outcomes, it is a challenge to say for sure that - the absence of accidents is by good design - or by lucky chance!
- Yet another much misunderstood concept is the James Reason's Swiss Cheese model that apparently seems to epitomize the luck by-chance concept of accepted holes in the series of barriers to a critical incident, happy with the situation that some barriers may fail, but some may still work!

This article challenges some traditional fundamental concepts of accident dynamics, accident prevention, and accident analysis prevalent in the shipping industry. The purpose is to emphasize that people dealing with safety must understand the underpinning theory of safety management and accident analysis and the practical application of *Integrated Safety Management* framework – by integration, we mean integrated with technology and how safety is considered in such a context.

Keywords: Accident analysis, Incident investigation, Safety 1 & II, Human element.

1. DECIPHERING THE SWISS CHEESE MODEL:

In its real understanding, the Swiss Cheese model (Reason,1990) is a linear but a more complex Cause & Effect model - where accidents are seen as the result of a combination of unsafe acts and latent unsafe conditions, example by-passing of barriers, that lay dormant for quite some time until triggered by the unsafe act. The concept of unsafe acts shifted from being synonymous with human error to the notion of deviation from the expected performance. Performance deviation (not human error). The model considers the contributing factors (as Conditions) that lead to the performance deviation. So, this directs analysis upstream from the worker and process deviations.

The model also considers failures of barriers or defenses at all stages of the accident development as well as 'latent conditions or dormant conditions that are present within the system well before there is any recognizable accident sequence. This model views the accident to be the result of long-standing deficiencies lying dormant - that are triggered by the active

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failures. The focus is on the organizational contributions to the failure - and views the human error as an effect, instead of a cause.

2. THE CONTEMPORARY UNDERSTANDING OF ACCIDENT CAUSATION:

Safety science today views serious accidents not as the result of individual acts of carelessness or mistakes; rather they result from a confluence of influences that emerge over time to combine in unexpected combinations enabling dangerous alignments, sometimes catastrophically. (Rasmussen, 1987). So human error really is a bi-product - of the ever-present latent conditions built into the complexity of organizational culture, and strategic decision-making processes (typically time vs safety). The triggering or initiating error - that releases the hazard is only the last in a network of errors - that often are only remotely related to the accident. Accident occurrences emerge from the organization's complexity, - taking many factors to overcome systems' network of barriers - and allowing a threat to initiate the hazard release.

Our normal - traditional accident investigation and risk assessment models focus on what goes wrong - and the elimination of "error." While this principle may work with machines, it does not work with humans. Variability in human performance is inevitable, - even in the same tasks we repeat every day. Our need to identify a cause for any accident - has colored all risk assessment thinking. Only simple technology and simple accidents may be said to be "caused."

For complex systems and complex accidents! - we don't "find" causes; we "create" them.

3. PITFALLS IN CAUSE & EFFECT RELATIONSHIPS:

Although generally accepted as the overarching purpose of the investigation, - the identification of causes can be problematic. Causal analysis gives the appearance of rigor - but the problem is that causality (i.e., a cause-effect relationship) is often constructed - where it does not really exist. Investigators look backwards - with the undesired outcome (effect) preceded by actions, which is opposite of how the people experienced it (actions followed by effects).

A. True cause and effect relationship must meet 2 requirements

- The cause must precede the effect (in time);and
- The cause and effect must have a necessary and constant connection between them, same cause always has the same effect.

This second requirement is the one that invalidates most of the proposed causes identified in accident investigations. As an example, a cause statement such as “the accident was due to inadequate supervision” - cannot be valid because - the inadequate supervision does not cause accidents all the time.

In a complex socio-technical system involving people, processes and programs, the effects are not ‘resultant phenomena’ due to cause and effect but are ‘emergent phenomena’ due to interactions within the system. Since accidents do happen, there are obviously many factors that contribute to the undesired outcome. These factors are often identified by missed opportunities and missing barriers which get mislabeled as causes. The investigation should focus on understanding the context of decisions and explaining the event. To understand human performance, one must not limit oneself to the quest for causes. An explanation of ‘*why people did what they did’* provides a much better understanding and with understanding, comes the ability to develop solutions that will improve operations.

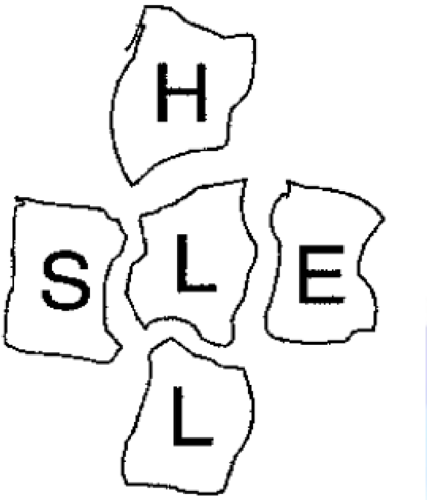
What is important to remember is not that individual in organizations make mistakes, but that mistakes themselves are socially organized and systematically produced. The accidents have systemic origins that transcended individuals, organization, time, and geography. Its sources are neither extraordinary nor necessary peculiar. Instead, its origins are in routine and taken for granted aspects of organizational life *that create a way of seeing that was simultaneously a way of not seeing*.

This is the contemporary safety science and organizational theory that will challenge the future investigators and safety specialists.

4. HUMAN ERROR – NOT THE ‘CAUSE’ BUT AN ‘EFFECT’:

To fully understand the work environment, where there are numerous interactions between the component elements, the SHEL model is used (IMO, 2000) . The SHEL Model takes into consideration all the important work system elements; it promotes the consideration of the interrelationships between these work system elements; and sit focuses on the factors which influence human performance.

There are four components to the SHEL model: Liveware – L, Hardware – H, Software – S, Environment - E. The SHEL Model is commonly depicted graphically to display not only the four components but also the relationships, or interfaces, between the liveware and all the other components.



Liveware – L - The most valuable and flexible component in the system is the human element, the liveware, placed at the centre of the model.
Hardware - H - includes the design of work stations, displays, ols.
Software - S - the non-physical part of the system including organizational policies, procedures, manuals, checklist layout, charts, maps, advisories and, increasingly, computer programs.
Environment – E - includes the internal and external climate, temperature, visibility, vibration, noise, and other factors - political and economic constraints, Safety Culture.

Figure 1: SHEL Model (IMO, 2000)

Figure above portrays the match or mismatch of the interfaces is just as important as the characteristics of the blocks themselves. A mismatch can be a source of human error and identification of a mismatch may be the identification of a safety deficiency in the system.

Safety science today views serious accidents - not as the result of individual acts of carelessness or mistakes; rather they result from a confluence of influences that emerge over time to combine in unexpected combinations enabling dangerous alignments -sometimes catastrophically.

Meanwhile, The James Reason’s model had identified the concept of unsafe acts having shifted from being synonymous with human error to the notion of deviation from the expected performance. The model also considers the contributing factors that could lead to the performance deviation, which directs analysis upstream from the worker and process deviations. It takes into consideration barriers or defenses at all stages of the accident development and the introduction of latent or dormant conditions that are present within the system (inadequate regulations, inadequate procedures, insufficient training, high workload, and undue time pressure.) well before there is any recognizable accident sequence.

The triggering or initiating error that releases the hazard is only the last in a network of errors that often are only remotely related to the accident. Accident occurrences emerge from the organization’s complexity, taking many factors to overcome systems’ network of barriers and allowing a threat to initiate the hazard release.

Investigations require delving into the basic organizational processes: designing, constructing, operating, maintaining, communicating, selecting, and training, supervising, and managing that contain the kinds of latent conditions most likely to constitute a threat to the safety of the system.

The idea of human error as "cause" in consequential accidents is one that has been debunked by safety science. As Perrow (1984) stated the situation "Formal accident investigations usually start with an assumption that the operator must have failed, and if this attribution can be made, that is the end of serious inquiry. Finding that faulty designs were responsible would entail enormous shutdown and retrofitting costs; finding that management was responsible would threaten those in charge, but finding that operators were responsible preserves the system, with some soporific injunctions about better training".

In contemporary safety science the concept of error is simply when unintended results occurred during human performance. Error is viewed as a mismatch between the human condition and environmental factors operative at a given moment or within a series of actions. Research has demonstrated that presence of various factors in combination increase the potential for error.

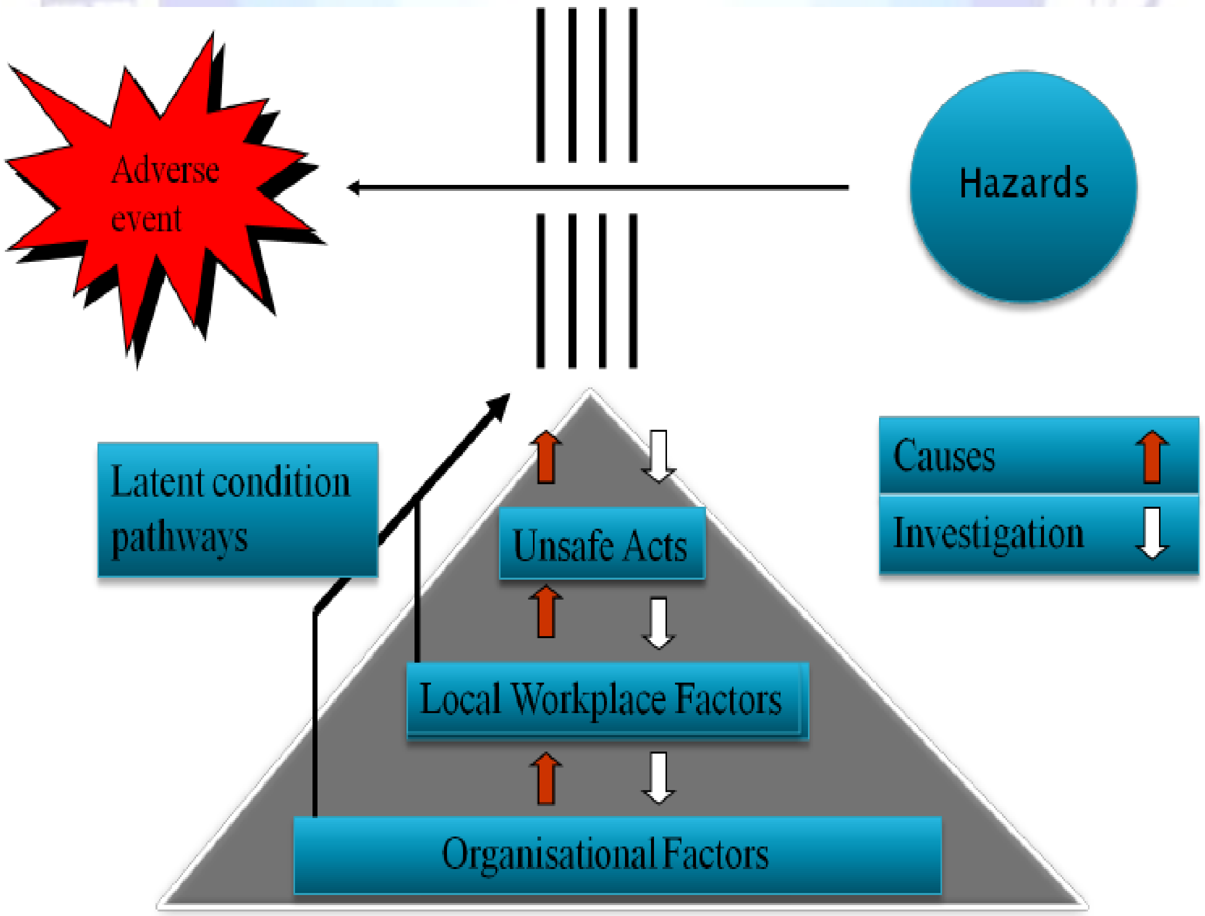


Figure 2: Organizational Factors (Perrow, 1983)

5. FROM SAFETY – I TO SAFETY – II

A Safety-I approach presumes that things go wrong because of identifiable failures or malfunctions of specific components: technology, procedures, the human workers, and the organizations in which they are embedded. Humans—acting alone or collectively—are therefore viewed predominantly as a liability or hazard, principally because they are the most variable of these components.

The purpose of accident investigation in Safety-I is to identify the causes and contributory factors of adverse outcomes, while risk assessment aims to determine their likelihood. The safety management principle is to respond when something happens or is categorized as an unacceptable risk, usually by trying to eliminate causes or improve barriers, or both.

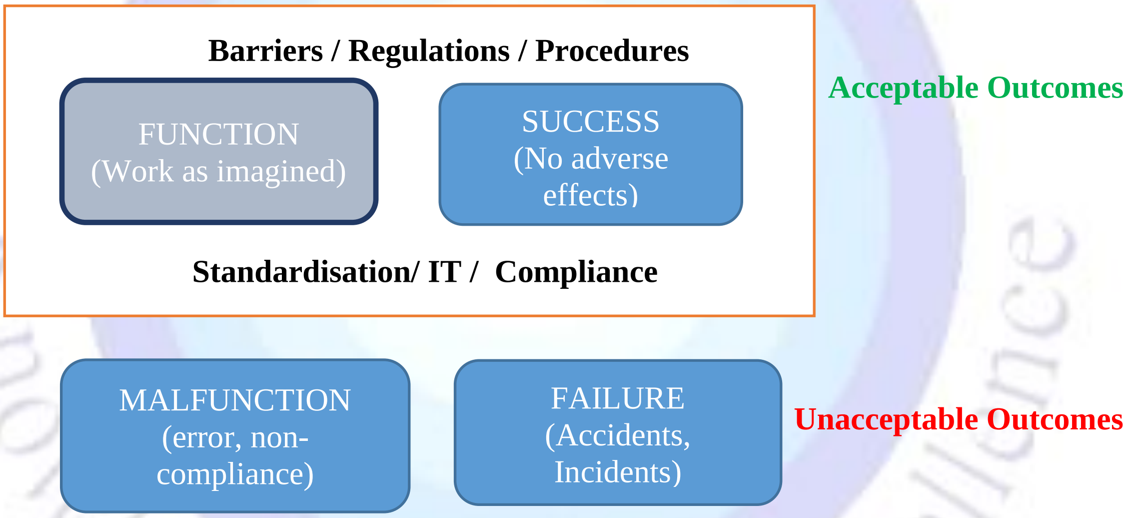


Figure 3: Safety by elimination and prevention

In Safety-I, the starting point for safety management is either that something has gone wrong or that something has been identified as a risk. The generic mechanism of Safety-I is the Causality Credo—a predominant belief that adverse outcomes (accidents, incidents) happen because something goes wrong, hence that they have causes that can be found and treated.

6. 'WORK-AS-IMAGINED' AND 'WORK-AS-DONE':

It is an unspoken assumption that work can be completely analyzed and prescribed and that ***Work-As-Imagined*** therefore will correspond to ***Work-As-Done*** (DOE Handbook, 2012) But Work-As-Imagined is an idealized view of the formal task environment that disregards how task performance must be adjusted to match the constantly changing conditions of work and of the world.

Work-As-Imagined describes what should happen under normal working conditions. Work-As-Done, on the other hand, describes what happens, how work unfolds over time in complex contexts. But the more intractable environments that we have today means that *Work-As-Done* differs significantly from *Work-As-Imagined*. Since *Work-As-Done* reflects the reality that people must deal with, the unavoidable conclusion is that our notions about *Work-As-Imagined* are inadequate if not directly wrong.

This constitutes a challenge to the models and methods that comprise the mainstream of safety engineering and human factors. It also challenges traditional managerial authority and how safety is managed in the shipping industry - through procedures and systems defined and controlled by the company. In the shipping industry this kind of control from the company is yet more accentuated because of the stringent mandatory regulations and far-reaching implications if the shore -management is seen to be in any fault.

A practical implication of this is that we can only improve safety if we get out from behind our desk, out of meetings, and into operational environments and with operational people. Today's work environments require that we look at everyday work or Work-As-Done rather than Work-As-Imagined, hence at systems that are real rather than ideal. Such systems perform reliably because people are flexible and adaptive, rather than because the systems have been perfectly thought out and designed or because people do precisely what has been prescribed. Humans are therefore no longer a liability and performance variability are not a threat. On the contrary, the variability of everyday performance is necessary for the system to function and is the reason for both acceptable and adverse outcomes. Because all outcomes depend on performance variability, failures cannot be prevented by eliminating it; in other words, safety cannot be managed by imposing constraints on normal work. The way we think of safety must correspond to Work- As-Done and not rely on Work-As-Imagined. Safety-I begins by asking why things go wrong and then tries to find the assumed causes to make sure that it does not happen again—it tries to re-establish Work-As-Imagined.

The alternative is to ask why things go right (or why nothing went wrong), and then try to make sure that this happens again. And that is SAFETY – II. In the normal course of work, seafarers perform safely because they can adjust their work so that it matches the conditions. Seafaring and ship operations by its very nature is made intractable by the bull-headed approach in this worst-case scenario of globalization. Given the uncertainty, intractability, and complexity of work, the surprise is not that things occasionally go wrong but that they go right so often. Yet as we have seen, when we try to manage safety, we focus on the few cases that go wrong rather than the many that go right. But attending to rare cases of failure attributed to ‘human error’ does not explain why human performance practically always goes right and how it helps to meet goals of safe voyages. Focusing on the lack of safety does not show us which direction to take to improve safety. The solution to this is surprisingly simple: instead of only looking at the few cases where things go wrong, we should look at the many cases where things go right and try to understand how that happens. We should acknowledge that things go right because seafarers are able to adjust their work to conditions rather than because they work as imagined. Resilience engineering acknowledges that acceptable outcomes and adverse outcomes have a common basis, namely everyday performance adjustments (see Figure bellow)

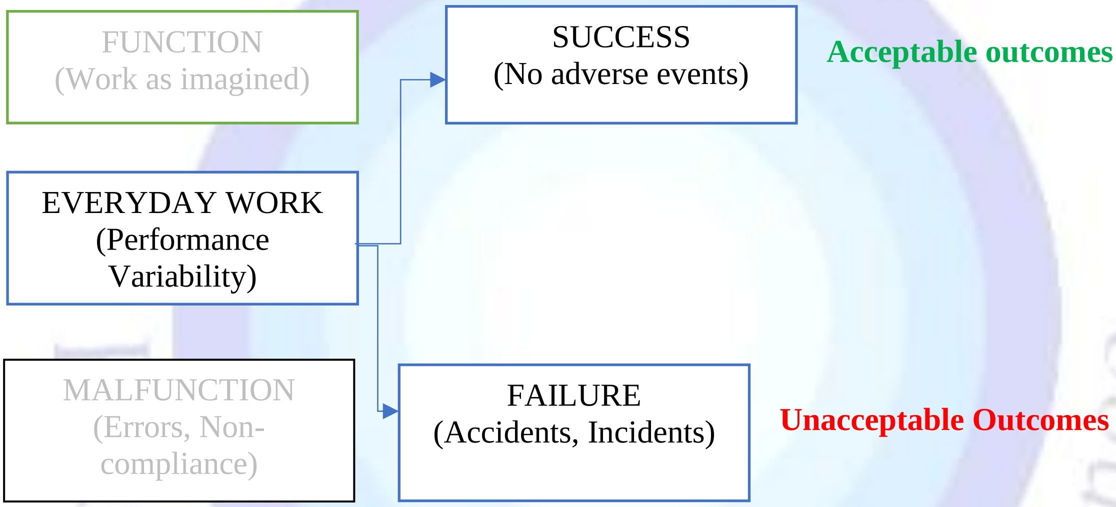


Figure 4: Things that go right and things that go wrong happen in the same way (Hollnagel, Wears and Braithwaite (2015)

Safety-II is the system’s ability to function as required under varying conditions, so that the number of intended and acceptable outcomes (in other words, everyday activities) is as high as possible. The basis for safety and safety management must therefore be an understanding of why things go right, which means an understanding of everyday activities.

7. THE MANIFESTATIONS OF SAFETY-II: THINGS THAT GO RIGHT:

In Safety – II, safety is defined by what happens when it is present, rather than by what happens when it is absent, and is thus directly related to the high frequency, acceptable outcomes. In other words, the more of these manifestations there are, the higher the level of safety is and vice versa. Even though things go right all the time, we fail to notice this because we become used to it. Psychologically, we take it for granted. But since everyday performance is unexceptional, it can be explained in relatively simple terms. For instance, everyday performance can be described as performance adjustments that serve to create or maintain required working conditions, that compensate for a lack of time, materials, information, etc., and that try to avoid conditions that are known to be harmful to work. And because everyday performance variability is ubiquitous, it is easier to monitor and manage.

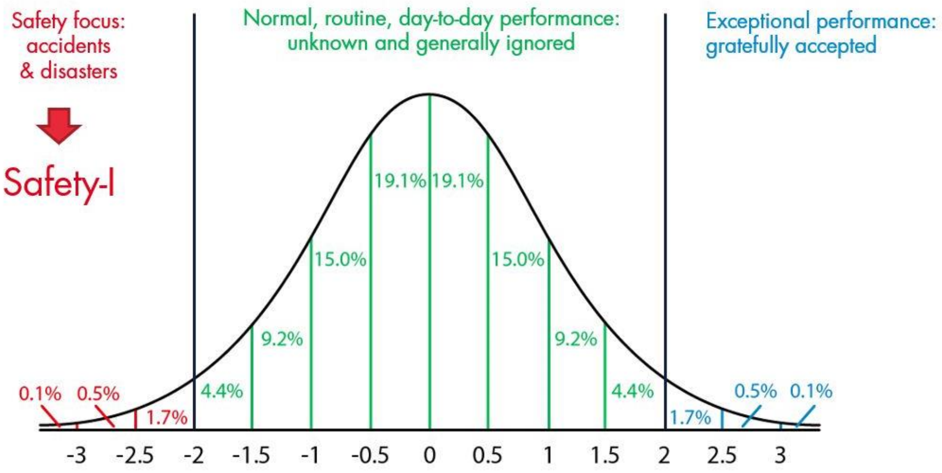


Figure 5: Safety - I and Safety – II

Source: Event Probability and Safety Focus (Hollnagel, Wears and Braithwaite (2015)

The main differences of Safety – I and Safety – II are summarized below:

	Safety-I	**Safety-II**
Definition of safety	That as few things as possible go wrong.	That as many things as possible go right.
Safety management principle	Reactive, respond when some-thing happens or is categorized as an unacceptable risk.	Proactive, continuously trying to anticipate developments and events.
View of the human factor in safety management	Humans are predominantly seen as a liability or hazard.	Humans are seen as a resource necessary for system flexibility and resilience.
Accident investigation	Accidents are caused by failures and malfunctions. The purpose of an investigation is to identify the causes.	Things basically happen in the same way, regardless of the outcome. The purpose of an investigation is to understand how things usually go right as a basis for explaining how things occasionally go wrong.
Risk assessment	Accidents are caused by failures and malfunctions. The purpose of an investigation is to identify causes and contributory factors.	To understand the conditions where performance variability can become difficult or impossible to monitor and control.

Table 1. Principal differences between Safety I and Safety II
(Hollnagel, Wears and Braithwaite (2015)

What seafarers do in everyday work situations is usually a combination of Safety-I and Safety-II. The specific balance depends on many things, such as the nature of the work, the experience of the people, the organizational climate, management and time pressures, and other characteristics. Everybody knows that prevention is better than cure, but the conditions may not always allow prevention to play its proper role. It is a different matter when it comes to the ranks of policymakers, and management and regulatory activities. Here the Safety-I view dominates. One reason is that the primary objective of policymakers, managers and regulators historically has been to make sure that there are no accidents. Another reason is that these levels are removed in time and space from the actual operation of the systems and services, and therefore have limited opportunity to observe or experience how work is done. A third reason is that it is much simpler to count the few events that fail than the many that do not in other words an efficiency-thoroughness trade-off. It is important to emphasize that Safety-I and Safety-II represent two complementary views of safety rather than two incompatible or conflicting approaches. Many of the existing practices can therefore continue to be used, although possibly with a different emphasis. But the transition to a Safety-II view will also include some new types of practices.

8. TRANSITIONING TO SAFETY-II:

8.1 LOOK FOR WHAT GOES RIGHT:

A key message is look at what goes right as well as what goes wrong and learn from what works as well as from what fails. Indeed, do not wait for something bad to happen but try to understand what takes place in situations where nothing out of the ordinary seems to happen. Things do not go well because people simply follow the procedures and work as imagined.

Things go well because people make sensible adjustments according to the demands of the situation. Finding out what these adjustments are and trying to learn from them is at least as important as finding the causes of adverse outcomes. It is necessary to understand how such everyday activities go well how they succeed to understand how they might fail.

From a Safety-II view, they do not fail because of error or malfunction, but because of unexpected combinations of everyday performance variability.

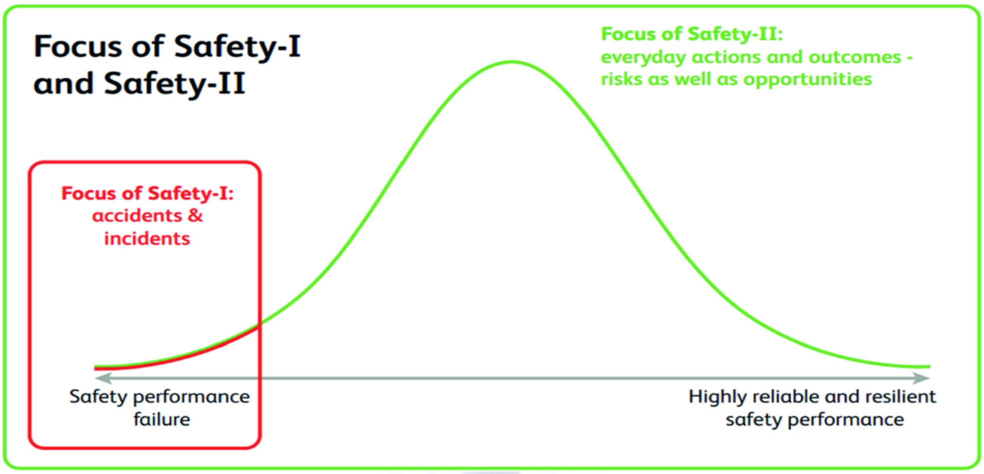


Figure 6: Focus of Safety – I and Safety – II
(Hollnagel, Wears and Braithwaite (2015)

Safety-II focuses on events in the middle of the distribution. These are 'difficult' to see, but only because we habitually ignore them in our daily activities. The 'logic' seems to be that if something works, then why spend more time on it? But the fact of the matter is that they usually do not work in the way that we assume, and that Work-As-Done may be significantly different from Work-As-Imagined. The events in the middle can be understood and explained in terms of the mutual performance adjustments that provide the basis for everyday work. Because they are frequent, because they are small scale, and because we can understand why and how they happen, they are easy to monitor and manage. Interventions are focused and limited in scope (because the subject matter is uncomplicated), and it is therefore also easier—although not necessarily straightforward— to anticipate what both the main and the side effects may be.

9. FOCUS ON FREQUENT EVENTS:

A second message is: look for what happens regularly and focus on events based on their frequency rather than their severity. Many small improvements of everyday performance may count more than a large improvement of exceptional performance. The investigation of incidents is often limited by time and resources. There is therefore a tendency to look at incidents that have serious consequences and leave the rest for some other time—that never comes. The unspoken assumption is that the potential for learning is proportional to the severity of the incident or accident. This is obviously a mistake. While it is correct that more money is saved by avoiding one large scale accident than one small scale accident, it does not mean that the learning potential is greater as well. In addition, the accumulated cost of frequent but small-scale incidents may easily be larger and if ignored, may lead to a larger event. And since small but frequent events are easier to understand and easier to manage, it makes better sense to look to those than to rare events with severe outcomes.

10. REMAIN SENSITIVE TO THE POSSIBILITY OF FAILURE:

A third message is: although Safety-II focuses on things that go right, it is still necessary to keep in mind that things can also go wrong and to ‘remain sensitive to the possibility of failure’. But the ‘possible failure’ is not just that something may malfunction as in a Safety-I view, but also that the intended outcomes may not be obtained, i.e., that we fail to ensure that things go right. Making sure that things go right requires an ongoing concern for whatever works well, not only to ensure that it continues to do so but also to counteract tendencies to employ a confirmation bias or to focus on the most optimistic outlook or outcomes. To remain sensible to the possibility of failure, it is necessary to create and maintain an overall comprehensive view of work—both in the near term and in the long term. This can anticipate and thereby prevent the compounding of small problems or failures by pointing to small adjustments that can dampen potentially harmful combinations of performance variability. Many adverse outcomes stem from the opportunistic aggregation of short-cuts in combination with inadequate process supervision or hazard identification. Being sensible to what happens, to the ways in which it can succeed as well as the ways in which it can fail, is therefore important for the practice of Safety-II.

11. BE THOROUGH AS WELL AS EFFICIENT:

A fourth message is: do not privilege efficiency over thoroughness—or at least, not unduly. (Hollnagel,2009). If most or all the time is used trying to make ends meet, there will be little or no time to consolidate experiences or understand Work-As-Done. It must be legitimate within the organizational culture to allocate resources—especially time—to reflect, to share experiences, and to learn. If that is not the case, then how can anything ever improve?

Efficiency in the present cannot be achieved without thoroughness in the past. And in the same way, efficiency in the future cannot be achieved without thoroughness in the present, i.e., without planning and preparations. While being thorough may be seen as a loss of productivity (efficiency) in the present, it is a necessary condition for efficiency in the future. To survive in the long run, it is therefore essential to strike balance.

12. INVESTING IN SAFETY, THE GAINS FROM SAFETY:

A fifth and final message is: making things go right is an investment in safety and productivity. Spending more time to learn, think, and communicate is usually seen as a cost. Indeed, safety itself is seen as a cost. This reflects the Safety-I view, where an investment in safety is an investment in preventing something from happening. We know the costs, just as when we buy insurance. But we do not know what we are spared, since this is both uncertain and unknown in size. In the risk business, the common adage is 'if you think safety is expensive, try an accident'. And if we calculate the cost of a major accident, almost any investment in safety is cost-effective. However, since we cannot prove that the safety precautions are or were the reason why an accident did not happen, and since we cannot say when an accident is likely to happen, the calculation is biased in favour of reducing the investment. (This is something that is typically seen in hard times.). In Safety-I, safety investments are seen as costs, or are non-productive. Thus, if an investment is made and there are no accidents, it is seen as an unnecessary cost. If there are accidents, it is seen as a justified investment. If no investments are made and there are no accidents, it is seen as a justified saving. While if accidents occur, this is seen as bad luck or bad judgement.

In Safety-II, an investment in safety is seen as an investment in productivity, because the definition and purpose of Safety-II is to make as many things go right as possible. Thus, if an investment is made and there are no accidents, everyday performance will still be improved. If there are accidents, the investment will again be seen as justified. If no investments are made and there are no accidents, performance may remain acceptable but will not improve. While if accidents occur, it is seen as bad judgement.

13. CONCLUSION:

Safety-II is a different way of looking at safety, hence also a different way of applying many of the familiar methods and techniques. In addition to that it will also require methods on its own, to look at things that go right, to analyze how things work, and to manage performance variability rather than just constraining it. Since the socio-technical systems on which shipping industry depends continue to become more and more complicated, it seems clear that staying with a Safety-I approach will be inadequate in the long run and in the short run as well. Taking a Safety-II approach should therefore not be a difficult choice to make. Yet the way ahead lies not in a replacement of Safety-I by Safety-II, but rather in a combination of the two ways of thinking.

Introducing a different understanding of today's world and of the systems we work in and depend upon may require something akin to a paradigm shift. The safety community has developed a consensus on how things work and how safety can be ensured, but the increase of knowledge has levelled off, and the wicked problem of adverse events has continued. We must face the fact that the world cannot be explained by cause-effect models. Incidents and accidents do not only happen in a linear manner but include emergent phenomena stemming from the complexity of the overall system. Asking for “why and because” does not suffice to explain the system in use and does not lead to an improvement in safety. As a consequence of the paradigm change, safety experts and safety managers need to leave their ‘comfort zone’ and explore new opportunities. The new paradigm also means that the priorities of safety management must change. Instead of conducting investigations after the event or striving to reduce adverse outcomes, safety management should allocate some resources to look at the events that go right and try to learn from them. Instead of learning from events based on their severity, people should try to learn from events based on their frequency. And instead of analyzing single severe events in depth, people should explore the regularity of the many frequent events in breadth, to understand the patterns in system performance. A good way to start would be to reduce the dependency on ‘human error’ as a near-universal cause of incidents and instead understand the necessity of performance variability.

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WALK TOWARDS SUSTAINABILITY….

Pawan Kapoor[1]
Poonam Kapoor PhD[2]

Abstract

Sustainability and Sustainable development are essential for Peace, Harmony and Wellbeing on our planet. Practice of Sustainable living requires a comprehensive understanding of the various elements of Sustainability, and a conviction that it is our decision making that impacts Sustainability and Sustainable Development and thus a holistic and balanced approach is needed. Further we need to understand the state of mind in which we can make holistic decisions and how such a state of mind can be attained.

Keywords: Sustainability, Sustainable development, Economic, Social, Environment, Conscious living, Yoga, Meditation.

1. INTRODUCTION:

Man's eternal quest has been for a state of peace, harmony, well-being, and happiness. Since we are affected by our surroundings, to attain such a state, the surroundings must be conducive. Unfortunately, this desire appears paradoxical when we look closely at human thinking and actions and their impact on the planet over centuries. History is replete with evidence of conditions non conducive to the eternal human quest, wars and conflicts being prominent amongst them. According to Peace Research Institute Oslo, between the years 2000-2016 the loss of precious human life across the globe due to fierce conflicts and wars has been nearly three quarter of million as per data available.

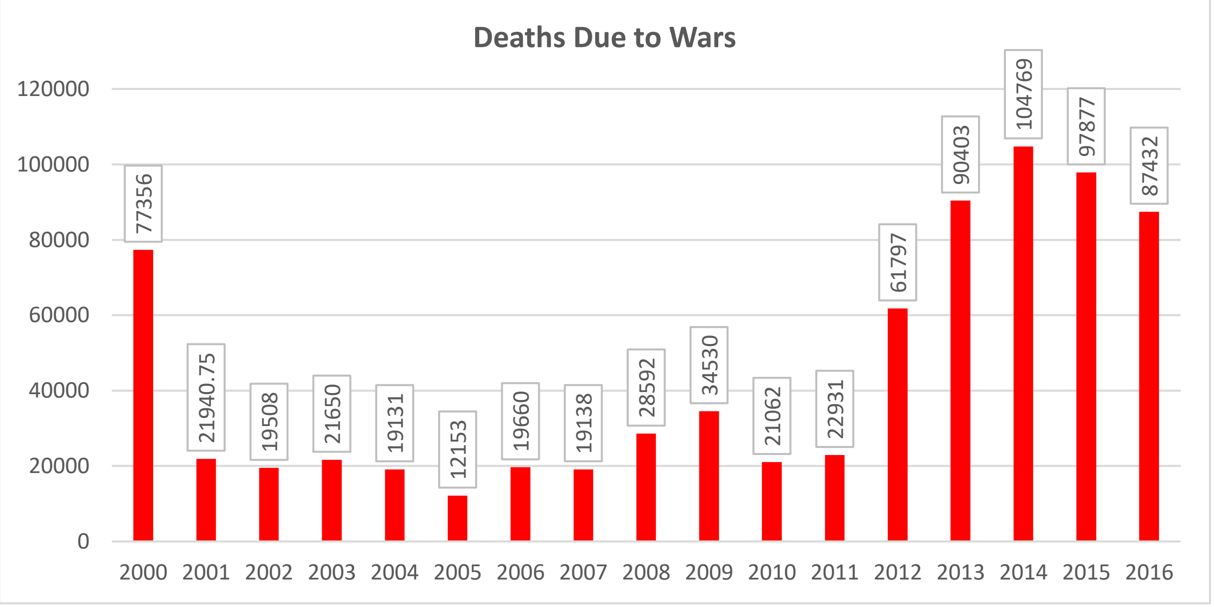

Figure 1

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Natural disasters which include floods, earthquakes, storms, wildfires, landslides, epidemics, droughts, volcanic activities, glacial lakes outbursts, etc. are another cause of enormous misery and suffering our planet has witnessed. While we may refer to them natural disasters, scientific evidence is beginning to show that we as humans may have had a role in these too. Available data on loss of human life, injuries, homelessness during the last two decades is indeed unbelievable. While nearly 1.3 million people have died and nearly 6.5 million injured, over 40 million people have been rendered homeless. The losses in money terms have crossed a whopping figure of 2.7 trillion dollars.

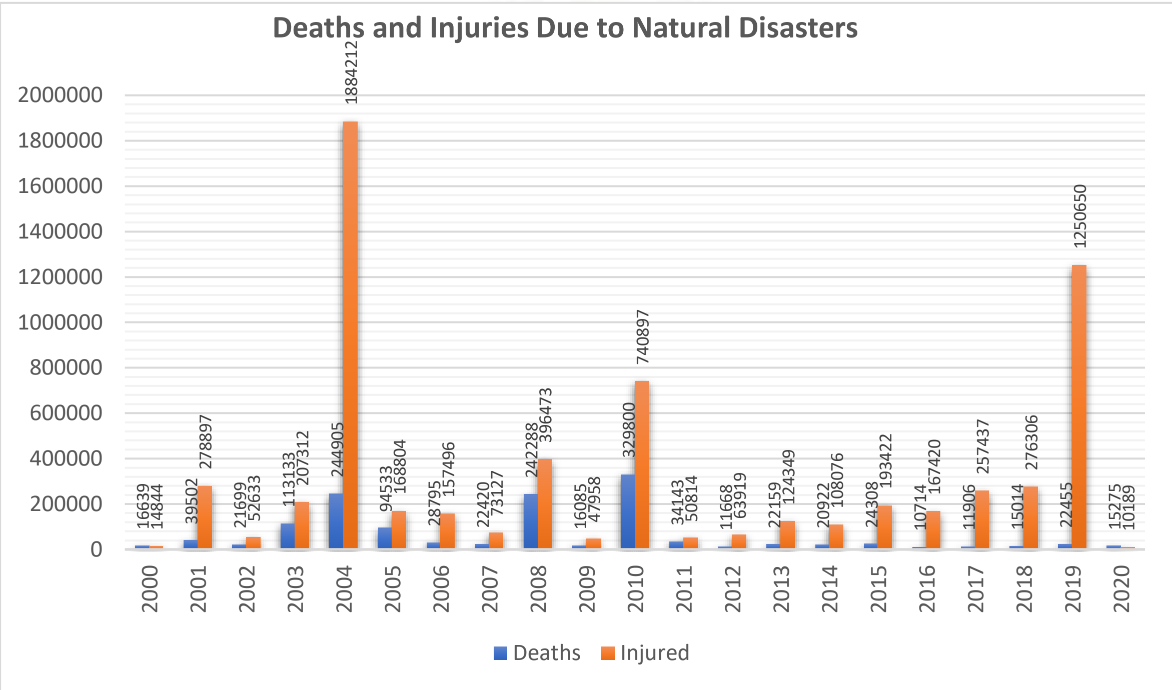


Figure 2

Besides the impact of wars and natural disasters, social unrest, inequality, poverty, diseases, etc. remain additional sources of strife and misery for humans. But despite such depressing data, there is a silver lining; there is now a growing global concern about what we may have done to our planet and a realization that we need Sustainable Development to ensure long term Sustainability for Equity, Harmony and Balance. Somewhere deep within we know that as humans, we can play a decisive role in preventing further damage and reversing the damage already done.

United Nation (2020) SDG Report states that the 2030 Agenda for Sustainable Development was launched in 2015 to end poverty, inequality, disease, etc. and set the world on a path of peace, prosperity, and opportunity for all on a healthy planet. The 17 Sustainable Development Goals (SDGs) demand nothing short of a transformation of the financial, economic, and *political systems that govern our societies today to guarantee the human rights of all. They require immense political will and ambitious action by all stakeholders.*

Conditions like Peace, Harmony, Happiness, Wellbeing, and Sustainability are indeed inseparable. A deeper look at what is Sustainability, and what supports it, will help us identify the course of action with appropriate measures.

2. SUSTAINABILITY:

In simple terms sustainability is the ability to be maintained at a certain rate or level. However, considering the damage inflicted resulting from reckless activities being pursued in the name of development and prosperity, Sustainability means much more.

Daniel Christian Wahl (2020), *sustainability is that which maintains the underlying pattern of health, resilience, and adaptability that maintain this planet in a condition where life, can flourish. This entails redesigning the modern societies using the regenerative principles which may reverse the damage and retain the planet and all its inhabitants in a state of balance, harmony, and wellbeing, in the future and beyond, as originally designed by nature.*

Sustainability is generally understood to have three aspects to it, i.e., Economy, Society and Environment. These aspects are inseparable from one another and are deeply intertwined. It is the limited and biased perception of humans that sees them as fragmented, separate from each other and is also the reason why we are where we are. The corrective measures involve facilitating integration of this perception progressively in a manner which ensures Sustainability. We examine each aspect to understand what they may mean, and the attention they require.

2.1. ECONOMIC ASPECT:

The economic aspect deals with flow of money and monetary well-being of individuals, businesses, and nations. Economy also entails technology, systems, resources, management, innovation, etc. and they all form the mechanism which make the money flow. Economic aspect is often also referred to as ‘Profits’. It is an obvious correlation because we live in times of stock markets, shareholder value, return on investment, growth in GDP, increased production, and consumption to propel economies, and so on; so, Profits in businesses are necessary. But should they be the core objective of any enterprise or an individual?

Peter Drucker says, “The essential purpose of any business entity is to fulfil the needs of the society in an innovative and productive manner; profits are a result that follow and sustain a business.” This philosophy applies equally to individual services providers, enterprises, and perhaps high net worth individuals holding senior positions in enterprises.

In reference to Profits, natural follow up may be, “How much Profit? Maximum, or Optimum? At what cost?” And who determines what should be the Profit margin?

Many great thinkers have also shared another interesting perspective on money. Dr Deepak Chopra, the well-known author and alternative medicine advocate, describes money as the life energy that we exchange and use because of the service we provide to the universe. So, when we work, we spend energy, we earn money which helps us buy means to sustain ourselves by replenishing energy. Sounds logical and convincing indeed!

The money energy obviously is a part of the total sum of energy that exists, and we have learnt in science, energy can neither be created or destroyed; it only changes form. So, if the relative energy levels at various entities are reasonably optimum, there are minimal natural or forced blockages of energy, then the flow of energy will be harmonious and serene! Unused money which is like blocked energy, or enormous surplus of money possessed only by a few entities, resulting from profit maximization, market capitalization, or hoarding, disturbs the ecological balance. While Corporate Social Responsibility is expected to release this surplus energy at least from the organized sectors, this may not come naturally, so is often induced with allurement of tax savings, etc.

Since the money energy is controlled by humans, unless there is awareness and understanding that all entities in the universe are interconnected, and that energy flow affects overall ecology and other inhabitants of the planet including the animals and plants, we remain blinkered, missing a holistic perspective and our decisions may be severely flawed. True Sustainability ensues from balanced overall ecology, which comes from equitable and effective management of the flow of money energy across.

2.2. SOCIAL ASPECT:

“Man is a social animal”, we have learnt this since our childhood. But the need for companionship does not exist only amongst human beings; it is found in abundance in animal kingdom, and for those who are truly aware, it exists in the plant kingdom too!

We need each other for our existence, and therefore harmony, equity, physical, mental, emotional well-being, education and growth, equal opportunities, gender equality, clean living conditions, etc. they all form essentials of life and social harmony and balance. Inequality is one of the key causes of conflicts.

Dr. Håvard Mokleiv Nygård (2020), writes about what causes armed conflicts.

Research has shown that such identity group inequality is an important cause of armed conflict. This is especially the case when the relative position of identity groups is changed—for instance, if a group that has had access to political power is suddenly excluded from political participation. There is a significantly higher risk of conflict in states that exclude ethnic groups from political power when those groups have previously had the opportunity to participate in political processes.

Sensitive and integrated decision-making by those in positions of power, remaining focused on what society truly needs for its well-being, strengthens the social aspect of Sustainability.

2.3. ENVIRONMENTAL ASPECT:

Environment is essentially everything that surrounds any organism. For us as humans, the environment comprises other humans, various species of animals and plants, the five elements of nature, i.e., earth, water, fire, air, and space. For the animals and plants, we humans, other animals, plants, and elements of nature comprise the environment, and so on. In reference to Sustainability, we usually consider environment to be air, water, waste, pollution, etc. We generally see things from a human perspective, ignoring that our sustainability will depend on the sustainability of animals and plants too, and that our actions do impact their sustainability. Animals and plants are known to follow the laws of nature for their existence. It is imperative that humans who are endowed with the ability to think, create, and change, need to be aware of what constitutes ecological balance, the relationship between different organisms, the role played by each one, and what is needed for survival of various organisms, etc. Modifications in the name of growth and economic development, with scant knowledge and regard for ecology, is a perfect recipe for long term damage which may not be apparent immediately but progresses slowly and surely.

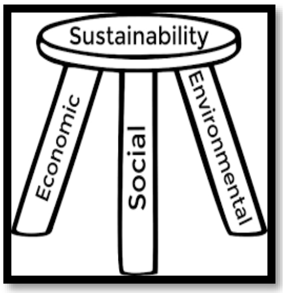
United Nations (2019), *The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Global Assessment Report on Biodiversity and Ecosystem*

Services brings to light some startling facts about harm caused to environment at the hands of humans.

- *Three-quarters of the land-based environment and about 66% of the marine environment have been significantly altered by human actions. On average these trends have been less severe or avoided in areas held or managed by Indigenous Peoples and Local Communities.*
- *More than a third of the world's land surface and nearly 75% of freshwater resources are now devoted to crop or livestock production.*
- *The value of agricultural crop production has increased by about 300% since 1970, raw timber harvest has risen by 45% and approximately 60 billion tons of renewable and non-renewable resources are now extracted globally every year – having nearly doubled since 1980.*
- *Land degradation has reduced the productivity of 23% of the global land surface, up to US$577 billion in annual global crops are at risk from pollinator loss and 100-300 million people are at increased risk of floods and hurricanes because of loss of coastal habitats and protection.*
- *In 2015, 33% of marine fish stocks were being harvested at unsustainable levels; 60% were maximally sustainably fished, with just 7% harvested at levels lower than what can be sustainably fished.*
- *Urban areas have more than doubled since 1992.*
- *Plastic pollution has increased tenfold since 1980, 300-400 million tons of heavy metals, solvents, toxic sludge and other wastes from industrial facilities are dumped annually into the world's waters, and fertilizers entering coastal ecosystems have produced more than 400 oceans 'dead zones', totaling more than 245,000 km2 (591-595) - a combined area greater than that of the United Kingdom.*
- *Negative trends in nature will continue to 2050 and beyond in all of the policy scenarios explored in the Report, except those that include transformative change – due to the projected impacts of increasing land-use change, exploitation of organisms and climate change, although with significant differences between regions.*

3. BALANCING AND INTEGRATING THE ASPECTS:

The three pillars that support Sustainability may be depicted by the simple model of a three-legged stool, where each one serves as one of the legs. Disproportion in the three legs will make the stool unstable and weak.



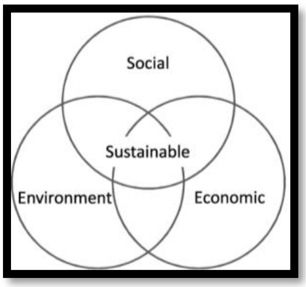


Figure 3

Irrespective of what we do, which walk of life we belong to, what business we may be in, our decisions and actions guided by a balanced approach to Economic, Social and Environmental aspects will only be able to promote true Sustainability.

Sustainability is often also depicted by a Venn Diagram of three circles representing the various aspects. Sustainability occurs at the Confluence of the three circles depicting Economic, Social and Environmental aspects of life on the planet. The closer the three circles move, indicating enhanced knowledge and awareness of the three aspects by an observer/decision maker, the sustainable area increases indicating possibility of long-term enhanced Sustainability.

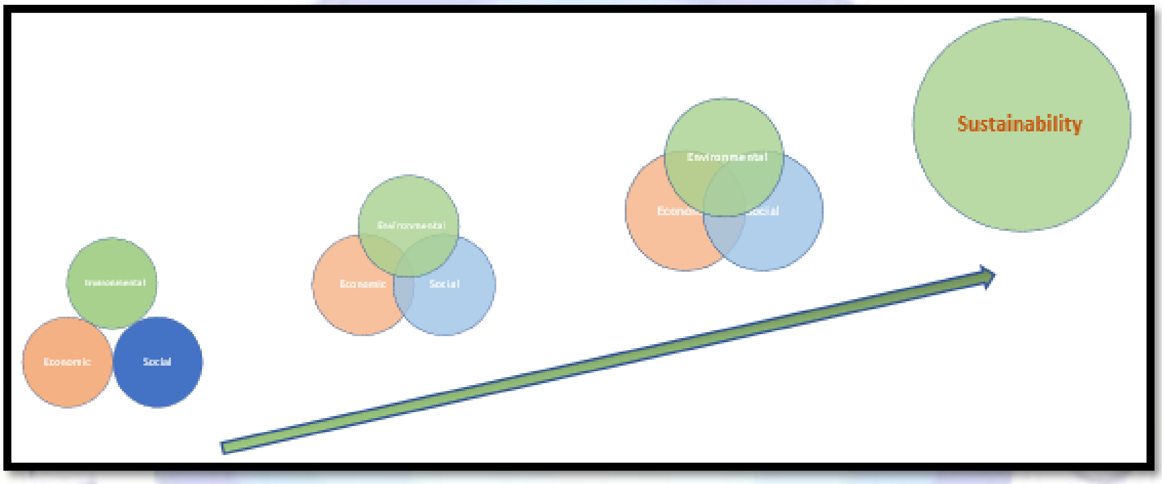


Figure 4

4. THE CORRECTIVE STEPS:

Problems cannot be solved with the same mindset that created them.

Albert Einstein

There is no doubt that with a superior ability to think and act, the responsibility of sustainability rests with us, the humans. Each one of us should be able to contribute to the extent our current capabilities permit and be prepared to progressively learn and become more aware for enhanced contribution.

This would demand breaking away from the set patterns of functioning and imbibing values and habits that support and promote sustainability; essentially changing our mind set, re-orientating our thinking process.

However, this may be easier said than done because we are products of our habit patterns - feeling habits, thinking habits, and doing habits. Breaking the mould would be challenging because our insecurities, ego inertia, and current affiliations may come in our way.

A conducive environment, and company of right mentors, guides, and co-seekers would however be able to initiate a positive change.

The contributory steps towards Sustainability that individuals can take entail:

1. Embark on transformation of personality – this is a continuous ongoing process and remains at the core.
2. Introspection before undertaking activities
3. Enhancing awareness on Ecology and Sustainability related to specific activities.
4. Taking decisions and performing actions with awareness
5. Assessing the impact of decisions and actions, expanding awareness, and refining further decisions and actions.

In simple terms these steps mean Practicing Conscious Living, where we break away from the mould of a set pattern and continuously evolve, practice constant situational awareness, or in other words Live in the Present!

Transformation of Personality remains at the heart of the process which involves the Human Mind, the finest instrument we are endowed with. All actions of ours are preceded by the thought process and the feelings which lie even deeper. Hence it becomes essential to sharpen this instrument and develop it. This does not just mean populating with more information, but to develop clairvoyance and discerning power to objectively choose from available options, a path which is conducive to Sustainability of self and the surroundings.

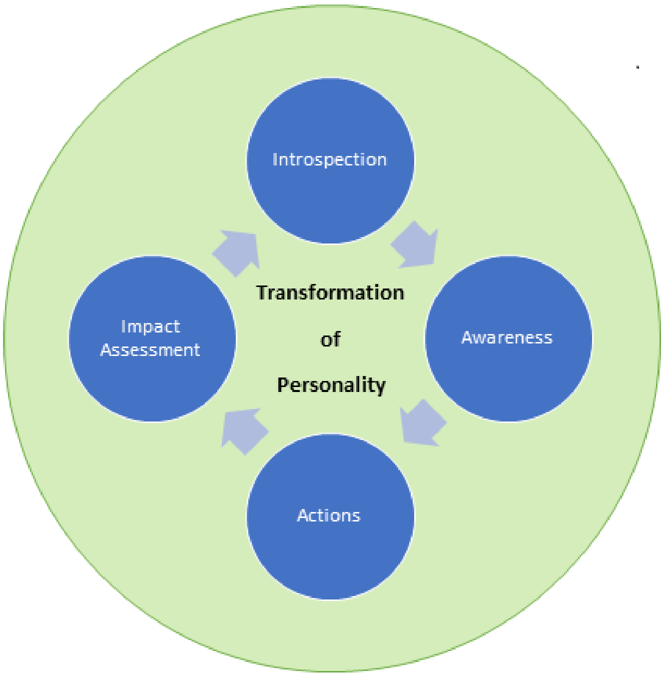


Figure 5

For transformation of human personality, there is no method or science as effective as practice of Yoga in its truest form which is the eight-fold path codified by Seer Patanjali in Yoga Sutras. Yoga supports progressive overall development of the physical, mental, emotional aspects and beyond. Meditation forms an essential part of the practice of Yoga and helps in calming the mind, sharpening the intellect, and freeing one of prejudices and biases.

Wanphen Sreshthaputra (2020), writes, "At the heart of the agenda of Sustainable Development Goals, is a comprehensive perspective on development and sustaining human life, based on an understanding that environment, economy and society are embedded, interdependent systems and not competing pillars, with the environment being the base that underpins all other goals.

One underlying message of the cross-cutting goals, the vision behind this inclusive and interconnected agenda, is also one of our shared humanity, indivisibility, interdependence, and interrelatedness. This implicit and essential message however might elude some in the development sphere.

As a yoga meditation practitioner since my teenage years, one missing link in my view is the immediate and living experience of our unity, in other words, the deep experience of the state of yoga, literally 'union' in Sanskrit, derived from the root 'yuj' 'to join' or 'yoke'.

A central element of the yogic philosophy, apart from enhancing the sense of oneness, unity (with your Self, the world and nature), is the understanding of one's interdependence with other humans within a fragile ecosystem, living as an integral part of a larger circle of life, in a harmonious co-existence and symbiotic relationship with the environment."

While facilitating an elevation and expansion of one's consciousness, removing artificial barriers and enhancing positive psychology, the yogic system of thought encourages respect for the ecological balance and deepens environmental consciousness, promoting inner peace and contentment.

As the Mind starts to develop through practice of Yoga and Meditation, the process of Introspection too becomes refined and objective. What follows is expansion of personality, development of inclusiveness and empathy, all essential for promoting Sustainability.

5. CONCLUSION:

Currently phenomenal amount of work is happening globally in the direction of Sustainability and Sustainable Development Goals. However, despite the program being in its 6th year since 2015, has made limited impact on the overall scenario. The UN report on SDGs 2020 states:

United Nation (2020), SDG Report Member States recognized at the SDG Summit held last September, global efforts to date have been insufficient to deliver the change we need, *jeopardizing the agenda's promise to current and future generations. The Sustainable Development Goals Report 2020 brings together the latest data to show us that, before the COVID-19 pandemic, progress remained uneven and we were not on track to meet the Goals by 2030. Some gains were visible: the share of children and youth out of school had fallen; the incidence of many communicable diseases was in decline; access to safely managed drinking water had improved; and women's representation in leadership roles was increasing. At the same time, the number of people suffering from food insecurity was on the rise, the natural environment continued to deteriorate at an alarming rate, and dramatic levels of inequality persisted in all regions. Change was still not happening at the speed or scale required.*

While global concentrated endeavors will hopefully bring about the desired improvements, realization and efforts must trickle down to the individual levels for sustained effectiveness. For a long-term sustainable impact, we need to address the human mind, through comprehensive education and training, and redesigning the modern societies using the regenerative principles as expounded by Daniel Christian Wahl. Yes, this would be challenging, but then, it is the need of the hour. We do it now or never!

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He is a certified trainer. Besides teaching marine engineering subjects, his experience of developing and running organizations, and interacting closely with management gurus of the well-known IIM Ahmedabad, has provided him with the expertise in training in management and human resource areas too. Through various human resource and management programs in maritime and offshore sector, he has trained close to 2000 people till date. These include professionals with seafaring as well as non-seafaring backgrounds. He also continues to guide engineers for developing their competence and conducts several value additions programs for deck and engineering staff. He is a lead auditor of ISO systems and has been consulting companies in development and restructuring of their systems to meet customer and internal requirements.

Dr. Poonam Kapoor has completed a Ph.D. in Economics from university of Mumbai; her study focused on International Trade in Services with special focus on Maritime Transport Services. Dr. Kapoor is also a professional counsellor and has worked extensively with children, young adults, professionals, and helped them overcome their physical, mental, attitudinal, and emotional problems.

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