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# A SYSTEM DYNAMICS FRAMEWORK TO OVERCOME THE SHORTCOMINGS OF TRADITIONAL METHODS OF RISK MANAGEMENT TO ADDRESS THE IMPACT OF HUMAN FACTORS ON PROJECT RISK MANAGEMENT

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**ABSTRACT**

Human Factors has been studied by various researchers with respect to human-human & human-machine interactions. It is studied from the perspective of human resource management, risk due to human error, safety, ergonomics and crucial role of project manager in the area of project management. However, a focused research on the impact of human factors on project risk management has been limited. This article presents the limitations of traditional methods of risk management to address the human factors impact on project risk management and how a System Dynamics approach can bridge this gap.

***Keywords:*** *Human Factors, Risk Management, Project Management, System Dynamics.*

## Introduction

The uncertainties due to the COVID-19 pandemic has given a new dimension to the complexity in projects. (Dean Rickles, 2007) explains the various types of systems and (John, Complexity Risk and Modeling Disorder, 2017) illustrates how they become chaotic and early warning system can help recover them. While crisis management will be a norm in the coming days & slowly get integrated in project risk management, automation and digital transformation will influence how projects are executed. This will bring emphasis on human factors and human–machine interactions. As the human factors gain importance in this sector, the crucial elements of trust amongst human relations and trust on technology will become an important and crucial area. Various researchers have studied, the role of project manager, competency of team members, motivation etc. as critical success factors in a project. Furthermore, researchers have also studied criticality of schedule, cost and quality for project performance and therefore its success. While risk management is widely used in financial markets and stocks, its application in companies are limited to compliances. The awareness in Risk management has increased with the bankruptcy and insolvency of many construction companies. As disaster management is becoming crucial with impact of corona virus, the Yes Bank and ILFS collapse, the fields of disaster and risk management are converging. A system dynamics approach is useful to capture the large complex subject and to make sense out of it. The ISO31000 is a risk management guideline and ISO 9001 and 14001 are all risk based thinking guidelines. The subject of research is very important and relevant to today's project management and business community.

The globalized world brings in challenges and risks unseen by business in the past..The corona virus disrupted the entire world economy sending a shockwave throughout the financial world. In such a world, a crisis management system is of utmost important. Mitroff model for crisis management initiated a scientific approach and much research is being done applying the diamond model of scientific analysis. In project management, risk management is a crucial element but not integrated into the project management processes in most projects. This paper is a literature survey of the possible risk management methods applied in theory and industry. Project finances play a key role in success of a project and these depend on the project leader and project team how the attract and manage the finance. Human factors research will be critical from this perspective in the coming days. Weelaborate the various

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types of contracts, the risks they contain for contractors and how human factors play an important role in this sector. The traditional methods of risk management are elaborated and the paper discusses how the shortcomings can be addressed with a system dynamics approach.

**Literature Review**

**(Yuri, Project Risk management- Popular facllacies and overlooked practices, 2017)** Introduces classes of fallacies inside standards of Project Risk Management (PRM) and practices to displace fallacies, gaps in PRM assessment. The author introduces 32 risk objects, best practices in PRM and ways to adopt correct methods, the psychological and organizational bias (Hidden Agends - Principal -Agent Theory, "Anchoring" ,Concious and Unconcious bias) which can effect decisions by project managers in Risk Assessment. (Swin, Improving Objectivity in Project Risk Management (PRM), 2017)uses fuzzy logic to assesses Risk Factors like: Expert diversification, risk culture, process mining, human biases reasons, Personal factors. (Hallowman, Systemic Risk and Parametric Modelling, 2017)illustrates concept of system risks in complex projects, project specific and systemic risks and how to handle them. The human factors constituting these two types.Systemic risks- State of team development- including business leadership, bias in estimates. Team development and IPA is critical and correlated to cost and schedule performance. Project Dicotomy of order and disorder is explained. (Corpoley, The case of for Truly integrated Cost and Scheule Risk Analysis, 2017)suggests shortcomings of prevalent risk management approaches and favors an Integrated schedule and cost risk management. (Townley, Modeling risk and opportunity reality, 2017)provides various alternatives to model risk. (Raydugin, Integrate risk based and project baed methodology for selection of project, 2017)provides risk based method to choose projects. (Thamhain, Managing Risks in Complex Projects, 2013)explains various ways to manage risks in complex projects. (Agarwal, Monte Carlo Risk Analysis, 2017) introduces Monte Carlo simulations for risk management (Malik, 2017) elaborates how MCS can aid assessing contingency estimates. (Nasirzadeh et al., 2013)provides a fuzzy logic approach to risk management. (Agarwal, Integration of Project Risk Management into Enterprise Risk Management, 2017)argues to integrate PRM to ERM. (Plumery, Risk centric performance messurement, 2017)provides speedy and forensic based project performance drawbacks and presents a risk centric approach. (Michale, A holistic multicriteria decision making and risk analysis method for CCS and GHS, 2017) a case study explaining complex decision making (Townley, Modeling risk and opportunity reality, 2017) illustrates various models to risk management.(Kreydieh, 1996) explains through a case study the financing risks in BOT projects. (Kahneman & Tversky, 2012)prospect theory introduces the outside view and how it can remove biases.(Zwikael & Smyrk, 2015) that trust of the project owner in the project manager is more effective in a turbulent environment, whereas more control by the project owner of the project management process is a superior management approach in a more stable project setting. Finally, a project governance model is introduced and the management role of the project owner is discussed. (Organ & Stapleton, 2017)outlines a study to address human factors in systemic financial systems providing a view to relationship between human and tech, functionalist, interpretive, radical humanist and radical structuralist world view. (Kahneman 1934- author, n.d.; Kannengiesser & Gero, 2019) provide an explanation of the prospect theory and a framework to apply the same. (Kahneman & Lovallo, 1993) explains how human psychological bias from overconfidence errs decision making. (Flyvbjerg, 2006) highlights inaccuracy and forecast risk in Project managers, optimism bias and strategic misinterpretation. (Flyvbjerg, 2009) & (Flyvbjerg et al., 2009) illustrates how biases decisions and principal-agent theory plays in large infrastructure projects. To resolve by reference class forecasting, an outside view de-biasing technique that has proven successful in overcoming both delusion and deception in private and public investment decisions is shown. (Flyvbjerg & Budzier, 2011) illustrates the risks in IT projects and the myths and dangers. (Nachbagauer & Schirl-Boeck, 2018) conclude that ideal types for managing the unexpected in projects are built based on resilience research and Human Factors research. While humans are possible sources of error, they are at the same time the most valuable resource to manage the unexpected successfully.(Andreas G.M. Nachbagauer, 2018) develop a useful framework combining the social dimension comprises the project manager, the project team and the project-oriented organization and the time-related dimension.(Marshall & Ceylan, 2019) illustrate how to obtain risk intelligence. (Giezen, 2012) studies a metro project in Rotterdam and lessons on how to reduce complexity.(Caulfield & Maj, 2001) explain benefits of SD to prove the Fred Brook's Law to capture the complexity of human interactions.(Hussein et al., 2019)human trust model under speed and accuracy. (Boateng et al., 2012)describe STEEP risks with a system dynamics model and their interactions in megaproject development and concluded the inefficiency of prevalent methods to assess risk.

**(Prakash Prabhakar, 2009)** research on Effective communication, engagement, flexibility and adaptability, preference for significant initiative and leadership, aggressiveness, confidence, persuasiveness, verbal fluency, ambition, activity, forcefulness, effectiveness as a communicator and integrator, broad scope of personal interests, poise, enthusiasm, imagination, spontaneity, able to balance technical solutions with time, cost, and human factors, well organized and disciplined, a generalist rather than a specialist, able and willing to devote most of his or her time to planning and controlling, able to identify problems, willing to make decisions, able to maintain a proper balance in use of time. (Korsakiene et al., 2020) the study revealed that communication and trust affect other human-related factor. (Hussein et al., 2019) trust as a human factor in human and human machine interaction.(Borsci et al., 2019) human machine trust and human factors in healthcare. Trust towards system concept (TTS).(Thompson, 2018) stress as a human factor. (Morris et al., 2010) Stress as a human factor. (Kadefors, 2004) factors that influence development of trust and co-operation in client–contractor relationships in construction projects. (Strahorn et al., 2017) Human Variables-Relationship, trust, project management, relationship interaction and trust, initial intent of stakeholder, Attribution Variables- Trust worthiness, reliable behaviour, communciation, competence, benevolence, integrity, honesty contextual variables- risk vulnerability and uncertainty, control mechanism, positive team environment, trust & project outscomes, trust and temporal nature of project. Trust failure- trust breakdown, trust repair, trustworthiness factor, social explanations, apology or denial, competency or integrity trust violation, apology and internal and external attributes, reticence. (Tejpal et al., 2013)complex multi-dimensional construct of supply chain partner's relationship and (Tejpal et al., 2013) factor analysis. (Sasu, 2018)Self awareness, (Love et al., 2009)innovator, (Costigan, R., Iiter, S., & Berman, n.d.)risk taking, assertiveness and motivation, (Moshood et al., 2020)emotional intelligence, educational background, safety, professional competency.(Alias et al., 2014)Human factors considered-Human-related factors involve client's experience, nature of client, size of client's organization, client's emphasis on low construction cost/ high quality of construction/ quick construction, and client's ability to brief including to make decision; to define roles; contribution to design; contribution and support from senior management ,Skilled designers, skilled project manager ,Troubleshooting, project team motivation, Commitment of all project participants ,Strong/detailed plan effort in design and construction ,Adequate communication channels ,Effective feedback, (Dul & Neumann, 2007)ergonomics in strategy and risk.(Francis et al., 2008)Project management and reputation of PM. (Zadeh et al., 2017)Cooperation and (Hsieh et al., 2020)goodwill, (Flyvbjerg et al., 2009)deception, (Flyvbjerg, 2006) inaccuracy and forecast risk in Pm, optimism bias and strategic misinterpretation.(Poster, 2013) Emotions, (Zwikael & Smyrk, 2015) control and trust.

**Project Contracts**

The various types of contracts are as follows:

- Turnkey contracts
- EPC contract
- Item rate contracts
- Cost-Plus contracts
- Build Own Operate
- Build operate transfer
- Public Private Partnership etc.

Depending on the type of contract the risk types vary. The risk is distributed between customer and contractor. We briefly explain these below:

- **Turnkey Contract:** The client will provide his requirement of plant he wants and will ask the contractor to take all responsibility. The concept is like the plant will be operative "by turn of a key" by the client. In such contracts the contractor takes all risks upon himself and may charge a premium for that. These are fixed price contracts and agreed before the contract award.
- EPC contract is similar in risk to the Turnkey contract but may have a price variation or escalation clause built in. EPC stands foe engineering, procurement and commissioning. Since in turnkey contracts time delay may have huge capital investment implications, the clients monitor and control such projects and prefer to go for EPC mode in such cases.
- **Item Rate Contracts:** These contracts are where design engineering is undertaken by the client and billof quantities are prepared by them. Through a competitive bidding, rates for various items areascertained by the client. Here the quantity variation risk lies with client. All other risks are handledby contractor.

- **Cost Plus Contract:** In these contracts, the client and contractor agree for a % mark up over the project cost. Here the client should be knowledgeable about the project costs and monitor the same. Design engineering may or may not be in contractor scope.
- **Build - Own-Operate:** These contracts call for the contractor to invest his own money to build theplant, Own the plant and operate it for a specified time. Here the government sells the rights to aprivate concern to carry out the entire project under said specifications.
- **Build –Own-Operate- Transfer:** In these contracts the private party has to arrange his own finance,construct the plant, own the plant, operate it for a said period and then transfer it to the client.
- **Build –-Operate- Transfer:** Similar to the Build Own Operate Transfer but the private party doesn'town the plant and then transfers it to the client. Here the cost of building plant and operating it maybe provided by client.
- **Public Private Partnership:** Both government and private companies share the cost of finance forbuilding the plants and then share the profits generated from operations. Here both CAPEX andOPEX models are possible and project risk lies with both client and contractor.

We can classify these contracts as per risk levels for the contractor in the descending order as:

**BOOT >BOO >PPP > BOT >Trunkey >EPC> Item rate>Cost-Plus**

Due to the conflict of interest in handling risks for each other, human relations and contract formation play a great role in project management in these contract types. Present reserch shows that contract management is very crucial to ascertain the way human relations are maintained. In practice though, contractors believe it is best till you touch the contract. The reason for such a view is because you touch the contract to establish a claim or settle a dispute, which they want to take as the last resort.

**Risk Management Methods**

- **Qualitative**

Various qualitative and quantitative techniques of risk management have been used in project management and construction projects. In the literature (CIOCA, 2011) describes the qualitative methods and a working paper by (GALWAY, 2004) and (Dale F. Cooper, 2005). Cause & Effect Analysis: In the qualitative risk analysis, we first identify the risks and to assess them assign the probability of occurrence and impact of the risk. Further for the analysis to be done, we assign description risk and risk triggers for these identified risks. The various methods are: Fish-Bone Diagram,Fault- Tree Analysis, Failure Mode and effect Analysis (FMEA), Risk Classification matrix: Here the risk level is given by Risk= probability of occurrence x impact of risk. (CIOCA, 2011) compares these methods according to an aircraft project management case with consideration of Consistency, Applicability,Design, Ability to use in a dynamic scenario and Utility and concludes that FMEA is the best of all such methods.

- **Quantitative**

Many quantitative techniques are available, we will elaborate the mostly used techniques in project risk management. (MJ Thaheem, 2012) elaborates 16 techniques in which the quantitative techniques are Bayesian Method, Belief Function Method, Decision Tree Analysis, EMV ( Expected Monetary Value), Monte Carlo Simulations , PERT ( Program evaluation and review technique), Scenario Analysis ,Sensitivity Analysis,Fuzzy Logic and AHP (Analytical Hierarchy Process).

- **Shortcoming of traditional methods in Project Risk Management to address human factors**

Most of the methods in qualitative and quantitative analysis mentioned above aim to capture, the quantum of risk and the probability of occurrence of the risk. Some also address the cause andeffect element of the risk. However, most of the qualitative methods are threat control mechanisms like Failure Mode and effect Analysis, Fault- Tree Analysis,Bayesian, Belief network, EMV &though most of them take a cause effect perspective, they fail to capture the dynamic nature in the uncertain future. Primarily static approaches theyare like snapshots of possible futures. For e.g. the RMM (risk matrix method) gives the degree of risk impact and a probability of occurrence, but the dynamic aspect is lacking. Just like the balance sheet is a snapshot of business health on a particular date but understand the company's actual position we have to supplement this with the P&L and cash flow statements, similarly we need a similar method for risk management. Furthermore, even on the balance sheet we lack the human capital element for which a balance score card is suggested.

- **System dynamics and how it can address the human factors impact in project risk management**

The Balance score card technique presents a strategic planning system by which 4 perspective including soft skills and human factors can be studied. A dynamic balanced scorecard presents a method to overcome shortcomings of a balanced scorecard applying system dynamics method. Similarly in risk management, delays in activities may lead to lags, such time delay remains unaddressed by traditional methods and a dynamic balanced score card for a project will present a solution.These methods ignore the intangible and human factors like competence, training needs, relationship with client and suppliers etc. Though the resource based view factors the resource cost and needs, it fails to account for the change in these factors and when should be changed. This is usually achieved through experience of the project managers. The system dynamics on the other hand takes a holistic view of the project management cycle and its primary objective is to capture the feedback processes.

(Sarojkant Singh, 2021) presents a method of dynamic balanced scorecard to apply to the health sector. The authors illustrate how drawbacks of a balanced score card is overcome by a Dynamic balanced score card. (Singh S. , 2021) present the various aspects of system dynamics and how it can be used to develop a model in system dynamics to capture the intangible values in the value chain.

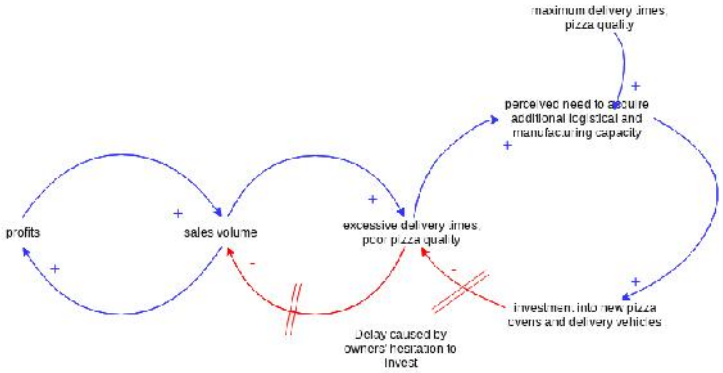


**Figure 1: Source: https://warren2lynch.medium.com/system-thing-with-casual-loop-diagram-learn-by-examples-61dabdc4cdd**

We briefly explain a system dynamics model. A system dynamics model uses stock and flow diagrams and causal loops.

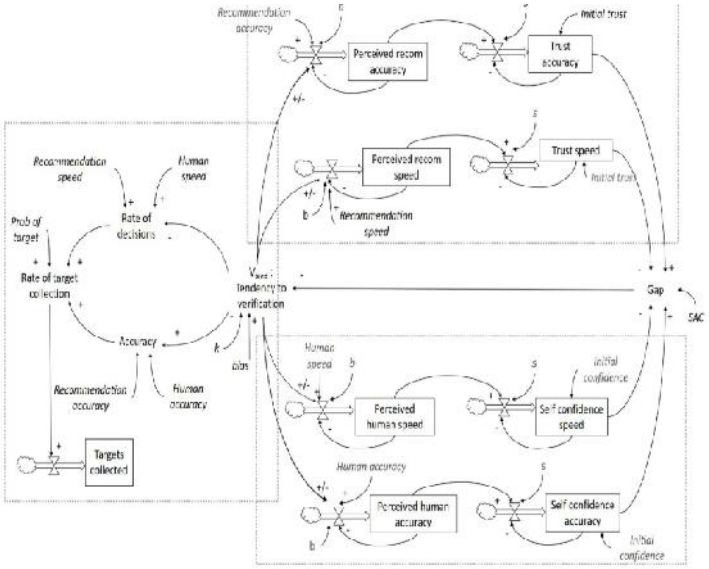


**Figure 2: Source : Hussein et al. 2019**

- **Casual Loops (CLD):** A causal loop diagram (CLD) is a visualization (fig1) of different variables in a system and their interrelation. It consists of a node & edge for eg in the diagram see profits & sales volume. Here, profit and sales volumes are nodes and the edge links them. The +ve sign indicates that increase in profit will lead to increase in sales.
- **Stock and Flow Diagram:** Stock variables are measured at a point in time. For example: the number of Covid-19 cases in Dec-2020. Number for errors made in inspections in Mar-2021. Flow variables are measured over a time interval. For example: Increase in competency of project team between Jan-2021 and May-2021 or Attrition of employees in FY 2020.

The power of the causal loop and stock and flow enable to capture the dynamic nature of human factors and thus their impact on project risk management. (Hussein et al., 2019) presents the following model.They explain how human rely on automated system for speed and accuracy (SAC) through this model. It shows nodes like Accuracy, human speed, tendency of verifications and flow variables like perceived recommended accuracy, trust accuracy etc. to conclude how the human trust plays a role in human reliance on automation.We propose a similar approach to study the human factors studied in literature.

For e.g. if we take project manager leadership style as a human factor variable, we take this as a node and develop a pace of execution of project, profit etc. as flow variables. As an illustration we give this in below diagram:

The open loop shows how autocratic leadership impacts profitsnegatively and creates a negative reinforcement loop to decrease profits. A system dynamics simulation for the whole project dynamics would lead to insights on how the leadership style effects profits. A similar scenario may be drawn for an affiliative leadership style which encourages collaboration and thus impacting profits positively. A decision making could thus take place which style to adopt. The illustration being only part of the whole system dynamics loop structure for the project, does not capture other benefits the specific leadershipapproach could bring. For e.g. timely completion with autocratic style could decrease costs and thus avoid penalties. The other traditional methodssuffer from limitation toprovide such anoverview for human factors. We have referred to a dynamic balance score card framework and how it can be utilized to balance soft and financial aspects of a business, a similar method can be adopted for projects thus establishing a holistic approach.

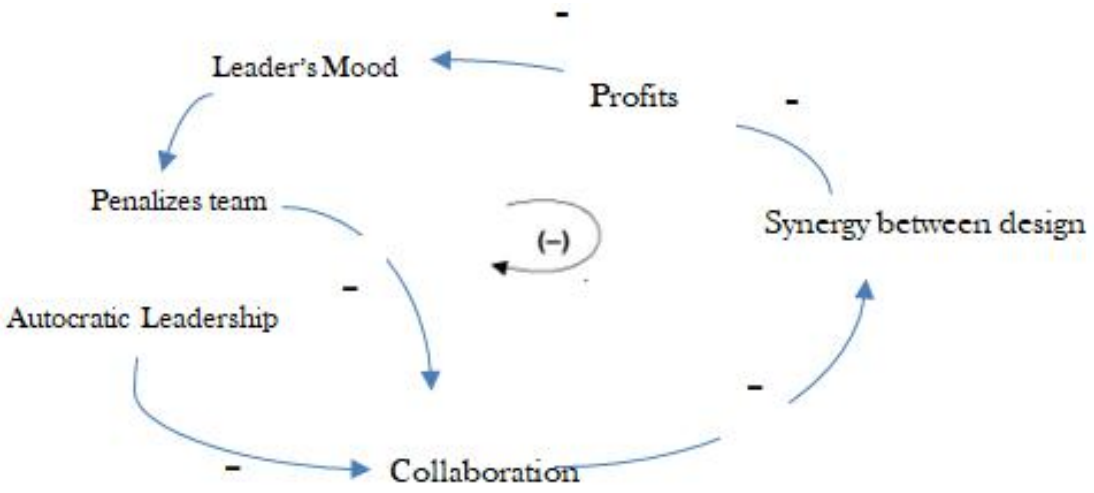


Figure 4: Causal Loop Illustration for human factor leadership style

**Limitations of research and further scope of research**

The present research limits itself to establish the framework to overcome the gap to study impact of human factors on project risk management. It also does not apply the impact on various types of contracts illustrated to establish the impact of human relations between contractor and client in projects. Further research may be carried out in this area to understand the impact of human factors specially trust on project risk management.

**Concluding Remarks**

The article shows that present researches in project risk management have a gap in addressing human factors in project risk management. The major reason is the inability to capture of intangible nature of human factors and dynamic aspect of the dynamic aspect of the impact of these factors. Due to static nature of the qualitative and quantitative methods of risk management presently prevalent in practice, the impact of such factors cannot be captured successfully. Further, there may be lag between the incidence of the impact and its outcome, which cannot be accessed with traditional methods. With a causal loop diagram and stock flow simulation these hurdles can be overcome with a system dynamics approach. Furthermore, as illustrated, a dynamic balance score card may be applied to the project to understand the impact of such factors on risk and thus financial factors of the project.

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