

# **Applying Social Network Analysis to Monitor Risk in Project Management**

**VERSÃO FINAL APÓS DEFESA**

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# Abstract

In today's business environment it is often argued that if organizations want to achieve sustainable competitive advantages or even just survive, they must excel in performance and innovation to meet complex and unpredictable market demands.

Often organizations alone do not always have the necessary resources such as brilliant minds, technologies, know-how, financial support, just to name a few, to properly respond to such market demands. To overcome such constraints organizations usually engage in collaborative working models (such as open innovation (Chesbrough, 2003)), which essentially consist in strategic partnerships with other entities such as other business partners, public institutions, universities, and development centers, just to name a few, whereby the collaborative exchange of resources and capabilities enables achieving their objectives in a faster and more efficient way.

However, it is often argued that the lack of effective models to support collaborative initiatives is the biggest obstacle for organizations to engage in a higher frequency in collaborative working models.

In project management, one of the biggest challenges that organizations face today as they deliver projects is to distinguish project critical success factors from project critical failure factors regarding how project stakeholders collaborate across the different phases of a project lifecycle. This challenge has been a growing concern particularly in organizations that deliver projects, essentially due to the potential high impact (both, negative and positive) in economic, environmental, and social dimensions. More concretely, this challenge is essentially related to how the dynamic interactions between the different project stakeholders - characterized by the mix of formal and informal networks of relationships that emerge and evolve across the different phases of a project lifecycle, and how these may or not impact project outcomes (success or failure).

In this work a heuristic two-part model to address the mentioned challenge is proposed. The development of the proposed model is supported by three distinct but interrelated scientific fields. They are: (1) project management - which contributes with the definitions and structure of a project lifecycle, (2) risk management - which contributes with the standard risk management process framework, and (3) social network analysis - which

provides the tools & techniques to identify and quantify the collaborative interactions between entities throughout a project lifecycle. The proposed model was developed to identify and quantitatively measure the extent to which such project participant's dynamic interactions (also called as dynamic behaviors), influence project outcomes (usually classified as successfully or unsuccessfully delivered).

The proposed model in this work named POL Model (which stands for the Project Outcome Likelihood model), has two parts. In part one the proposed model will analyze five key project collaboration types ((1) Communication and Insight, (2) Internal and Cross Boundaries-Collaboration, (3) Know-how sharing and Power, (4) Clustering (variability effect—*PSNVar*), and (5) Teamwork efficiency) that emerge and evolve in each project phase of a given project lifecycle, by accessing, analyzing and interpreting project data-related collected in three different sources ((1) project meetings, (2) project emails, and (3) through the application of a SNA-based survey) from successfully and unsuccessfully delivered projects.

The model will search in both successfully and unsuccessfully delivered projects for unique repeatable behavioral patterns (RBPs) regarding each one of the five key project collaboration types. If the model identifies different RBPs in projects that were successfully delivered from those that were unsuccessfully delivered, such RBPs are classified as critical success factors (CSFs). If not, then no CSFs are identified. If the latter outcome is the case, then, according to the proposed model in this work, collaborative projects outcomes (successful or unsuccessful) are not influenced by the dynamic interactions of project participants that emerge and evolve across the different phases of a given project lifecycle.

Once part 1 of the POL model is concluded, and if CSFs have been found, then part two can initiate. In part two the POL model will provide guidance to an ongoing or upcoming project by analyzing the deviation between an actual project evolution (*actual state*), and the CSFs identified in part 1 regarding each one of the already mentioned five key project collaboration types.

## **Key Words**

Risk Management; Project Management; Risk Management in Project Management; Risk Management Tools & Techniques; Social Network Analysis; Critical Success Factors; Graph Theory; Predictive Models; Social Network Analysis Centrality Measures; Project Key Players; Project Life Cycle; Project Outcome Likelihood Estimation, Project Success Outcome, Project Failure Outcome.



# Resumo

No atual ambiente económico e social, é muitas vezes afirmado que se as organizações pretendem alcançar vantagens competitivas sustentáveis ou simplesmente sobreviver, elas têm de ser capazes de atingir elevados níveis de performance e inovação. No entanto, a maioria das organizações, por si só, nem sempre têm as capacidades necessárias e suficientes para eficazmente responder às crescentes atuais e futuras necessidades dos mercados. Tais capacidades como, mentes brilhantes, tecnologias de ponta, acesso a informação mais restrita e vital, conhecimento adquirido, experiência em várias dimensões, entre outras, normalmente só estão ao alcance de algumas organizações.

Para tentarem ultrapassar este obstáculo, as organizações que por si só não dispõem ou não consegue adquirir as tais capacidades necessárias e suficientes para eficazmente responder às tais exigências por parte do ecossistema dos mercados, procuram encontrar soluções por outras formas. Uma das formas que ao longo dos últimos anos tem tido uma crescente procura consiste essencialmente em partilhar recursos e capacidades através do estabelecimento de parcerias estratégicas com outras organizações, tais como universidades, institutos, parceiros de negócio, ou mesmo concorrentes diretos e indiretos. Estas tais parcerias estratégicas são essencialmente denominadas de modelos organizacionais colaborativos que permitem às organizações participantes obter benefícios que de uma forma individual nunca conseguiriam atingir (Camarinha-Matos, & Afsarmanesh, 2006; Arana & Castellano, 2010).

Um modelo que se tornou muito popular nos últimos anos, é o modelo de inovação aberta (*Open Innovation*, ou simplesmente *OI*) proposto por Chesbrough, (2003). Chesbrough defende que para que as organizações consigam atingir resultados mais positivos e mais rápidos estas deveriam optar por trabalharem em conjunto (colaborarem) no desenvolvimento e comercialização de ideias e inovações, tendo por base essencial, a troca supervisionada de informação, ideias, recursos (materiais e imateriais) entre as organizações participantes.

E de referir ainda que este modelo de colaboração que potencialmente trás consideráveis benefícios ás organizações tais como a partilha de riscos e oportunidades, um acelerado *time-to-market* de produtos e serviços desenvolvidos, otimização ou criação de produtos e serviços a um preço muito mais baixo, entre muitos outros, é contrário ao modelo que ainda é tradicionalmente adotado pela maioria das organizações que assenta essencialmente num processo de inovação fechada em que as organizações não partilham recursos e capacidades no processo de desenvolvimento e comercialização de ideias e inovações. No entanto, a realidade mostra que não só potenciais benefícios resultam dessas parcerias estratégicas. De acordo com literatura consultada, de um modo geral, são muitas as organizações, que ainda têm receio de optar por estes modelos de parcerias estratégicas que envolvem a partilha ativa e supervisionada de informação, ideias, e recursos, essencialmente devido á falta de modelos que permitam uma eficiente gestão das diferentes dinâmicas colaborativas que existem dentro, e entre diferentes organizações (Santos et al., 2019; Nunes & Abreu, 2020(a); Nunes & Abreu, 2020 (b)). Este aspeto, de acordo com a literatura consultada, tem ainda mais peso na limitação da entrada das organizações em modelos colaborativos como o Open Innovation, do que propriamente aspetos técnicos (Deichmann et al., 2017).

De acordo com varia literatura consultada um dos maiores desafios que as organizações atualmente enfrentam, é a capacidade de identificar fatores críticos relacionadas com a colaboração que levam projetos e operações a ter um desfecho com sucesso (Workday studios, 2018; Arena, 2018; Nunes & Abreu, 2020(c); Nunes & Abreu, 2020). Na verdade, esta preocupação tem crescido exponencialmente ao longo dos últimos anos essencialmente devido á crescente perceção dos elevado impactos (negativos e positivos) que este fator projeta no seio das organizações. No entanto, embora este tema está ainda muito pouco explorado, em gestão de projetos, cada vez mais cresce o interesse de perceber a relação entre o sucesso e o insucesso de projetos com as diferentes interações dinâmicas que emergem e evoluem entre pessoas, grupos, departamentos e organizações que executam projetos (Santos et al., 2019; Nunes & Abreu, 2020(a); Nunes & Abreu, 2020 (b)).

Dada a importância deste aspeto, é proposto neste trabalho um modelo que tem como principal objetivo contribuir para a identificação de fatores críticos de sucesso relativos á gestão das interações dinâmicas entre organizações em ambientes de projetos.

Neste trabalho é apresentado um modelo heurístico composto de duas partes (parte 1 e parte 2), onde o seu desenvolvimento foi apoiado em três áreas científicas ((1) gestão de projetos, (2) gestão do risco, e (3) análise de redes sociais) e que tem como principal objetivo a identificação da importância (de uma forma mensurável) das diferentes interações dinâmicas entre pessoas que trabalham num ambiente de projetos no desfecho desses mesmos projetos.

Cada uma das áreas científicas acima mencionadas contribui de forma única para o modelo proposto neste trabalho. A área científica de gestão de projetos (1), contribui para o modelo proposto neste trabalho com as definições e estrutura de um projeto, onde inclui as definições de projeto, gestão de projeto, fases de um projeto, ciclo de vida de um projeto, entre outras. A área científica de gestão do risco (2), contribui para o modelo proposto neste trabalho com as definições de risco, e gestão de risco, e com os processos e estrutura de análise mais utilizados na identificação, tratamento e controle do risco. Finalmente, a área científica de análise de redes sociais (3), contribui para o modelo proposto neste trabalho com as definições e características de rede social, capital social, redes colaborativas, e ainda com as ferramentas e técnicas de análise para quantitativamente medir as interações dinâmicas entre pessoas, grupos, departamentos de uma dada organização, ou mesmo entre organizações diferentes que colaboram na execução de projetos.

O modelo proposto neste trabalho de nome POL Model (*project outcome likelihood*), tem duas partes – parte 1 e parte 2. Na primeira parte o modelo vai analisar cinco tipos dinâmicas chave que emergem e se desenvolvem numa dada rede social de um projeto ao longo das diferentes fases do ciclo de vida de um projeto. Estes cinco tipos chave de dinâmicas são: (1) comunicação, (2) intra e intercolaboração organizacional, (3) partilha de conhecimento e poder, (4) variabilidade de participação ativa em reuniões de projetos, e (5) eficiência do trabalho em equipa.

Para analisar os cinco tipos de dinâmicas chave, o modelo proposto neste trabalho vai utilizar informação recolhida em reuniões de projetos, emails que contenham informação relacionada com tarefas e atividades de projetos, e questionários estrageiros endereçados aos elementos que participam num dado projeto.

Uma vez recolhida toda a informação necessária o modelo vai aplicar um serie de técnicas e ferramentas desenvolvidas com base na área científica da análise de redes sociais

identificar padrões de comportamento de uma forma quantitativa, associados a projetos que tiveram um desfecho com sucesso, e associados a projetos que tiveram um desfecho sem sucesso, relativamente aos cinco tipos genéricos de colaboração dinâmica acima mencionados. Estas técnicas e ferramentas consistem essencialmente em métricas que medem a centralidade de uma rede social apoiadas na teoria dos grafos (matemática discreta).

Se os resultados da aplicação do modelo mostrarem evidentes diferentes padrões de comportamentos relativos as cinco dinâmicas chave de projetos em projetos que tiveram um desfecho com sucesso, de projetos que tiveram um desfecho sem sucesso, conclui-se que foram encontrados fatores críticos de sucesso. Uma vez terminada a parte 1 do modelo, e se fatores críticos foram encontrados, pode-se iniciar a parte 2 do modelo POL. Se por outro lado não foram encontrados fatores críticos, então a segunda parte do modelo não pode ser executada.

Na segunda parte (parte 2), o modelo POL essencialmente vai monitorizar o quanto um projeto que esteja em execução está ou não desalinhado com os fatores críticos identificados na parte 1. Na segunda o modelo vai primeiro efetuar uma análise aos cinco tipos chave de colaboração dinâmica ((1) comunicação, (2) intra e intercolaboração organizacional (3) know-how, partilha de informação e poder, (4) variabilidade de participação ativa em reuniões de projetos, e (5) eficiência do trabalho em equipa) de um projeto que esteja a *atualmente* decorrer e comparar os resultados obtidos com os fatores críticos identificados na parte 1 do modelo. Por fim em função da quantidade de fatores (métricas) que estejam ou não alinhados com os fatores críticos de sucesso, o modelo calcula uma probabilidade de desfecho (sucesso ou insucesso) do projeto que está a ser executado.

Para efeitos da ilustração do funcionamento, aplicação e validação do modelo proposto neste trabalho, é apresentado no capítulo 6 deste trabalho um caso de estudo de uma real aplicação do modelo POL na execução de um projeto com a participação de várias pessoas com diferentes competências, ao longo de uma específica fase de um projeto colaborativo. Ao longo do capítulo 6 é possível observar que o modelo proposto neste trabalho identifica de uma forma simples e eficiente diferentes padrões de comportamento existentes em redes colaborativas, o que permite às organizações correlacionar resultados obtidos da aplicação do modelo, com os diferentes desfechos de projetos (sucesso ou insucesso) e dessa forma identificar quais os fatores críticos de sucesso.

# Palavras Chave

Gestão do risco; Gestão de projetos; Gestão do risco em gestão de projetos; técnicas e ferramentas de gestão do risco; Análise de redes sociais; Fatores críticos de sucesso; Teoria dos Grafos; Modelos preditivos; métricas de centralidade de análise de redes sociais; Pessoas chave em projetos; Ciclo de vida de um projeto; estimativas de desfechos de projetos, Projetos executados com sucesso e com insucesso.



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# Chapter 1

*“Those who plan do better than those who do not plan, even though they rarely stick to their plan.”*

Winston Churchill

## 1 Introduction

In today’s complex, turbulent, and unpredictable business landscape if organizations want to achieve sustainable competitive advantages or even just survive, they should develop strategies that enable them to boost performance and innovation so that they can efficiently meet actual market needs and demands. Therefore, organizations should develop effective and efficient strategic plans that enable them to predict upcoming trends and social and economic conjectures.

It is nothing new saying that organizations that better plan have higher chances to achieve success. However, effective planning requires a mix of several components, such as meaningful information and insights, unique expertise, flexibility, dynamic approaches, use of effective strategic predictive models, and fluid organizational structure, just to name a few. As the historic recurrence (repetition of similar events across history) phenomena has been repeating itself across the years, being able to predict the future (to a certain extent) by analyzing the past, can be considered as one of the greatest capacities that humans have.

Throughout this chapter it will be introduced the background and the motivations that originated the research and development presented in this work. In a nutshell, the present work introduces a heuristic model based on three scientific fields ((1) project management, (2) risk management, and (3) social network analysis), which in a holistic way will analyze five key project collaboration types ((1) Communication and Insight, (2) Internal and Cross Boundaries-Collaboration, (3) Know-how sharing and Power, (4) Clustering (variability effect—PSNVar), and (5) Teamwork efficiency) from delivered collaborative projects searching for unique repeatable behaviors (RPBs) that are associated with success, and failure outcomes. In other words, the proposed model in this work will search for critical success factors (CSFs) regarding the dynamic interaction of project people as they work together across the different phases of a project lifecycle. By doing so, the proposed heuristic & holistic model in this work will be contributing to answer the following central research question: *to which extent do the dynamic interactions of project people that participate in project activities across the different phases of a project lifecycle, influence a project outcome (success or failure)?*

To answer the proposed research question two hypotheses must be tested. They are: **H<sub>0</sub>**, and **H<sub>1</sub>**. The **H<sub>0</sub>** hypothesis is described as follows: yes, the dynamic interaction of project people across the different phases of a project lifecycle impact project outcome. The **H<sub>1</sub>** hypothesis is described as

follows: no, the dynamic interaction of project people across the different phases of a project lifecycle do not impact project outcome. The application of the proposed model will enable to reject or accept  $H_0$  and /or  $H_1$ . In this chapter the principal subjects to be introduced are the three key scientific pillars ((1) Project management, (2) risk management, and (3) social network analysis) that support the development of the proposed model in this work. It will be also explained how the three key scientific pillars are interrelated and the steps undertaken to develop the proposed model in this work. Finally, the structure of the present work describing the principal chapters it will be illustrated.

## **1.1 Project Management, Risk Management, and Social Network Analysis in Organizations**

### **1.1.1 The Importance of Project Management in Organizations**

In today's turbulent and complex global markets, organizations continuously look for support in best practices, tools & techniques, and methodologies, that help them to consistently deliver business results in the most possible effective and efficient way (PMI, 2017). One way through which organizations implement their strategy, create benefits, and deliver value, is by the successful delivery of projects (PMI, 2017). However, complex and increasing project constraints, such as tight budgets, short timelines, scarcity of resources, rapid changing of technology, aggressive competitors, general uncertainties, just to name a few, puts a great deal of pressure in organizations leaving no room to develop adequate decision-making strategies that could contribute to the successful delivery of projects. Often, this characterizes the environment in which organizations today exist, which if not properly managed drastically decreases the chances of success.

Facing such scenario organizations adopt approaches, tools and techniques recommended by world renowned institutes or bodies of knowledge, such as the PMI (Project Management Institute (PMI, 2017)), the APM (Association for Project Management (APM, 2020)), or the ISO (International Organization for Standardization (ISO, 2019)), to efficiently manage projects and thus increase their success outcome likelihood. This is essentially the major objective of the project management scientific field, which according to the PMI can be defined as the application of knowledge, skills, tools, and techniques to project activities to meet project requirements (PMI, 2017). Literature shows that the efficient application of project management best practices (developed and suggested by the above-mentioned renowned institutions), provide organizations a solid foundation to achieve their goals and objectives, while simultaneously contributes to the achievement of sustainable competitive advantages (Serrador, 2012; Wells, 2012; PMI, 2015; Nakayama & Chen, 2016; PMI, 2017).

According to the Project Management Institute (PMI, 2017) – one of the most important and respected project management institute (Chin et al, 2012) –, the application of project management best practices should be part of any organizational strategic competencies body, because it is a driver that enables organizations to compete in a more efficient way. This in turn, contributes to efficiently deal with project challenges or problems, optimize the use of project organizational resources, respond to project risk in a properly and timely manner, deliver the right products at the right time, properly address project change initiatives, increase stakeholder satisfaction, and increase predictability capacities, just to name a few (PMI, 2017).

### **1.1.2 The Importance of Risk Management in Organizations**

It is often argued that if organizations want to achieve sustainable competitive advantages or even just survive in the actual turbulent complex and highly demanding business landscape that more often than not are characterized by fierce and unfair competition, unpredictable customer behavior, disruptive changes, and an unstoppable advance of technology, they must adopt one or multiple business strategies that enables them to engage in win-win partnerships to outperform their competitors (Workday studios, 2018; Nunes & Abreu, 2021). In this line of thought, organizations should craft strategies to minimize or eliminate risks that may threaten their chances to success which almost always requires effective and efficient strategic risk management planning (Hillson & Murray-Webster, 2007; Kot & Dragon, 2015; Aven, 2015; Mohammed & Knapkova, 2016; Aven, 2017).

Risk management as a science is still relatively young – about 40 years old (Aven, 2015) –, where the existing main principles and methods were essentially developed in the 70´s and the 80´s in the Oil & Gas and the Space industries (Aven, 2015). Although risk management is a ruled statistical and probability-driven scientific model, it should be considered as a natural process of everything an individual does (Kaplan & Mikes, 2012; Hillson & Murray-Webster, 2007). This is so because risk is a living phenomenon and no matter how sophisticated the predicting and identification system an organization or individual has, risk comes without warning (Hillson & Murray-Webster, 2007; Kaplan & Mikes, 2012).

Risk Management can be defined as a combined and continuous process of decision analysis and proactive management, which should be seen as an integrative part of the organizational governance, design & structure, strategy, change, and culture of an organization, and should be supported, incentivized, and not policed by internal or external experts to the organization (Davies, 1997; Hunger et al., 2012; Mohammed & Knapkova, 2016).

Although some organizations develop their own risk management approaches and frameworks, there have been efforts to establish an international normalization (standardization) approach when it comes to the process of risk management (Hillson & Murray-Webster, 2007; Bosetti, 2015).

However, cultural differences seem to be the major constraint that hinders such normalization, essentially because there are very different ways risk (threats and opportunities) is perceived and understood (Hillson & Murray-Webster, 2007).

Nevertheless, institutions and knowledge bodies such as the International Organization for Standardization (ISO, 2021), promote international proprietary, industrial, and commercial standards. Essentially, ISO standards such as the risk management standard ISO 31000 (ISO, 2021), aim to help businesses to increase productivity and performance, while minimizing errors and waste. Effective risk management enables to a certain extent to look “into the future” regarding the likelihood of uncertain upcoming events. This in turn, provides organizations a chance to proactively and in a timely manner, develop and plan adjusted responsive strategies (rather than reactive strategies), in case such events take place. In other words, it contributes to identify the most adequate strategies to deal with opportunities, and threats that may arise with future uncertain events.

Furthermore, effective risk management is a critical factor in decision-making activities and increases the sense of individual and collective responsibility and accountability. This in turn, leads to a higher mental satisfaction state which positively impacts the health and well-being of employees of an organization, that often is a neglected aspect by organizations top management (Hillson & Murray-Webster, 2007). Still, according to several research, effective risk management is one of the principal drivers to achieve project success and organizational sustainable competitive advantages (Elahi, 2010; Pimchangthong & Boonjing, 2017; Saeidi et al., 2019; McKinsey, 2020).

### **1.1.3 The Importance of Social Network Analysis in Organizations**

Organizations can be defined as social organized structures designed to get things done through cooperation of individuals by means of rational-legal authority system, where the position matters (rather the person who holds the position) based on universalistic rules principles that are understood to be fair matters, and where leaders are accountable to shareholders and owners, and leaders are appointed instead of elected (Kadushin, 2012).

One of the most influential strategists in organizational business-strategy Michael Porters (Porter, 1985), developed in the 1980's a strategic organizational framework based on two different types of strategies to help organizations achieve competitive advantages. They are (Porter, 1985): (1) The cost strategy (characterized by reducing operating costs and charging lower prices to customers by investing hard in new technology and assuring economies of scale), and (2) The differentiation strategy (characterized by offering unique and added value products or services by investing hard in innovation and specialization).

Not without critic, according to latest research (Pulaj & Cipi, 2015; Suleman & Suleman, 2019; Moon et al., 2014; Pretorius, 2008) the above-mentioned Porter's generic strategies, are still valid today. In fact, across the literature there are several references stating innovation is still today the key for success (Friar, 2003; Hewlett, 2013; Mirbabayev, 2015; Bouncken et al., 2015; Amorim Carvalho & Silva, 2020). Innovation initiatives supported by an appropriate innovation model – which can essentially be characterized by having a higher control from top management (also called a more hands-on approach management style) – is one of the critical success factors to increase success chances (Narsalay, 2016).

However, some authors argue that due to multiple ways in which innovation can occur, it is not simple to measure the results of the influence of management in innovation performance (Simao et al., 2019). Literature also shows that in the current business landscape several organizations combine both Porter's strategies (cost and differentiation - usually called as Hybrid strategies), such as Swedish IKEA, the German Auto Industry, American Tesco, Wal-Mart, just to name a few (Kim et al., 2004; David, 2011; Baroto et al., 2012), as a key strategy to achieve success (Lapersonne, 2018). Adopting a Hybrid strategy (delivering simultaneous low-cost and differentiator products or services) usually requires a specific approach regarding the organizational structure and working culture (Lapersonne, 2018).

Latest research in organizational management (Bledow et al., 2011; Zacher & Kathrin, 2015; Zheng et al., 2017; Pertusa-Ortega & Molina-Azorin, 2018; Deloitte, 2020), shows that the adoption of an ambidextrous leadership style – characterized by exploiting present conditions by optimizing the current business model's operation on one hand, and on the other hand exploring opportunities that help redefine the business model by taking pioneering risks (Deloitte, 2020) – is a major driver for innovation and performance that helps in the achievement of sustainable competitive advantages. In other words, organizations must be more agile, and adopt new ways of thinking and executing work (Workday studios, 2018).

According to sociologists and organizational theorists (Ernst & Chrobot-Mason, 2010; Kubheka, 2013; Workday studios, 2018; Arena, 2018), organizations need to be more fluid than static, interiorizing key subjects, such as flexibility, accountability, empowerment, engagement, and cross functional collaboration. These subjects are critical to enable alignment towards a hybrid strategy. Often, this implies a transformation from tall to flat organizational structures (Kubheka, 2013; Workday studios, 2018). This will enable organizations to better adapt, think as start-ups when needed, act in a nimble way, scale, and deliver with reliability and quality (Arena, 2018).

It is nothing new saying that employees of an organization cannot strictly rely on the organizational formal structure of command to get all the information they need to accomplish their tasks. In fact, very often, and even without having such perception, employees engage in informal collaborative

networks to get the information they need to do their job (Cross & Parker, 2004; Borgatti et al., 2009).

Informal collaborative networks – also known as informal organizational networks –, are social organized structures that emerge as a network form of organization, often fueled on particularistic principles, such as, friendship, homophily, and propinquity (also called as fundamentally unfair). These, in opposition to formal networks – also known as the formal organizational chart –, are designed to maximize control of the employees and minimize their informal interaction (Podolny & Page, 1998; Kadushin, 2012). Informal networks are strongly dependent on trust, obligations, and sanctions (Rousseau et al., 1998). They are particularly influenced by the homophily principle which can be defined as the tendency of individuals to get together by sharing a set of common values, beliefs, or attitudes (Borgatti, 2009). Homophily creates a high level of acceptance based on trust, which accelerates social engagement. This in turn helps people to exchange information and ideas in a more open way (Ernst & Chrobot-Mason, 2010).

Almost in all organization employees create informal groups with whom they may interact on regular basis (Cross & Parker, 2004). Such spontaneous connections are essentially used to provide advice or solve problems, or even provide personal support (Cross & Parker, 2004). Furthermore, such connections that are usually hidden are critical for an organization because they define how knowledge is generated, distributed, and retained across an organization (Cross & Parker, 2004). They are very often the core working culture of an organization (Cross & Parker, 2004). Research shows that the way organizational informal networks are organized in an organization (the way people communicate, share information, solve problems, influence, energize others and so on), are a stronger predictor of outcome than individual talent or expertise skills (Pentland, 2012; Cross et al., 2017; Workday studios, 2018).

Research shows also that if organizational informal networks are neglected or improperly managed, they will evolve towards two opposite extremes - (1) total lack, or non-efficient collaboration (characterized by siloed organizations or isolated employees or departments), or (2) collaboration overload (characterized by having employees or departments in a disproportional central position within the organizational informal network, which are sought to provide work information-related or advice, ending up bottlenecking an organization at both, informal and formal levels) (Cross & Prusak, 2012; Cross, 2016; Nuryakin, 2018). Furthermore, research shows that organizations are not able to manage their informal networks by themselves due to the nature of the purpose organizations were first designed, for which is to drive operational efficiencies, by managing, coordinating, and controlling activities (Arena, 2018).

It is exactly at this point that Social Network Analysis (SNA) is pointed by several researchers as the unique capable tool that enables organizations to identify, analyze, and efficiently manage the mix of formal and informal organizational networks (Krackhardt & Hanson, 1993; Wasserman & Faust,

1994; Cross et al., 2002; Otte & Rousseau, 2002; Cross & Parker, 2004; Freeman, 2004; Borgatti et al., 2009; Kadushin, 2012; Scott, 2017; Arena, 2018; Deloitte, 2018; Leonardi & Contractor, 2018).

Social Network Analysis studies how social structures evolve through time and how they impact the environment (outcomes) where they exist (Otte & Rousseau, 2002). SNA comprises a set of tools and techniques based on the graph theory which are used to model pairwise relationships between entities (persons, organizations, or others). These in turn can be used to quantitatively measure the importance, influence, prestige, control, prominence, and decision-making power of an entity within an informal organizational network (Freeman, 2004), helping thus to understand the extent to which dynamic interactions of organizational entities (usually people or groups of people), influence outputs and outcomes.

Finally, the application of SNA in organizations helps to explain certain organizational subjects, such as talent shortages and retention, collective and individual performance, innovation performance, risk propagation, cultural fit, values, fraud, wellness and so on (Meyer et al., 2011; Saqr et al., 2018; Ongkowijoyo & Doloi, 2018). The application of SNA in organizations can also be used to develop predictive models which helps organizations to “see” future events and enables them to appropriately develop the best response strategies (Xing, 2016; Saqr et al., 2018).

## **1.2 Research Subject**

### **1.2.1 Motivation & Objectives**

According to several authors and researchers in project management despite the existence of a high number of tools and techniques to support project management, such as standards, frameworks, institutes, bodies of knowledge, or even specialized schools and universities, projects keep failing at an incredible pace (Discenza & Forman, 2007; McManus & Wood-Harper, 2008; Hillson, 2010, 2012; Stanley & Uden, 2013; The Standish Group, 2015; Pulse, 2017). However, it looks that project and risk management experts and researchers are becoming consensual regarding the major reasons that lead projects to failure.

According to a survey done by the Standish Institute in 2015 only 29 % of world-wide delivered projects had a successful outcome (The Standish Group, 2015). These results are in line with the results published by the PMI Pulse of the profession that shows that in average more than 50% of delivered projects experienced any time of scope creep (PMI, 2017).

According to David Hillson, a renowned risk and project management author and researcher, the results published by the Standish Group in 2015 and later by the PMI in 2018 are no surprise. According to Hillson, these results simply clearly support what he has been observing throughout several years of research in project management (Hillson, 2012). Hillson argues that there are still

three major areas where further investigation should be undertaken. They are (Hillson & Murray-Webster, 2007; Hillson, 2012): (1) **Processes** (different approaches and standards still needs improvements to perform project and risk management), (2) **Principles** (difficult in defining what risk really is. It is still today a very subjective perception), and (3) **People** (project management is still done by people. People’s culture, know-how, skills, interactions, roles, dynamic are different from people to people). Hillson highlights the factor People, which is in line with many other renowned project and organizational experts (Krackhardt & Hanson, 1993; Freeman, 2004; Cross & Parker, 2004; Borgatti et al., 2009; Meyer et al., 2011; Krivkovich & Levy 2015; Blacker & McConnell, 2015; Leonardi & Noshir, 2018; Arena, 2018; Workday studios, 2018; Abreu et al., 2018; Nunes & Abreu, 2020) as being the major factor that impacts organizational outcomes. More concretely, Hillson argues that there is still a lot of work do to understand the extent to which different people perceive, understand, and respond to risk (Hillson & Murray-Webster, 2007; Hillson, 2012).

To better understand the extent to which people’s dynamic interactions (also called as interactive dynamic behaviors) impact project outcomes, a heuristic two-part predictive model is developed based on three scientific pillars as illustrated in Figure 1. The pillars are: (1) Project Management - contributing with the definitions and structure of a project lifecycle, (2) Risk Management - contributing with the standard risk management process framework, and (3) Social Network Analysis - providing the tools and techniques to identify and quantify the collaborative interactions between entities throughout a project lifecycle. The proposed heuristic two-part predictive model aims to contribute to answer the following research question: *To which extent do the dynamic interactions of project participants across the different phases of a project lifecycle influence project outcome (success or failure)?*

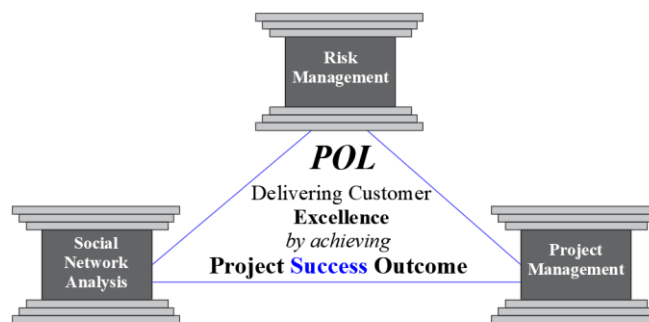


Figure 1 - Three Scientific Pillars of the proposed model in this work – the POL Model

In part 1, the proposed model in this work named as POL Model – Project Outcome Likelihood model – will analyze five key project collaboration types (5-GCT) that usually occur in each project phase of a project lifecycle (Nunes & Abreu, 2020). The five key project collaboration types result from an extensive literature review in project management as being the most important regarding the impact that they have in project outcome (Freeman, 1977; Pinto & Slevin, 1988; Cross & Parker,

2004; Hillson, 2012; Borgatti, 2016; Strategyex, 2017; PMI, 2017; Workday, 2018; Arena, 2018; Nunes & Abreu, 2020; AMP, 2020; ISO, 2021, Nunes et al., 2021(a)). The proposed model will analyze project data-related collected in project meetings, project emails, and through the application of SNA-based questionnaires. Such data will be used to characterize the five key project collaboration types (dynamic interaction of project people) for both, successful and unsuccessfully delivered projects. Next, the model searches for unique repeatable behavioral patterns (RBPs) regarding the 5-GCTs in both, successful and unsuccessfully delivered projects. RBPs are called in this Project Critical Success Factors (CSFs). The 5-GCT are illustrated in Table 1.

Table 1 - Five global collaboration types (5-GCT) of the POL model

5-GCT	Brief description
1- Communication and Insight	How are important project stakeholders (Project managers and project experts for example), are conducting the project-phase global communication? How is the feedback level between the different teams that work in networks of collaboration across a project lifecycle?
2- Internal and Cross Boundaries-Collaboration	To which extent is one project team more or less dependent on project-related information provided from another different project team?
3- Know-how sharing and Power	To which extent is the project-related information, provided by one project team is recognized as important and / or decisive?
4- Clustering (variability effect—PSNVar)	To which extent does the project social network variability (changing the project team set) vary across the different phases of a project lifecycle?
5- Teamwork efficiency	To which extent project outcome is associated to the speed of feedbacking project information-related between the different project teams?

In part 2, the proposed model in this work will provide guidance to an ongoing project by analyzing the deviation between an ongoing project evolution (*actual state*) and the CSFs identified in part 1 of the proposed model. Detailed information regarding the fundamentals, objectives, and approaches of the proposed model in this work are presented throughout Chapter 5 – Proposed Model to Monitor Risk in Project Management.

### 1.2.2 Investigation Methodology

Throughout this section subjects such as research design, research methodology, research process, and model reliability and validity will be discussed.

The research design process adopted in this work is supported by the well-known research onion process proposed by Saunders et al., (2012). The research design process essentially describes the

stages through which a given research process must go through to develop an effective and efficient methodology regarding the data collection and the analysis methods that enable to answer a given research question. Figure 2 illustrates the research onion process framework proposed by Saunders et al, (2012).

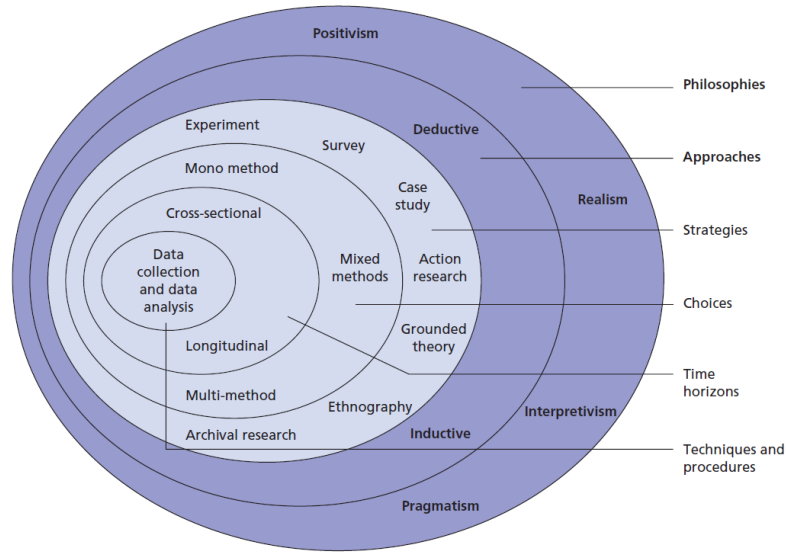


Figure 2- The Research Onion (Saunders et al., 2012)

In the research onion illustrated in Figure 2 the research sequence starts at the most peripheral layer and goes towards the inside of the onion in successive steps. The research onion comprises six different layers. The first three peripheral ones refer to philosophies, approach, and research strategies respectively. The other remaining three, refer to the choices, time horizons, and research techniques and procedures respectively. According to Saunders et al. (2012) the first step to be taken in any research process is to define the research philosophy and choosing the most appropriate approach type. It follows then by the development of strategies regarding how and wherethrough research data will be collected. At the fourth layer the data-analysis methods must be defined, which essential lay into qualitative and quantitative. In the sixth layer the research timeline must be defined. Finally, in the last layer of the research onion, techniques and procedures that will be used to analyze the collected data must be defined.

The research process conducted in the present work goes as follows: the research philosophy lays under the positivism side (characterized by the adoption of quantitative research methods such as surveys) however and without any explicit philosophical commitments (Saunders et al., 2012)). This implies mathematical measures essentially derived from discrete mathematics – from graph theory - will be applied to quantify observable phenomena, which in turn is expected to lead to the

production of credible data and generalizations. The researcher acts as an observer, not influencing the results.

The strategy implemented in the present work follows an experiment path based on a multi-method choice type which comprises the existence of more than one method to achieve quantitative results. The research in this work follows a cross-sectional time horizon type once the analysis period is bounded by the duration of an activity (duration of a project). However, the research timeline can be as well considered longitudinal. This is directly depending on the duration (duration of a project lifecycle) of the phenomenon to be observed, quantified, and analyzed, which in some cases can be extended to more than one-year period. Finally, data will be collected using two different data collection methods. They are: (1) **the questionnaire** (survey) type, also known as active collection type, requires the direct participation of the elements which will produce the object to be studied (dynamic interactions between such elements), and (2) **the log-information collection type** (project mails, and project meetings), also known as passive collection type, which does not require the direct participation of the elements which will produce the object to be studied, which as mentioned before, are the dynamic interactions between such elements.

The research methodology classification of the proposed work is detailed illustrated in Figure 3 a). It is proposed a framework to better understand where the research developed across the work lays, regarding the scientific research aspects. The framework illustrated in Figure 3 a) is inspired in the description proposed by Saunders et al. (2012), concerning science and research scientific matters.

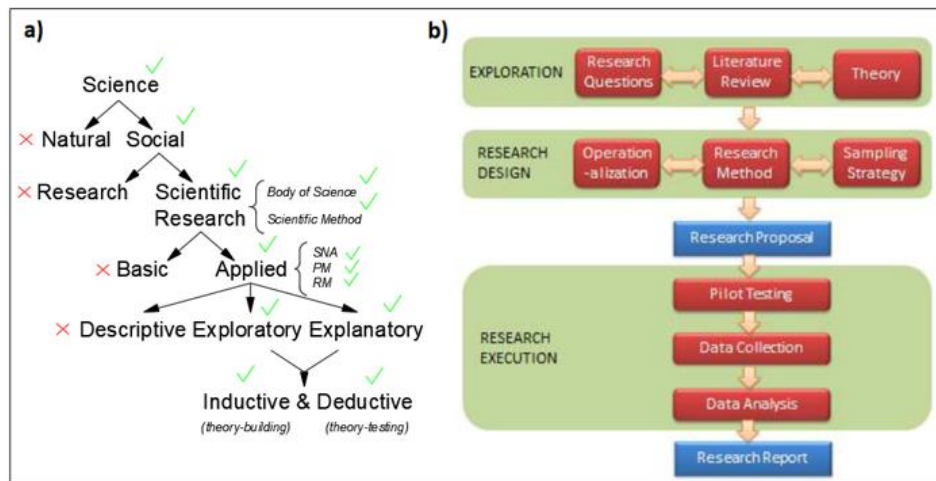


Figure 3 - Research methodology classification of the proposed work (adaptade from Bhattacharjee, (2012)). b)Functionalistic research process (Bhattacharjee, 2012).

First, and according to the framework illustrated in Figure 3 a) the research in this work is considered science because it meets the intrinsic purpose of science, which is essentially to create scientific knowledge. As it can be seen in Figure 3 a) the research conducted in this work is not related or addressed to natural science rather related to social science. Natural science, contrary to

social science, is the science of naturally occurring objects or phenomena, such as the human body, light, objects, matter, just to name a few. Natural science is accurate, deterministic, precise, fully independent of the person or group that makes the scientific observations, and can be classified into physical sciences, earth sciences, life sciences, among others.

Social science on the other hand is characterized as the science of people or agglomerated of people, such as groups, organizations, economies, and their respective individual or collective behaviors. Social science is less accurate, deterministic (often contrasted with free-will it argues that all events are completely determined by previously existing causes, which in other words means, there exists always a cause-and-effect), ambiguous (a particular subject, event, or other, is subjected to different interpretations having different meanings to different persons), more prone to errors and uncertainty, and can be classified in disciplines such as psychology (which is the science of human behaviors), sociology (which is the science of social groups), and economics (which is the science of firms, markets, and economies).

The conducted research in this work is classified as research in social science because it scopes the investigation towards the analysis of individual, and group behaviors. Furthermore, the research conducted in this work deals with a huge amount of uncertainty and ambiguity regarding different matters that relate with project management. For example, although not to be directly addressed and classified by the proposed model in this work, the definition of what a successful or unsuccessful project is, is still today susceptible to different interpretations (Hillson, 2007). This is so, unless organizations use the project success criteria proposed by the project management institute (PMI), known as triple constraint (PMI, 2017). This fact may lead that the results output by the proposed model in this work are interpreted in different ways. Another example relates to the reliability of collected data namely in project questionnaires. In this case, the proposed model in this work will analyze subjective data which may be strongly biased, that characterizes the dynamic preferences of different people that interact project environment.

Finally, it is major goal of the proposed model in this work to quantitatively identify a correlation between cause and effect. This happens when the model tries to explain project outcomes as a function of a set of project actors' behaviors.

The research presented in this work is considered science because it meets the scientific knowledge criteria as proposed by Bhattacharjee, (2012). This affirmation is supported in the intrinsic definition of scientific knowledge, which refers to a set of theories and a body of laws that aim to explain a particular phenomenon or behavior. In this line of thought, the research conducted in this work is considered scientific research because the aim of the research is to build scientific knowledge that can explain social phenomena by postulating new theories or supporting or contesting existing ones.

The proposed model in this work will correlate quantitatively measured observed behaviors with project outcomes. By doing so, function of the metrics applied, and the context analyzed by the proposed model in this work, new theories related to the correlation between behaviors and project outcomes may be postulated. For this matter, the proposed model in this work was designed according to the laws of the scientific method, which are characterized as a set of empirical techniques to build scientific knowledge. These include how to make valid observations, how to interpret results, and finally, how to generalize results obtained.

The research conducted in this work follows a logical approach, where scientific inferences are based in supported assumptions taken with proof, rather than arbitrary axioms. This happens as the proposed model in this work analysis behavioral data in a quantitative way that characterizes past events. The correlation between measurable behavioral data and past outcomes, provides the model a capacity to inference based in observed evidence. The proposed model in this work which results from the scientific research developed in this work, can be applied by other scientists, and in other environments, if similar data is used as input and the same methodology (metrics, calculations and so on) are followed. This latter fact presupposes that the research that led to the model proposed in this work, was already analyzed by other scientists, and that has already withstood international critical scrutiny. Regarding this matter, the developed research presented in this work has already been object of several peer review analysis. please see (Nunes & Abreu, 2020 (a, b, c, d, e); Nunes et al., 2020; Nunes et al., 2021(a); Nunes & Abreu, 2021). Finally, regarding the scientific research aspect, the research conducted in this work contributes to the development of several bodies of science, such as the network the theory, sociology, risk, and project management.

The research developed in this work is considered applied scientific research because it applies scientific knowledge that comes from basic sciences in a physical environment. Contrary to basic science (also known as pure science) which is used to explain the most basic objects and forces, relationships, and the laws that govern them (which includes mathematics, physics, and biology), applied science (also known as practical science) is usually the combination of two or more basic sciences to solve quotidian problems and challenges. For example, the proposed model in this work (as illustrated in Figure 3 a)) is supported by the graph theory (discrete mathematics) which is the basic science that enables the quantification of the different behavioral patterns observed across a finite period of time (a project lifecycle phase). Another example regards the application of the event chain theory (also known as dependency theory) in project management to sequentially plan project tasks and activities (also known as by the application of Gantt charts, and PERT methodology (PMI, 2017)). Finally, another example regards the application of basic statistics (basic science) in the field of risk management, to estimate a likelihood that an event has to occur.

The research presented in this work is considered exploratory and explanatory, rather than descriptive, regarding the scientific research dimension. Contrary to descriptive research - which is

characterized as precise, fully replicable - explanatory research is more concerned in identifying the underlying reasons that lead to a certain behavior or outcome. Although this research type may not lead to very accurate (mathematical) understanding of the underlying reasons, it may be very useful in pointing in which direction more in-depth research should be conducted. Regarding this aspect, the proposed model in this work does not disclose the real reasons of a given set of observed behaviors (as it correlates project people behavioral patterns with project outcomes), rather it identifies hot spots where it is worth to conduct in-depth research. For example, the proposed model in this work may identify a strong correlation between a particular behavior and a particular outcome, however, it does not identify the underlying reasons for the emergence of such behaviors. However, by correlating behaviors with outcomes, the proposed model in this work is seeking explanations for such outcomes in particular behaviors. This fact characterizes the proposed model in this work as having also an explanatory dimension in the sense that it seeks answers to questions that comprise the why (why a particular outcome?) and what (what behaviors are associated with a particular outcome?)

Regarding the applied-scientific research approach of this work, the two forms of scientific inquiry (inductive and deductive research) co-exist, however dominated by the inductive approach. Inductive research (also called theory-building) is characterized by inferring theoretical concepts and patterns from observations. This aspect is present in the proposed model in this work as follows: once a substantial number of observations in different contexts - however within the same ecosystem (project environment) - have been made, theories regarding the influence of given observed repeated behaviors in project outcomes might be postulated. Regarding the deductive approach (also known as theory testing) which is characterized by testing concepts and patterns from known developed theories, the research conducted in this work is strongly supported in the theory of social network analysis, which stresses the importance of organizational informal networks (informal dynamic behaviors) in organizational outcomes, such as performance and innovation as suggested by several literature (Cross & Parker, 2004; Borgatti et al., 2009; Arena, 2018; Workday, 2018; Müller, 2020)

Figure 3b) illustrates the functionalistic research process proposed by Bhattacharjee, (2012). This research process was adopted by the research developed in this work. According to Bhattacharjee, (2012), the most traditional research structure approach is the research type that can be divided into three major phases (Figure 3 b)). They are: (1) exploration, (2) research design, and (3) research execution. However, Bhattacharjee, (2012) argues that the proposed framework (Functionalistic research process) is arranged in a generic way and can be adjusted to meet research or researcher needs. The exploration phase comprises the following: the exploration and selection of the research question(s) for further investigation, analyzing the available literature regarding the field of the area of inquiry to capture the current state of knowledge in that field, and selecting theories that answer the research question(s). The research design phase comprises the creation of a

set of activities that aim to answer the research question(s). It includes the selection of a research method, operationalizing constructs of interest (the process of designing precise measures for abstract theoretical constructs) and design an adequate sampling strategy (set a proper data collection process).

In the last phase – research execution – it is recommended to write a research proposal detailing all of the decisions made in the preceding phases of the research process and the rationale behind each decision. It comprises pilot testing which is essential to detect potential problems in the research design and/or instrumentation and to ensure that the measurement instruments, tools, and techniques used in the study are reliable and valid measures of the constructs of interest. If the pilot-test has been successfully conducted, it is time to proceed to the data collection process (qualitative or / and quantitative), usually using the population sample type. After this step follows the analysis step. In this step, collected data will be analyzed and interpreted with the purpose of drawing conclusions regarding the research questions of interest.

The research from which resulted in the proposed model in this work (the POL model), is fundamentally empirical research. Unlike theoretical research which is by nature hypothetical and does not use empirical data, such as observations, measurements, and so on, empirical research on the other side comprises always any type of data gathering that mirrors phenomena observed in the real world. However, the proposed model in this work was developed based on theoretical research in the field of discrete mathematics, namely the graph theory. For this matter counts the developed SNA centrality metrics, such as the in-degree, out-degree, density or PSNVar, just to name a few. More detail on this is available in chapter 5. Finally, the last stage, research report, comprises the preparation of the final document containing the entire research process and its findings or conclusions in the form of a research paper, dissertation, or monography.

The research process illustrated in Figure 3 b) can also be more pragmatically explained through a relatively new approach to design science research that is gaining high attraction within the scientific community especially in the IT field (Peffer et al., 2007; Lapão et al., 2017; Teixeira et al., 2017). Known as the design science research process (**DSRP**), it is a model for producing and presenting information systems research, that aims to conduct and guide research in a more pragmatic way (to a certain extent strongly derived from the positivism, empiricism, and pragmatism philosophical world views (Bhattacharjee, 2012; Creswell & Creswell, 2014)). In DSRP, instead of deep explaining an existing reality or helping to make sense of it within a particular context, research is more directed to develop fast, valid, reliable, and actionable knowledge for designing adaptative and functional solutions for general problems (Peffer et al., 2007; Lapão et al., 2017; Teixeira et al., 2017). Once proposed model in this work is fully suitable to be integrated into a traditional organizational business intelligence architecture assuming the form of a supervised machine learning model (Nunes & Abreu, 2020 (1), (b), (c)), it is appropriate to describe

the proposed research investigation conducted in this work mirrored in the DSRP methodology. The DSRP methodology has six steps that should be executed in scientific research. They are (Peppers et al., 2006): **Step 1: Problem identification and motivation**: This step comprises the definition of the specific research problem and justify the value of a solution. In the context of this work this step regards the understanding the extent that people dynamic interactions may or not impact project outcomes. **Step 2: Objectives of a solution**: This step involves the rational inference of the objectives of a solution from the problem definition. In the context of this work, it regards the identification of project critical success factors in order to maximize project success outcome. **Step 3: Design and development**: This step comprises the creation of an artifactual solution (models, frameworks, methods, or approaches), to lay the foundations of how the problem is to be addressed and analyzed. In the context of this work, it implies the development of a software solution that can be integrated into a business intelligence architecture in order to automatically identify and refine project critical success factors. **Step 4: Demonstration**: This step comprises the demonstration of the efficacy of the proposed artifact to solve the identified problem. This step involves the use of experimentation, simulation, case study, proof, or other appropriated activity. In the context of this work, it implies the application of the proposed model in different project's environments. **Step 5: Evaluation**: This step involves the observation and measurement of how well the artifact supports the solution to the identified problem. It involves the comparison between the solutions objectives and the actual observed results from the use of the developed artifact. In the context of this work, it implies the analysis of results of the application of the model and the effectiveness of implemented measures function of those results. **Step 6: Communication**: Finally, this step comprises the communication of the problem and its importance, the developed artifact, its utility and novelty, the rigor of its design, and the effectiveness to researchers and other relevant audiences such as practicing professionals, when appropriate. In this work, this step is characterized by the publication of scientific literature in renowned scientific magazines, scientific conferences, and books (Nunes & Abreu, 2020 (a), (b), (c), (d), (e); Nunes et al., 2021), and other ongoing or/and upcoming publications. The communication step should also comprise the definition of the nominal structure of an empirical research process, which is a common structure for empirical research papers that is aligned with the basic principles of scientific methods which usually comprise the following traditional steps: (1) problem definition, (2) literature review, (3) hypothesis development, (4) data collection, (5) analysis, (6) results, (7) discussion, and (8) conclusion. Finally, the communication step should contain the four principal pillars of the scientific method to be credited as scientific research in the scientific community. They are (Bhattacharjee, 2012; Creswell & Creswell, 2014): (1) Logical (scientific inferences must be based on logical principles of reasoning), (2) confirmable (inferences derived must match with observed evidence), (3) repeatable (other scientists should be able to independently replicate or repeat the proposed scientific study and obtain similar or identical results) and (4) scrutinizable (the procedures used the inferences derived must withstand critical scrutiny (also known as peer review) by other scientists).

Reliability can be defined as something that can perform consistently well, and therefore has the quality of being trustworthy (Bhattacharjee, 2012). In other words, reliability regards the overall consistency of a measure. In this line of thought, reliability implies consistency but not necessarily accuracy. Contrary to an unreliable measurement, such as the guessing of a person's height for example, reliable measurement uses tools and techniques based on logic, rational and mathematics and statistics to make the so-called educated guess regarding an event or situation.

Validity can be defined as the extent to which a particular measure correctly represents the underlying construct that it is supposed to measure (Bhattacharjee, 2012). In other words, the validity of a measurement is the degree to which a particular tool really measures what it claims that it can measure. It can be concluded that reliability and validity are not from each other dependent, however interrelated. For example, a particular tool can measure something with high degree of consistency (which means that he will do what he was designed for) however, it may be measuring something different from what is desired. The reason may be that the tool is not properly calibrated.

As the research conducted in this work is research in the social sciences field, the concepts of reliability and validity gain another dimension. This happens because research in this field, very often requiring information from others, deals with a huge amount of uncertainty and ambiguity. This is so because unlike machines, humans are usually extremely sensitive to internal (states and traits) and external factors (the formal and informal social network where it exists). This fact leads to high unpredictability regarding human behavior, being however, one of the most exciting fields to study.

Regarding reliability in the social sciences research, there are some aspects that must be taken into consideration which are part of the research done in this work. First, in the social sciences, the researcher's subjectivity may introduce an amount of bias in the reliability of the observations (data collection). The developed model in this work uses three different types of data collection (emails, meetings, and questionnaires). Regarding the data collected in project emails and project meetings, there is absolutely no influence of the researcher regarding the reliability of collected data. This is so because data collected in project emails and project meetings, directly refer to quantitative data rather than preferential data. For example, in project meetings one vital information for the proposed model in this work is the number of people who are present in a given project meeting. In the case of emails, one vital information for the proposed model in this work is the number of emails exchanged between any two persons within a bounded period of time. However, regarding data collected in questionnaires, the same cannot be said. Bias may be introduced if the researcher, while creating the questionnaire, asks imprecise or ambiguous questions. Still, some respondents may be not very familiar or comfortable in answering some questions made by the researcher. These facts suggest that collected data is strongly biased, which directly implies that conclusions drawn by the researcher may not be accurate. Nevertheless, collecting behavioral data by

conducting observations (which by nature introduces a higher degree of ambiguity and uncertainty) the proposed model in this work uses questionnaires to collect behavioral data, which increases the reliability of data collected.

Regarding the results output by the proposed model in this work, reliability is a given fact, because it depends on the mathematical operations which are comprised in the proposed model in this work (graph theory metrics). Due to this, reliability tests, such as for example the Split-half reliability test, the Inter-rater reliability test, or the Test-retest reliability (Bhattacharjee, 2012), have no practical application. This happens because, for example, the Split-half reliability test is usually used to analyze the consistency of a trend across time that was calculated based on a set of variables of a sub-sample out of the total sample collected. To calculate evolutions across time, the proposed model in this work does not analysis samples, rather the population. This comprises all participants within a given project ´s environment, as it happens for the metric role attendee degree for example (see chapter 5). The inter-rater reliability test also does not apply in the proposed model in this work, because there is no need for different observations to rate collected or outputted data. This is so because collected data and outputted results, are factual (numerical) and not subjective dependent. The test-retest reliability test does also does not apply in this model because the model generalizes its application in studying of the dynamic interaction phenomena (usually everybody, in a formal, informal, or a mix of both, interacts one way or the other with other people, when they work together to accomplish a task or activity in project environment), but particularizes the correlation between behaviors and outcomes, which are directly function of the several existing cultures and sub-cultures within a given organizational or private social network. In other words, it means that a given observed behavior in a context A drives an outcome B, while the same given behavior in a context D, may drive an outcome C. Therefore, the research conducted in this work focuses on the correlation between formal, informal, or the mix of both behaviors and outcomes.

Research validity should be ideally assessed using theoretical and empirical approaches (Bhattacharjee, 2012). The validity of the output results by the developed model in this work can be essentially characterized by the transactional validity type. Transactional validity (also known as representational validity) characterizes how well a theoretical idea, developed based on observations, mirrors the reality. In other words, a translation validity examines whether a measure or results of the application of a metric, is a good reflection of its underlying construct (Bhattacharjee, 2012). Although concerns regarding validity of results are more susceptible in qualitative research than quantitative research (Cho & Trent, 2006), a word can be said regarding this aspect concerning the proposed research and model in this work. In this aspect, four different validity aspects are worth to be addressed. The first – face validity (is a validity type which is based on what makes more sense, regarding an observed phenomenon), it can be said that the results output by the application of the proposed model in this work, have face validity, namely backed up

by quantitative results. This happens, as the proposed model in this work correlates observed quantitative behaviors with outcomes (if they exist).

Content validity (which is an assessment of how well a set of items matches the relevant content domain of the construct that it is trying to measure) in the research conducted in this work, namely concerns the collection data process. This happens when defining the indicators that most insight may output regarding a particular desirable subject. For example, the goal of this research is to identify project critical successful factors regarding the collaborative dimension of project participants. For this matter a meticulous and meaningful definition and creation of the indicators that best characterize the dependence comprised in the mentioned research question was done. For example, all the metrics (indicators) used in the research presented in this work (mail cohesion degree, feedback degree, information sharing degree, action key players, and transferring speed degree) as illustrated in chapter 5, have one objective only – measure the dynamic interaction between project participants across a bounded period of time. As the spectrum of collaboration comprises network, coordination, and cooperation (Camarinha-Matos & Afsarmanesh, 2006) it can be concluded that all mentioned indicators (metrics) and the respective research conducted in this work, has content validity.

Finally, although the model proposed in this work aims the estimation of an outcome likelihood by inferring an observed trend within a bounded period of time, due to good practice reasons, it cannot be tested regarding predictive validity. This happens because the proposed model in this work regarding the estimation of an outcome likelihood, works in the anticipation, rather than in the concretization of a previously observed trend. In other words, this means that in project management, when the proposed model calculates an estimation of an outcome likelihood, the good practice rules demand that the immediately taken of actions in order change the observed ongoing trend, if such ongoing trend is not aligned with project critical success factors previously calculated. On the other hand, if a particular ongoing trend is aligned with the identified critical success factors, then, the good practice rules demand that such trend must be supported. By doing so, predictive validity test would be one-sided only. This means, the predictability validity of the proposed model in this work can only be accessed if all ongoing trends would be aligned with the path to success, which often is not the case.

### **1.2.3 The research sequence**

Table 2 illustrates the sequence of activities carried out across the major phases of the present work. These are adjusted to the three major phases proposed by Bhattacharjee, (2012), as illustrated in Figure 3 (Exploration, Research design, and Research execution).

The exploration phase includes literature reviewing regarding the main subjects that support the development of a particular subject or research question. The research design phase includes the

sequential activities to prepare the design of a research plan to answer the refined research question. The research execution phases include the research process map, containing all the previous steps that illustrate the development of a given proposed research. It includes testing the developed research model, refinement of the proposed research model, and collection data methodologies.

Table 2 - The research sequence of the present work

Phases	Activities	Objectives
Exploration	Literature review regarding Project Management, Risk Management and Social Network Analysis in organizations. Creation of generic research questions and refine them down to one research question that appropriately adjusts the relationship cost-benefit of the business case.	<p>Understand, in the available literature, what valuable information regarding Project Management (namely the reasons why projects fail), Risk Management, and Social Network Analysis (history, importance, applications in project and risk management, existing models, issues, developments, state of the art), could be useful to help formulate a set of research questions regarding the reasons that lead projects to failure. Formulate the final research question (what is the influence of the dynamic interaction (collaborative behaviors)) of project people, in project outcomes?</p> <p>Analyze to which extent different analyzed major subjects (Project Management, Risk Management, and Social Network Analysis) can contribute to the development of a research model.</p> <p>Defining model type: predictive model, to identify project critical success factors.</p>
Research design	Define a set of sequential activities to prepare the design of a predictive model to answer the refined research question. Final design and building the model.	Analyzing existing models regarding the potential of the application of Social Network Analysis as a risk management tool in Project Management and in organizations. Design a prototype of a predictive model: defining the scope of analysis (projects), the data to be collected (data that mirrors how project people collaborate regarding project activities), the collection data methods (project meetings, emails and questionnaires), the mathematical approach (essentially graph theory, from discrete mathematics) and basic statistical operations which include average, mode, and linear regression, and define how outcomes (results), are to be interpreted when answering the refined research question (associated results obtained by the application of graph theory to project outcomes – success or failure). First identification of project critical success factors (CSFs).

Research execution	Write a research map containing all the previous steps that illustrate the development of the predictive model. Do a test-drive to the developed model. Refine the model. Collect, and analyze data, to formulate conclusions. Formally present results.	<p>Create a working framework that encompasses all the steps of the developed model. Run a set of tests to the developed model and optimize inputs (data to be provided to the model), processes (SNA centrality metrics) and outputs (how to efficiently relate results with events (project outcomes)).</p> <p>Collect data for “final” application of the model, to draw conclusions.</p> <p>Run the model, to identify project critical success factors, and guide an ongoing project based on identified CSFs.</p> <p>Quantitatively output results, draw conclusions, and further research steps / optimizations of the proposed model-continuous improvement.</p>
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Continuation of Table 2 - The research sequence of the present work.

### 1.2.4 Structure of this Work

The present work is divided in seven Chapters. **Block one** (1) comprises chapter 1, where a global introduction to the proposed work is addressed, essentially pointing out the motivations, objectives, and research methodology throughout the proposed work. **Block two** (2) comprises chapters 2, 3, and 4, where a detailed literature review is conducted regarding the three pillars (Project Management, Risk Management, and Social Network Analysis) that lay the foundations of the proposed work. It will be addressed the importance, benefits, and limitations in the actual business context. **Block tree** (3) comprises chapter 5, where the detailed development regarding the predictive model (objective of this work) developed in this work is addressed. Finally **Block four** (4) comprises chapters 6 and 7, where a case study is conducted illustrating the application of the proposed model in this work, its benefits, and limitations, and finishing with conclusions and recommended further developments. Each of the mentioned blocks are detailed described in Table 3.

Table 3 - Structure of the present work

<b>Blocks</b>	<b>Chapters</b>	<b>Brief description</b>
Block 1	Chapter 1 – Introduction	Chapter 1 describes the motivation and objectives of the proposed work, as well as the importance of the three different scientific fields (pillars) and approaches (Project Management, Risk Management, and Social Networks Analysis) that supported the development of the proposed work. It also describes the research methodology that guided the overall development process of the proposed model in this work.
Block 2	Chapter 2 – Projects, and Project	In Chapter 2 an extensive literature review has been conducted regarding the first scientific pillar that supported the developed model presented in

	Management in Organizations	this work- Project Management. Subjects, such as the importance, application, advantages, and limitations, approaches, and methodologies of Project Management in organizations in the actual business landscape are addressed.
	Chapter 3 – Risk, and Risk Management in Organizations	In Chapter 3 an extensive literature review has been conducted regarding the second scientific pillar that supported the developed model presented in this work- Risk Management. Subjects, such as the importance, application, advantages, and limitations, approaches, and methodologies of Risk Management in organizations, and in Project Management in the actual business landscape are in detail addressed.
	Chapter 4 – Social Network Analysis (SNA) in Organizations	In Chapter 4 an extensive literature review has been conducted regarding the third scientific pillar that supported the developed model presented this work- Social Network Analysis. Subjects, such as the importance, application, advantages and limitations, approaches, and methodologies of Social Network Analysis in organizations, and in Project Management in the actual business landscape are in detail addressed.
Block 3	Chapter 5 – Proposed Model to Monitor Risk in Project Management	Chapter 5 is extensively present the development, of the proposed predictive model in this work. This chapter, are illustrate the individual contributions of the different three scientific pillars (Project Management, Risk Management, and Social Networks Analysis) that lay the foundations to the proposed model (POL Model), and how each contribution adds value to the proposed model in this work.
Block 4	Chapter 6 – Model Application & Validation – A Case Study	In Chapter 6 a case study is conducted illustrating the application (input, process, and output), and validation of the proposed model in this work. Essentially, it is illustrated how the proposed model identifies project critical success factors, and how guidance can be provided to an ongoing project, based on identified critical success factors, and ultimately estimating a project outcome likelihood.
	Chapter 7 – Final Considerations	In Chapter 7 conclusions regarding the development and application of the proposed model in this work are drawn and further developments regarding the optimizations / development (continuous improvement cycle) regarding the proposed model are suggested.

Continuation of Table 3- Structure of the present work

# Chapter 2

## 2 Projects, and Project Management in Organizations

*“Management is, above all, a practice where art, science, and craft meet.”*

Henry Mintzberg, 1979

### 2.1 Introduction

If projects are efficiently delivered, organizations can execute their strategies that may contribute to the achievement of their short and long-term goals and objectives (Nunes & Abreu, 2020). Projects are important because they can solve problems, satisfy needs, add value, capitalize on/exploit opportunities, enable change, enable learning and adaptation, just to name a few (Nunes & Abreu, 2020). In this chapter is introduced the first scientific pillar – (1) Project Management –, that supports the development of the proposed model in this work. Throughout this chapter, subjects such as the importance of projects for organizations, definitions of project and project management, project management history and evolution, project management state of the art, reasons that lead projects to failure and success, and project management methodologies tools & techniques will be presented.

### 2.2 Projects, and Project Management

#### 2.2.1 Projects, and Project Management History & Definition

Across reviewed literature there is consensus regarding to what a definition of a project is (Chiu, 2010; Seymour & Hussein, 2014; PMI, 2017; APM, 2020; ISO, 2021). According to reviewed literature a project is a temporary or transient endeavor (with defined start and end), that creates a unique product, service, or result (outputs, outcomes, or benefits) comprising a set of controlled and planned activities to deliver that unique product, service, or result. The last aspect mentioned in the definition of a project refers to a set of activities that must be controlled in order effectively deliver a service product or result. In other words, a project needs to be managed. This opens the way to the next key term applied in project environments – project management. Again, across reviewed literature there is consensus regarding to what a definition of a project is (APM, 2007; Kazak-Holland, 2011; Gupta, 2013; PMI, 2017; Nunes & Abreu, 2020; APM, 2020; ISO, 2021). According to reviewed literature project management is the application of skills, tools, techniques, methods,

competencies, processes, knowledge, and experience, to meet project activities requirements and objectives.

It is still unclear when was the first time the word project was mentioned or even defined (Kazak-Holland, 2011). However, diverse literature shows that the word *project* comes from the Latin word *projectum*, which derives from the verb *proicere* which is the composition of the word *pro* – meaning something before an action or something that comes before something else in time, and *iacere* – meaning to do something (Kazak-Holland, 2011). According to Mark Kazak-Holland, 2011 in his book *The History of Project Management*, project management is not a 20th century discipline, rather a discipline that has been around since humans exist and inhabited the planet Earth. Mark Kazak-Holland argues that actual project management science is the result of a natural evolution and has been practiced throughout the history of humanity until today.

However, there seems to be no consensus on when exactly the so-called modern project management did start. Nevertheless, not without critic, most of the reviewed literature points to two renowned project management names as being the forefathers of project management. They are Henri Fayol and Henry Gantt (APM, 2007; Chiu, 2010; Seymour & Hussein, 2014). Henry Fayol (1841-1925) was a French engineer that worked as a manager in a steel company during the decade before the World War that through observation on his workers, identified five functions of management he believed to be universal. They are (Seymour & Hussein, 2014): (1) Planning, (2) Organizing, (3) Commanding, (4) Coordinating, and (5) Controlling. The proposed five functions of management have stood the test of time. They still are used today in organizations (Fells, 2000; Kwak, 2003; APM, 2007; Seymour & Hussein, 2014; Nunes & Abreu, 2020).

The second important name in project management – Henry Gant (1861-1919), an American engineer and consultant credit for the development of the Gant Chart – which is still today a crucial tool for project management –, gave important contributions to the project management field, essentially by showing the important and benefits of dividing projects into small manageable activities (Richman, 2002). However, some authors (Marsh, 1975) argue that his invention was first developed much earlier by a polish economist Karol Adamiecki (1866-1933) as he invented a method to visualize interdependent processes.

Some authors and institutes (Kwak, 2003; APM, 2007; Seymour & Hussein, 2014) argue that modern project management started between 1956 and 1958 with the development and application of project management tools and techniques such as CMP and PERT. The CPM method (Critical Path Method) was developed by Kelley and Walker while developing tools to an American chemical Industry (E.I du Pont de Nemours Company). The PERT technique (Program Evaluation Review Technique) was developed by the United States Navy as they were working on the Polaris project – the first submarine-launched ballistic missiles carrying nuclear warheads. According to Kwak, 2003

there are four different periods in the history of modern project management. They are summarized and described in Table 4.

Table 4 - Four periods of modern project Management (Kwak, 2003)

<b>Period</b>	<b>Brief description (major events / developments)</b>
Period 1: 1900 - 1950	<ul style="list-style-type: none"> <li>• Origin of modern era of project management. Project management transformed from a Craft system to Human Relations Administration.</li> <li>• First time defined the concept of job specification, which is specifying knowledge, skills, and abilities needed to successfully perform an activity or job.</li> <li>• First use of the Gant Charts, in Hoover Dam and then in the Interstate Highway projects</li> </ul>
Period 2: 1958 - 1979	<ul style="list-style-type: none"> <li>• CPM and PERT tools adopted as crucial for any project management activities as well as obligatory the use of WBS (work breakdown structure) for big projects.</li> <li>• Creation of the first project management association, known as the International Project Management Association (IPMA).</li> <li>• Creation of the Project Management Institute (PMI)</li> <li>• The advances in computer technology enabled the emergence of several project management software companies and tools</li> </ul>
Period 3: 1980 - 1994	<ul style="list-style-type: none"> <li>• Development of the Projects in Controlled Environments (PRINCE) model</li> <li>• Development of the theory of constraints (TOC)</li> <li>• Development of SCRUM and Agile methods</li> <li>• First release of the PMBOK by the PMI, as an attempt to document and standardize accepted project management and practices.</li> <li>• Standish Group published the first CHAOS report, which is a collection of information on real project failures in Information Technology (IT)</li> </ul>
Period 4: 1995 - today	<ul style="list-style-type: none"> <li>• Development of Critical Chain Project Management (CCPM) – focus on resources to complete project tasks rather than on specific tasks.</li> <li>• Upgrade from PRINCE to PRINCE2</li> <li>• First written Agile Manifesto was published.</li> <li>• Development of the Total Cost Management (TCM) method</li> <li>• Project management is becoming more a science than an art, in terms of understanding the big picture and effectively communicating with others.</li> <li>• Project management must adapt to constant change, uncertainty, and disruptions</li> </ul>

According to Table 4 it can be concluded that the evolution of the project management discipline strongly relies on the advances of computer technology. At the same time, it can also be observed that is turning attentions to social sciences in an attempt to try to understand the extent to which people interaction may impact project outcomes.

### **2.2.2 Project Management - *The State of the Art***

Project management started as an art, turning later into a science (Kwak, 2003; PMI; 2021). This essentially occurs due to the sequential introduction of the several scientific disciplines across the years such as computer technology, probabilistic theories, and social sciences.

There are today innumerable sources where organizations can access latest developments, best practices, tools & techniques regarding how to efficiently manage projects. These include institutes, bodies of knowledge, universities and many more. Much of the work done in such institutes, bodies of knowledge, universities, is done by project management experts that work in projects all around the world (PMI, 2017). Subjects such as, hard (project management tools and techniques) and soft (social sciences) skills, ethics, economy, business, management, and so on, are addressed in such institutes resulting in highly educated and certified project people.

Today's disruptive and unpredictable market conditions put great deal of pressure in organizations, leaving to room for mistakes or to overlook opportunities. In the present time, although the project management tools & techniques have not suffered substantial changes, computer technology continues changing the landscape of project management throughout. In an attempt to standardized project management processes and procedures, organizations have been investing in networked infrastructures whereby cloud solutions (Fox & Peterson, 2014) enable project people to have instantaneous access to the necessary and adequate tools, techniques, and approaches, in order minimize or completely eliminate project risks. Furthermore, renowned project management institutes are adopting a more transversal approach regarding to the methodologies that they apply in project management (PMI, 2017). This reflects the actual high interdependency of project activities. For example, the Project Management Institute (PMI, 2017) published for the first time ever in 2017 in the PMBOK an Agile practice guide standard, arguing that one methodology in isolation is no longer sufficient to achieve success. They argue that a switch to Hybrid Methodologies is vital to project success (PMI, 2017).

However, according to recent research project keep failing at an impressive pace (The Standish Group, 2015; PMI, 2018). According to reviewed literature (Seymour & Hussein, 2014; Orouji, 2016; Radujković & Sjekavica, 2017; PMI, 2017; Almamlook, 2018) the actual trends in project management are essentially focused in two related areas. They are: (1) Project Critical Success Factors, and (2) The role of the Project Manager. The first - Project Critical Success Factors -, concerns to the identification of factors that are vital to guarantee the success of projects (PMI, 2017). According to the research critical success factors may be divided into two dimensions. They are (PMI, 2017; Leonardi & Contractor, 2018): (1) Technical and (2) Relational. Technical critical success factors comprise know-how, know-what, and tangible resources to efficiently accomplish project deliverables. Relational critical success factors comprise essentially soft skills. The second - The Role of the Project Manager – concerns organizational non-tangible aspects such as capital

social. Due to the complexity and interdependence of project activities, managers should be able to coordinate multi-disciplinary knowledge to deliver projects efficiently and successfully. Project managers must adapt to new technologies and be aware of which specialized available tools will work best for each project approach (PMI, 2017; APM, 2020). Furthermore, a project manager must effectively communicate with other project stakeholders from different department organizations, countries, cultures and so on while simultaneously be able to filter the critical information that arrives from the most diverse project communication channels (PMI, 2017; APM, 2020). According to the latest version of the PMBOK from the PMI Institute project managers must adapt to constant change, uncertainty, and disruptions (PMI, 2021). These may include constant changes in the project organizational structure (formal chart), changes in project scope, changes in the project constraints, changes in the project stakeholders and so on. Finally, project stakeholders must interiorize change as constant while working in projects (PMI, 2021). This means that project stakeholder must adopt an agile mind set in every project they work in.

### 2.2.3 Project Management Methodologies, tools & Techniques

A methodology in project management defines the approaches, tools, and data sources that will be used to perform risk management in a project (PMI, 2017). There are different methodologies for different project types (Joslin & Müller, 2014). Although there are universal principles that guide the development of the different project management methodologies, there is not best or worst methodology rather the one that best suits a particular project type (Joslin & Müller, 2014). However, according to latest research there seems to exist a tendency to adopt hybrid methodologies (Chin et al, 2012; PMI, 2017).

There are numerous project methodologies that have been developed by private associations and institutes, or even governmental agencies (PMI, 2017; APM, 2020). A popular approach to classify the different project methodologies is to divide them in two separated fields. They are: (Strategyex, 2017): (1) Software development, and (2) other areas, such as construction, health care, food, and beverage, and so on. In Table 5 are illustrated the most common project management methodologies applied in the two above mentioned fields (Strategyex, 2017).

Table 5 - Project management methodologies (Strategyex, 2017)

Methodologies	Description
Waterfall	A project is completed in distinct stages and moved step by step toward ultimate release to consumers. Activities on waterfall projects have to happen in the exact order and one set of activities cannot start before the previous one ends. It doesn't react well to frequent changes, which is why it gets a bad reputation in software development community.
Agile	It favors responding to change over careful planning. It assumes that there's no one-size-fits-all approach in managing a project. It lets people solve problems by collaborating than forcing them to follow a procedure. Timelines and budgets are difficult to define. Very huge

	reputation among the software development community.
Kanban	Kanban is a Japanese term that means – billboard. It helps organizations visualize, plan, and organize their work by controlling various logistic elements and prioritizing tasks on boards.
Scrum	Scrum helps small, close-knit teams develop complex products incrementally. Scrum focuses on how people work instead of what they do. Scrum relies on agile principles and is the most popular agile methodology among the software development community.
Extreme Programming	It prescribes everything, from how to organize projects and develop software, to how to increase developers' productivity and what is the best way to collaborate on code. It advocates frequent releases, iterative development, and high level of customer involvement
Crystal methods	It focuses primarily on people and their interactions when working on a project rather than on processes and tools. people's skills and talents as well as the way they communicate has the biggest impact on the outcome of the project.
PM methodology	General Methodologies for general business types based on PMBOK (PMI, 2021)
Traditional project management	It is a universal practice which includes a set of developed techniques used for planning, estimating, and controlling activities reach a desired result on time, within budget, and in accordance with specifications. It is mainly used on projects where activities are completed in a sequence and there are rarely any changes.
CPM	Critical Path Method is a mathematical algorithm that helps analyze, plan, and schedule complex projects. It identifies longest path of planned tasks necessary to meet the deadlines and identify the early start and finish dates
PERT	The Program Evaluation Review Technique, is a visual tool in project planning that helps organizations analyze and represent the activity and evaluate and estimate the time required to complete the project within deadlines, identify start and end dates, and ultimately reduce costs and time needed to complete the project.
CCPM	Critical Chain Project Management is a schedule network analysis technique that considers task dependencies, limited resources availability (people, equipment, physical space), and buffers necessary to successfully complete the project.
Six Sigma	It is a problem-solving methodology that aims the improvement of business and organizational performance by using several methods and tools. It primarily identifies and corrects errors and defects in manufacturing and business processes.
PRINCE2	Projects IN Controlled Environments, is a flexible process-based method that helps wrap up projects more effectively and efficiently.
ToC	Helps identify the crucial limiting factors (usually referred to as a constraint or a bottleneck), that stands in the way of achieving project objectives.

Continuation of Table 5 - Project management methodologies (Strategyex, 2017)

Although not consensual, some literature suggests choosing the project management tools to manage a certain project type instead of a project methodology. The reason is because a given project management methodology can incorporate multiple project management tools & techniques (PM<sup>2</sup>, 2016; PM<sup>2</sup>, 2016; PMI, 2017; PMI, 2021). In Table 6 are illustrated the most common 16

tools & techniques used in project management proposed by the Directorate-General for Informatics of the European Commission (PM<sup>2</sup>, 2016).

Table 6 - Project Management recommended tools and techniques (PM<sup>2</sup>, 2016)

<b>Tools &amp; techniques</b>	<b>Brief description</b>
PESTEL Analysis	Is used to understand how the external factors (Political, Economic, Social, Technological, Environmental, and Legal factors) impact objectives.
Make or Buy Analysis	Analysis the pros and cons of make or buy assets (tangible and intangible)
Stakeholder-Interest/Influence Matrix	It facilitates and documents the analysis of the interest and influence of each stakeholder in the project
Risk Likelihood/Impact Matrix	Is used in the qualitative assessment of risks, after the project risks have been identified
Work Breakdown Structure (WBS)	It is a hierarchical division of the project into smaller work components, that can be used to assign work or to estimate effort & cost.
Deliverables Breakdown Structure (DBS)	Used to identify and document the deliverables of a project and their interdependencies
Effort and Cost Estimates	The Effort and Cost Estimates technique derives from the Work Breakdown Structure (WBS): each work item (task) is estimated in terms of effort and cost
Three-Point Estimates using PERT	Is part of the PERT toolset and provides a weighted average of activity duration or cost, outputting an optimistic estimate of duration or cost, a most likely estimate, and a pessimistic estimate.
Project Scheduling	Used to identify dependencies between tasks, to assign resources for each task, to identify task start and end dates, and to work out the overall project duration
Gantt Charts	This technique is used to represent the schedule, phases, and activities of a project in a single visual sheet
Critical Path Method (CPM)	It is a modelling technique that uses a mathematically based algorithm, to calculate the total duration of a project.
Critical Chain Method (CCM)	It is a modelling technique, used to plan and schedule a set of activities, or projects. It considers resources and their levelling, as well as the behavior of the Project Manager when estimating duration of activities in a project
Earned Value Management (EVM)	It is a technique used to monitor and control the performance of projects, providing an objective view of performance based on the project financials
Pareto Analysis	Identify those issues, that cause most problems in a project. The Pareto principle states that generally 80% of the effects come from 20% of the causes
Lessons Learned	It is a way of identifying development / improvement areas within a project for the purpose of helping similar projects avoid certain pitfalls in the future

The tools and techniques illustrated in Table 6 are not the only ones applied in project management. More tools & techniques regarding risk management in projects are illustrated in Chapter 3 – Risk, and Risk Management in organizations.

## 2.3 Project Management Challenges

### 2.3.1 Why Projects Fail and why Projects Success?

Before starting to enumerate the reasons found in the literature that may lead a project to failure, it is important to introduce the definition of what project success and failure is. According to the reviewed literature there is no consensus on the definition of project success and project failure, rather different criteria that defines a project success and a project failure (PMI, 2017; PMI, 2020; APM,2020; ISO, 2021).

Project success is not only delivering according to scope if the project deliverables are not used, or do not provide sufficient benefit to the customer or end-user (Bannerman, 2008). The definition of project success is then a commitment between several elements, such as time, cost, quality, and client success reflected by the efficient use, satisfaction, and effectiveness of the project in benefiting intended users (Pinto & Slevin, 1988; Lewis, 2011). In terms of project outcome type, the Standish Group (The Standish Group, 2015) defines three different resolutions for all projects. They are: (1) **Project Success** (Successful): a project that met all the project defined objectives. (2) **Project Unfinished** (Challenged): project that met some but not all the objectives. (3) **Project Failure** (Failed): a project that did not met any of the defined objectives.

Harold Kerzner (Kerzner, 2017) a renowned name in Project Management and professor at the Baldwin Wallace University proposes a more complete approach to define a project outcome. He defines four different resolutions for all projects. They are: (1) **Complete Success**: The project met the success criteria; value was created and all constraints were adhered to. (2) **Partial Success**: The project met the success criteria, the client accepted the deliverables and value was created, although one or more success constraints were not met. (3) **Partial Failure**: The project was not completed as expected and may have been canceled early on, in the life cycle. However, knowledge and/or intellectual property was created that may be used on future projects. (4) **Complete Failure**: The project was abandoned, and nothing was learned from the project.

According to Baccarini, 1999, Project Success could have four dimensions that must be addressed. They are (Baccarini, 1999): (1) Efficiency, (2) Impact on the customer, (3) Direct and business success, and (4) Preparing for the future. Baccarini argues that success depends on the point of view (Baccarini, 1999). This means that a project may have been classified as successfully delivered by those who participated in (internal and external stakeholders) and classified as unsuccessfully delivered from the point of view of the customer (end user or general society). Baccarini suggests that project success should be divided into two major components. They are (Baccarini, 1999): (1) Project Management Success, and (2) Product Success.

Baccarini argues that project management success and product success are different possible outcomes of a project, and special attention should be given to the component of higher order or of greater importance, which according to Baccarini is the product success (Baccarini, 1999). Furthermore, Baccarini, argues that the criteria for measuring project success must be set at the beginning of a project, otherwise different team members will have different perceptions regarding the directions a project is heading to. As seen in the above presented literature review there is no consensus regarding what project success or failure is. Instead, there are criteria and dimensions that must be successfully accomplished to classify a successfully delivered project. Therefore, it can be concluded that organizations must define their own criteria that defines what project success or failure outcome is before initiating a project.

According to a report from the Standish Group Institute, an independent organization that reports on world private and public project management activities, over the last 20 years the project management field has experienced increasing layers of project management processes, tools, governance, compliance, and oversight. However, these activities and products have done little or nothing to improve project success (The Standish Group, 2015). In fact, according to a survey done by the Standish Institute in 2015 only 29 % of the delivered projects had a successful outcome (The Standish Group, 2015). Such results are supported by the survey published by the PMI Pulse of the profession (PMI, 2018), where it shows that in average more than 50% of delivered project experienced any time of scope creep (a continuous or uncontrolled growth in a project's scope (PMI, 2017)).

There can be four major reasons why projects fail. They are (The Standish Group, 2015): 1- Low or lack of End-user Involvement and input, 2- Low or lack Executive Management support, 3- Unclear statement of Requirements, 4- Uncontrolled change Requirements & Specifications. The results published in the Standish Group report in 2015 are no different from the research conducted by David Hillson in 2012 and more recently in 2018, a renowned project risk researcher and author.

Hillson argues that regardless of the tools and techniques available to manage projects, these will keep failing at an impressive pace if three major areas are not properly addressed (Hillson & Murray-Webster, 2007; Hillson, 2012; Hillson, 2018). They are: (1) **Processes**, (2) **Principles**, and (3) **People**. Processes because different approaches and standards still needs improvements to perform project and risk management. Principles because it is still very difficult to universally define what risk really is because it is precepted by different people in different ways (what may be a risk for one may not be for another person). People because project management is still done by people. People's culture, know-how, skills, interactions, roles, dynamics are different from people to people and there is (and there will never be) no universal behavioral model to people follow on (Hillson & Murray-Webster, 2007; Hillson, 2012; Hillson, 2018).

While some authors argue that the major cause of project failure has to do with poor or lack of management and leadership (Boikanyo & Kaiser, 2011; Holgeid & Thompson, 2013; Anthopoulos et al., 2016; Floris & Benvie, 2017), others argue that poor or lack of project risk management is the major cause of project failure (Abbasi et al., 2014; PMI, 2017; Mesly, 2019; West, 2019; Gunduz & Yahya, 2018). Edward Shehab, a renowned name in the project management field, identifies nine major reasons why projects fail. They are illustrated in Table 7.

Table 7 - Reasons Why Projects Fail (Shehab, 2018)

<b>Reasons why projects fail</b>	<b>Brief description</b>
Organizational Culture	Not all the Organizations are prepared with the infrastructure, education, training, or management discipline.
Inadequately Trained of Project Managers	Especially in developing countries where business grow faster than the organizational infrastructure often people that work in projects lack the proper knowledge and certifications that should be expected for them to perform their tasks successfully.
Lack of Project Governance	Sometimes Organizations grow so fast or change the type of organizational structure (Function to Projectized as example) that they have no time to adjust the Project Governance accordingly.
Inadequate Tools and Methods	Often Organizations grow so fat, or become so ungoverned that for one same task, different documents, procedures, and multiple software, may be used to plan and estimate projects – redundancy in task execution.
Poor Requirements Management	This may result in delivering a wrong product, deliver a product without important features and functions, make constant changes in the scope, or even lead to drop the project once the true scope and feasibility is known.
Poor Planning and Estimating	This task should be done by very professional people, high educated, certified, and huge experience within the respective branch. Poor planning will lead to underestimations of efforts and budgets, as well as fatal outcomes.
Inadequate Communication and Reporting	Once again, the necessary skills are needed to create a Communication Plan. It is always better to have someone certified (PMP, PHD) on the communication are to bring all the needed loose ties together.
Poor Risk Management	Most Organization underestimate the power of effective risk management and how it could help meeting the Organization objectives. Some are reluctant in adopting risk management practices because it may show how not-well prepared an organization is in order to pursuit the desired Goals.
Misalignment between Projects and Organizational Strategy	Often choosing the wrong activity to start a project, or start the wrong project, will bring countless problems. The Organization should implement an enterprise view of all the project portfolios and group investments in order help to identify, prioritize and where the efforts should be applied.

### 2.3.2 Project Management Critical Success Factors

Before addressing the proposed subject in this chapter, a few definitions regarding the means used to measure critical factors will be introduced. More concretely, the terms indicators, their importance and types will be defined in the first sub-chapter.

To accurately perform any type of measurement one must first define through which means (tools) these will be done. Usually, such means, or tools are called of indicators. Defining and interpreting indicators is extremely important because depending on how indicators are defined, assessed, and interpreted decision-making is performed and the impacts of such decision may involuntarily hurt an individual, group, or organization.

In project management, an indicator is a variable that measures elements of a portfolio, program, or project (PMI, 2017). An indicator provides a sign or a signal that something exists or is true and is used to show the presence or state of a situation or condition (PMI, 2017). Indicators provide critical Monitoring & Evaluation data at every level of portfolio, program, or project. An indicator can thus be defined as a quantitative metric that can be used to evaluate the quality of an activity, project, or program (Camarinha-Matos & Abreu, 2006; Rugg, 2010). There are many types of indicators. Some of them are business area, or industry specific (Parsons et al., 2013; DAAD, 2019). For each variable that can be measured there can be one or more different indicators. However, usually indicator types lay into four major categories ((1) input indicators, (2) process indicators, (3) outcome indicators, and (4) impact indicators. They are illustrated in Table 8 (Parsons et al., 2013; DAAD, 2019).

Table 8 - Types of Indicators (Parsons et al., 2013; DAAD, 2019).

<b>Categories</b>	<b>Description</b>
Input Indicators	Also called as Resources Needed Indicators refers to the needed resources for the implementation of an Activity, Intervention or Project. Usually, they are set at the initial phase of a Project. They include. Policies, Human Resources, Materials, Financial Resources.
Process Indicators	Also called as Immediate Results / Performance Indicators whether planned activities were accomplished or not. Output Indicators add more details in relation to the output (product) of the activity.
Outcome Indicators	Also called as Intermediate Results/Change Indicators, refer to the Objectives of an Intervention, Project, or Activity outcome. They refer to the reason why it was decided to conduct certain Project or Activity. They are the result of both the “quantity” (“how many”) and quality (“how well”) of the activities implemented.
Impact Indicators	Also called as Long-Range Results Indicators measure long-term impacts of a Project. Include the cumulative effect of programs over time.

A very popular way to characterize indicators is credit to G. Doran in his work "There's a S.M.A.R.T. way to write management's goals and objectives" in 1981 (Doran, 1981). However, a team of researchers from a non-governmental organization (Lennie et al, 2011) while participating in cross - border aid program in 2011 concluded that the typical characterization of indicators proposed by Doran, 1981 was no longer enough to translate the needs felt on the field. They proposed the SPICED indicators in opposition to the SMART indicators. Nevertheless, the literature very often considers the SMART approach as being the more reasonable approach to define a good indicator. In Table 9 are illustrated the SMART, and SPICED indicators according to Doran, 1981, and Lennie et al, 2011, respectively.

Table 9- SMART and SPICED Indicators (Doran, 1981; Lennie et al, 2011)

<b>SMART Indicators</b>	<b>SPICED Indicators</b>
Specific (to the change being measured)	Subjective Measurable: have a special position or experience that gives them unique insights which may yield a very high return on the investigators time. In this sense, what others see as 'anecdotal' becomes critical data because of the source's value.
Measurable (and unambiguous)	Participatory Attainable: Objectives and indicators should be developed together with those best placed to assess them. This means involving a project's ultimate beneficiaries, but it can also mean involving local staff and other stakeholders.
Attainable (and sensitive)	Interpreted (and communicable): defined objectives/indicators may not mean much to other stakeholders, so they often need to be explained.
Relevant (and easy to collect)	Cross-checked: The validity of assessment needs to be cross-checked, by comparing different objectives/indicators and progress, and by using different participants, methods, and researchers.
Time bound (with term dates for measurement)	Empowering: The process of setting and assessing objectives/indicators should be empowering in itself and allow groups and individuals to reflect critically on their changing situation.
N/A	Diverse and disaggregated: There should be a deliberate effort to seek out different objectives/indicators from a range of different groups

Another way to characterize indicators and goals which is gaining huge popularity across the industry is known by the acronym FAST (Nunes & Abreu, 2020). FAST stands for: (F) **frequently discussed**, (A), **ambitious**, (S) **specific** (S), (T) **transparent**. This way of characterizing indicators and goals is considered a more efficient approach to conceptualize and implement an organization's strategy because it enables to faster respond to the actual dynamic business's environment (Nunes & Abreu, 2020). Furthermore, FAST indicators are tightly interrelated with the OKR framework (Objectives and Key Results) which is one of the most popular methodologies to drive organizational strategy with an agile mind set (Wodtke, 2016; Strategyex, 2017).

Critical Success Factors (CSFs) can be defined as those few things that must go well to ensure success (Boynton & Zmud, 1984). Therefore, those few things represent those managerial or organizational areas that must be given special and continuous attention (Boynton & Zmud, 1984). Very often CSFs are confused with Key Performance Indicators (KPI's). One simply way to understand the difference is to say that CSFs from KPI's is as follows: **CSFs** are the factors that cause success (actions that are important to achieve goals and objectives), (Caralli, 2004). **KPIs** are tools to measure success. In other words, are tools that are used to measure and monitor the achievement of objectives and goals (Caralli, 2004) Both, KPI's and CSF's should be defined across the different levels of an organization as illustrated in Figure 4. The sum of all of them form part of an organization's strategy (Mosse, & Sonthmeier, 1996).



Figure 4 - Typical Pyramid Corporation (Adapted from Mitzenberg, 1979).

Because in projects it is usual to have several tasks running simultaneously, it may be very difficult to the project team understand which tasks are “more” or “less” important - in a certain point in time of the project lifecycle -, to successful deliver a project (Rockart, 1979). For example, such “more” important tasks can be considered as critical success factors in Project Management (Rockart, 1979). CSFs are critical organizational areas where things must go right for the business to flourish (Rockart, 1979). Critical success factors are components of the project that have to be put in place to ensure the successfully accomplishment of a project (Gerry, 2009). CSFs may be those products and features that are particularly valued by a group of costumers, and of course, the organization that delivers those products and features must excel to outperform the competition (Gerry, 2009).

Hillson, 2002 suggests that effective project management is essential dependent on a fundamental scientific field in project management: Risk Management (Hillson, 2002; Hillson, 2012; Hillson, 2018).

In Table 10 are illustrated the five top-critical success factors in project management consensual among several researchers (Steinfort & Walker, 2007; Cao & Swierczek, 2010; Alexandrova & Ivanova, 2013; Orouji, 2016; Strategyex, 2017; Workday, 2018; Arena, 2018; Nunes & Abreu, 2021).

Table 10 - Five Principal Critical Success Factors in Project Management

<b>CSFs</b>	<b>Brief description</b>
Full Engagement	Commitment of all stakeholders including, team members, project program and portfolio managers, top management, sponsors, and so on.
SMART Goals	Ensure that Project goals and deliverables are SMART: <b>(S)</b> Specific, the goal should target a specific area of improvement or answer a specific need. <b>(M)</b> Measurable, the goal must be quantifiable, or at least allow for measurable progress. <b>(A)</b> Attainable, the goal should be realistic, based on available resources and existing constraints. <b>(R)</b> Relevant, the goal should align with other business objectives to be considered worthwhile. <b>(T)</b> Time-bound, the goal must have a deadline or defined end.
Leadership	Good Project Leadership all way through all project phases. Best Practices must be employed at every phase of the Project.
Planning	Existence of an Agreed Conflict resolution plan, a proper Risk Management plan, and a proper Project Planning plan
Effective Information Flow	Communication - Probably one of the most important aspects! An effective project manager must be an effective communicator. Communication is the only way via which tasks are assigned and monitored, project issues are escalated and the medium via which goals, performance, and feedback are passed across.

Another approach regarding the critical success factors in project management is proposed in the notable works done by Pinto and Slevin in 1987, and 1988, which are among the most ever cited works to be found in the literature review (Shenhar et al., 1997; Shenhar et al., 2007; Müller & Jugdev, 2012; Cesar et al., 2014; Du Randt et al., 2014; Lamprou & Vagiona, 2019).

Pinto & Slevin, 1988, surveyed circa 600 project managers from 7 different project fields (Construction, Hardware, Software, Food, Drugs, Services industries) asking them to name the principal issues related with project success or failure accomplishment. They find out not only the main critical success factors regarding project management in general, but also which factors are more, or less important across the different phases of a project lifecycle (PLC). An adapted reproduction of their findings is illustrated in Figure 5.

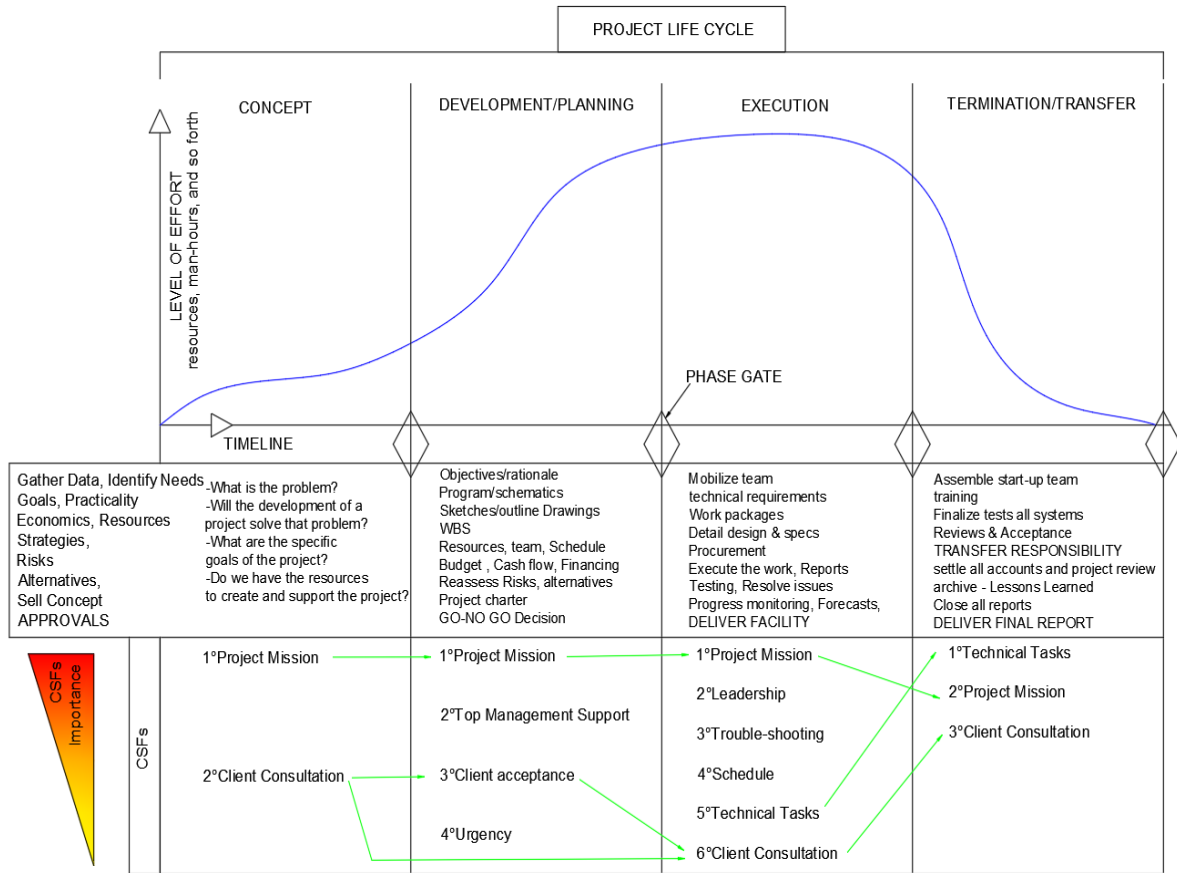


Figure 5 - Critical Success Factors across the PLC (Adapted from Pinto & Slevin, 1988)

According to Figure 5 the principal critical success factor for project phases I, II, and III, is the Project Mission. In the last phase (Termination / transfer phase), the Project Mission is no longer as important as the Technical Tasks, which rise from almost the bottom at the previous phase (Phase III) up to the top in the last phase. When analyzing the first three major critical success factors in all the different project phases, it can be concluded that factors that relate to people relationships (Project Mission, Top Management Support, Leadership, Client Consultation) and objectives (Project Mission, Client Acceptance, Technical Tasks) are the ones with the highest importance. Such results concluded in 1988 are still valid today and in line to what is presented in Table 10 - Five Principal Critical Success Factors in Project Management, to what Hillson, 2012 argued regarding the Principles, Process, and People, and with the results of the Standish Group, 2015 report. These three investigations / research - Pinto & Slevin, 1988; Hillson, 2012, and The Standish Group, 2015 – that were conducted in different points in time spaced on circa 30 years show that the results are pretty much identical which leads to the conclusion that few or nothing has improved regarding two of the major critical factors in projects – (1) communication and (2) collaboration (relational interactions between project people across a project lifecycle).

Although some authors already tried to establish a framework to identify project critical success factors - as illustrated across this section (*critical success factors in project management*) - they are still very high-level ones which often do not bring measurable benefits to organizations (Nunes & Abreu, 2020). This happens essentially because such high-level project critical success factors do not offer organizations a quantitative dimension of what such project critical success factors represent, and thus are considered as non-actionable critical success factors (Strategyex, 2017; Nunes & Abreu, 2020). This means that such critical success factors are not able to be properly used in decision making because they lack a quantitative propriety that would enable the understanding, and the implementation of actionable measures. As the saying goes, only what is measurable can be managed.

It is exactly in this point that the proposed model in this work aims to help organizations by providing a solution that quantitatively identify and understand project critical success factors regarding the collaborative dimension, which connects the several independent project critical success factors illustrated in Figure 5 (mission, leadership, troubleshooting, technical tasks, and so on).

# Chapter 3

## 3 Risk, and Risk Management in Organizations

*"A ship is safe in harbor, but that's not what ships made for."*

William Greenough Thayer Shedd

### 3.1 Introduction

Risk management is considered by many as a fundamental pillar in project management as in many other areas that span from pharmaceutical, aviation, nuclear, food and beverage, medicine, operations, just to name a few (Hillson, 2014). Several researchers consider project risk management as project management (Hillson, 2006; Dionne, 2013; Hillson, 2014; PMI, 2017). Efficient risk management in organizations is viewed as an enabler to achieve organization's goals and objectives. Therefore, some organizations, function of the services products or solutions that they deliver, develop their own risk management approaches standards and frameworks (Hillson, 2006; Dionne, 2013; Hillson, 2014; PMI, 2017). Although renowned and accredited institutes, body of knowledges, non-governmental and governmental associations, such as the ISO (International Organization for Standardization), the PMI (Project Management Institute), the IRM (The Institute of Risk Management), the APM (Association for Project Management), the IEC (International Electrotechnical Commission), the ANSI (American National Standards Institute), the RIMS (The Risk Management Society), or other less known that operate at both, regional and nation level, such as AXELOS (Cabinet Office on behalf of Her Majesty's Government - UK), FAA (Federal Aviation Administration - USA), NIST – National Institute of standards and Technology (USA), FISMA – Federal Information Security Management Act of 2002 - USA), ASSE – American society of safety engineers - USA), ENISA – European Union Agency for Network and Information Security - EU), FRC – Financial Reporting Council - UK) developed risk management standards, organizations develop own their in-house risk management procedures. (Hillson, 2006; Dionne, 2013).

Given the importance of this subject an extensive literature review regarding risk and risk management in organizations has been conducted across this work, documenting the most relevant subjects regarding the application of risk management in organizations, namely in organizations that deliver projects. In this chapter is introduced the second pillar that supports the development of the proposed model in this work – (2) risk management. Throughout this chapter will be essentially discussed the importance of risk management in project management. Subjects, such as

risk and risk management definitions, risk management processes and framework, risk management benefits and limitations in a project organizational context will be detailed addressed.

## 3.2 Risk

### 3.2.1 Risk & Uncertainty

Risk can be simply defined as an uncertain event or condition that, if occurs has a positive or a negative effect on one or more project objectives (PMI, 2017; APM, 2020; ISO, 2021). Risk is often expressed in terms of a combination of the consequences of an event and the associated likelihood of occurrence of that event (Hillson, 2006). Uncertainty is the state, partial or full, of lack of information related to the understanding or knowledge of a potential event and its consequence or likelihood (Hillson, 2006). An event can be one or more future occurrences and can have several causes (PMI, 2017; APM, 2020; ISO, 2021). If an event occurs, consequences are expected. Consequences are the outcome of an event affecting project objectives. A consequence can be certain or uncertain and can have positive or negative effects on objectives. Consequences are expressed quantitatively and qualitatively. Uncertainty can be defined as a situation where the current state of knowledge is such that the order or nature of things is unknown, the consequences, extent, or magnitude of circumstances, conditions, or events is unpredictable, and credible probabilities to possible outcomes cannot be assigned (APA, 2018). According to this definition of uncertainty, it can be concluded that risk is not the same as uncertainty. In fact, risk is related to uncertainty, but it is different from uncertainty. In this line of thought it can be concluded that all risks are uncertain, but not all uncertainties are risks. The definition and relationships between risk and uncertainty according to Hillson are illustrated in Figure 6.

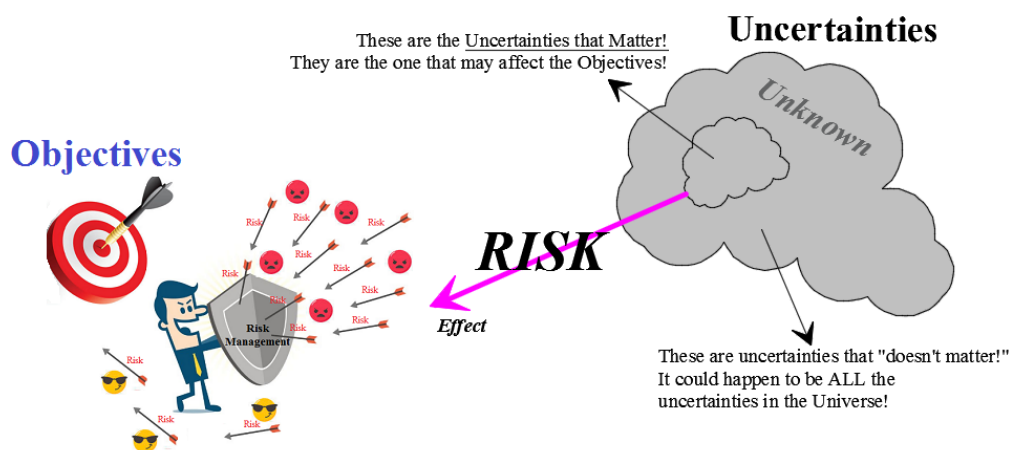


Figure 6 – Risk is the Uncertainty that matters.

If risk is the uncertainty that matters, it is then important to find out how many uncertainties exist and how they may impact project objectives. In Table 11 are illustrated the four different types of uncertainties according to Hillson, 2014.

Table 11 - Uncertainties types (Hillson, 2014)

<b>Risk Type</b>	<b>Brief description</b>
Stochastic uncertainty or Event Risk	This type of uncertainty is widely known and accepted and can be found in most project Risk Registers. It is as well where most of the actual thing is because this is of the future event type that may or may not occur. They are of the type of possible events! – Events that happen or don’t happen! To manage these types of risk, there are well-established techniques for managing them (Risk Management Standards)
Aleatoric uncertainty or Variability risk	It is a known limited number possible of results that will happen. It has to do Variability (Aleatoric (in an event, there fixed number of known outcomes not knowing which will come up). Example is People’s productivity level within a task. The expected it may differ from the actual, but one thing we know, either its faster, slower or the same! An example of this type of uncertain could be for example when the questions arise; what is the probability of meeting a specific Target? And what is the potential range of variation in outcome? In this case, needs to be considered both types of uncertainty Stochastic and Aleatoric! To be able to answer these questions a Monte Carlo Simulation would be required! Three Point Estimation! - Variability of things we planned to do that it could be as an outcome.
Epistemic uncertainty or Ambiguity risk	It comes from the Greek word-episteme, and it means knowledge. It has to do with things that we are not sure that we know, or that we do not have enough information about! Things are not clear! It has to do with Ambiguity, meaning ambiguity that we are not sure of what we are doing. There is a lack of knowledge about some event. There is uncertainty about the event itself. It is not in the future, rather a present uncertainty and it matters! Needs to be rerecorded understand, sized and managed. As an example, is to figure out that we do not know exactly what the customer wants. Learning from experience (lessons learned), prototyping and simulating, before acting, seems to be the best approach to manage such risk types.
Ontological uncertainty or Emergent risk	Known as Unknow-Unknowns or Black Sawn. The state that results when a new experience does not fit nicely into existing mental models of how things work and remembered experiences. This is of the type of unknown-unknowns or blind spots. It has to do with concept, mindset, and conceptual framework. These are things that we cannot even imagine! They are out of our frame of reference. These are the one that we cannot see, we cannot think about it, and when they happen is already too late, they are no more risks, but consequences! These types of uncertainties cannot be written in a Risk Register, but we can respond to that: HOW? - The answers have to do with robustness, resilience, flexibility, disaster recovery and preparedness, all the issues related to Organizational readiness!

It can be concluded that uncertainties are things from a very different nature than risk and need to be managed in a different way. Some types of uncertainties are well known and well characterized but others, like the ontological uncertainty, are completely out of the normal common sense wide of

range and thus the risk management discipline cannot properly address respective resulting events. In this case the only solution is the adoption of contingency measures (Hillson, 2012).

Considering that all risks are uncertain and that not all uncertainties are risks, risk is an uncertainty that matters, and if it occurs, it can affect project objectives in a negative or positive way. Furthermore, risk has probability of occurrence (Pipelow, 2012), therefore, it can be concluded that a threat is a risk characterized with a probability of occurrence and an uncertainty effect regarding the impact that may have in project objectives. An opportunity, on the other side, is a risk characterized by an uncertainty, that if it occurs will positively affect the objectives of a project.

### **3.2.2 Risk History & Evolution**

The history of risk is embedded with the mathematics' breakthroughs that happened in the renaissance period (Stahel et al., 2017). The way that risk is seen today, is rooted in the Hindu-Arabic numbering system that arrived in Europe about 800 years ago (Stahel et al., 2017). However, the first serious studies on risk began in Europe during the renaissance period as people start to leave old constraints (beliefs) behind and embracing the new world (Bernstein, 1998; Stahel et al., 2017; Bardi, 2007).

It is credit to Pascal and Pierre de Fermat the discovery of the theory of probabilities. This occurred as they were challenged to solve an old gambling problem studied by Luca Paccioli, posted by their friend Chevalier de Méré. This is considered as the mathematical heart of the concept of risk which made possible for the first time in history to make decisions and forecast the future with help of numbers (Covello & Mumpower, 1985; Bernstein, 1998).

As the years went through, mathematicians transformed probability gambling theory into a powerful instrument for organizing, interpreting, and applying information. It follows a period of great discovery in the field of mathematics. For example, Bernoulli invented the Law of Large Numbers, De Moivre suggested the structure of the bell curve and discovered the standard deviation, Thomas Bayes demonstrated that by mathematically blending of new information into old information better and more informed decisions can be taken, and Francis Galton discovered the regression to mean (Bernstein, 1998). In 1952 Markowitz made a demonstration that revolutionized Wall Street, corporate finance, and business decisions around the world. He demonstrated that investing only in one product is an unacceptable risk, and that diversification is the right choice (Bernstein, 1998). Later in 1964 Sharp and Lintner in the finance area, develop the CAPM (Capital asset pricing model) model which is a model used to determine a theoretically appropriate required rate of return of an asset to make decisions about adding assets to a well-diversified portfolio (Rossi, 2016). The model aims to calculate and explain what the relationship between the risk is and expected return of an investment (Rossi, 2016). The CAPM is one of the underlying building blocks of Modern Portfolio Theory and is constructed on several strong

theoretical assumptions regarding the behavior of financial markets and investors (Boda & Kanderova, 2014). In 1976 Stephen A. Ross in the finance and market fields invented the APT (Arbitrage Pricing Theory). The APT is a one-period model in which every investor believes that the stochastic properties of returns of capital assets are consistent with a factor structure (Huberman & Wang, 2005). Risk as a science gained strong popularity in the late 70's (Ruckelshaus, 1983). Politicians, civil organizations, researchers, experts, generals, publishers, and institutions had the need to tackle risk in a more systematic way

In 1980 the international risk research community created its own professional society - Society of Risk Analysis (SRA) which has published Risk Analysis: An International Journal since the year 1981 until today (Renn, 1990). In 1992 Eugene Fama and Kenneth French, developed a model in asset-pricing and portfolio management, to describe stock returns (Almwalla & Karasneh, 2011). In 1994, JP Morgan develops Value at Risk (VaR), which is a measure of the risk of loss for investments. The model estimates how much a set of investments might lose (with a certain probability) under normal market conditions, in a period such as one day, for example (Abad et al., 2014). Another very important breakthrough occurred as risk started no longer to be seen only as a threat, rather as an opportunity. Before 1997 all official published risk management standards used exclusively negative definition of risk as being synonymous of danger, hazard, loss – it was an uncertainty that could only have a negative effect on objectives (Hillson, 2007). Since then, risk started to be seen as neutral meaning that risk is an uncertainty that that could affect positively or negatively objectives (Hillson, 2007).

### 3.2.3 Risk Types

To better decide which strategy should be taken to efficiently manage risk, is critical to understand first how risks can be classified regarding risk perspectives. In Table 12 are illustrated the principal types of risks perspectives.

Table 12 - Risk Types perspectives: Particular, Personal, and Global (Hillson, 2007; Iso, 2021)

Perspective	Description
Specific Perspective	Threats, opportunities, risk individual, and risk overall
Personal Perspective	Risk attitude, risk seeking, risk tolerant, risk averse
Global Perspective	Corporate governance risk, business risk, reputation risk, business continuity risk, disaster recovery risk, strategic risk, financial/credit/treasury risk, country risk, political risk, information security risk, fraud risk, market risk, project risk, operational risk, project risk, operational risk, technical risk, health and safety risk, environmental risk, collaborative risk

Some authors suggest three major risk dimensions that are likely to be experienced by organizations as they engage in open innovation projects (Abreu et al., 2018). They are: (1) **pure risk or uncertainty** (the probability of an event occurrence that puts at stake the success of the innovation

project), (2) **risk of an innovation project** (that is related to the fact that there is substantial portion of the risks associated with estimates, such as resources, duration of the task, costs, among others, and comprises the business, political or regulation, and operational risk sub types) and, (3) **collaborative risks** (that is related to the fact that a collaborative ecosystem can be characterized by a set of relationships that are established between several entities, such as companies/organizations, knowledge, resources, and tasks, and contains the risk of collaborative management, behavioral risks, risk of assigning tasks to partners, and the risk of critical enterprises).

Another approach to classify risks is to classify risks in terms of losses (Figure 7). This type of representation is mainly applied in the field of operations and investments but has been extended to other areas (Pezier, 2002). The advantage of this classification is that relates risk with possible losses. This immediately indicates out what is likely expected to happen in a certain situation. Risks and losses can be categorized based on degree of severity and frequency of occurrence, and can be divided in Nominal, Ordinary, and Exceptional Operational Risks (Pezier, 2002).

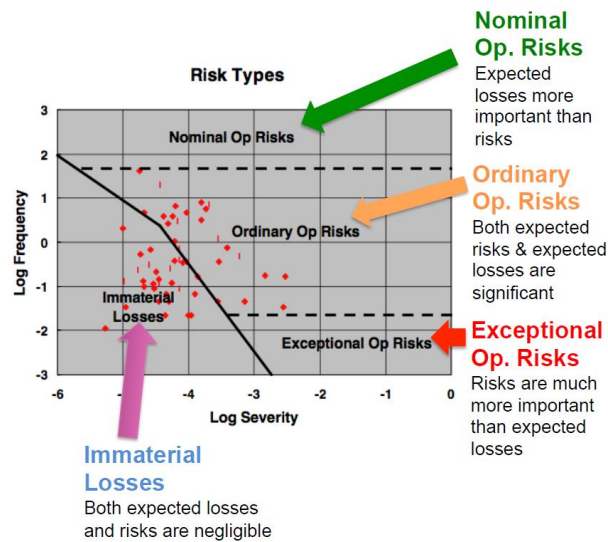


Figure 7 - Losses Risk Classification Type - Operational Risks (Pezier, 2002)

As it can be seen in Figure 7 nominal, ordinary and exceptional risks, can have an impact regarding the immaterial losses. In the x axis the log severity indicates the impact of a risk from a scale between 0 (small harm) up to -6 (very harm). In the y axis is indicated the log frequency that ranges from -3 (low frequency) up to 3 (high frequency). In a nutshell, according to Figure 7 it can be concluded that exceptional risks (also called as totally unexpected) have high immaterial losses than for example nominal risks (also called as expected risk). This clearly illustrates the impact of uncertainty in project objectives is higher than the impact on project objectives from known risks.

### 3.2.4 Factors that Trigger & Influences Risk

Factors that trigger and influences risk can be divided into two major categories according to Hillson, 2007. They are: (1) **intrinsic characteristics** (internal), they have to do with personal characteristics, and (2) **environment** (external), that arise from the environment where one is embedded. Internal and External factors are illustrated in Table 13 (Hillson, 2007).

Table 13 – Factors that Trigger & Influences Risk (Hillson, 2007)

Internal (personal)	External (environment)
<ul style="list-style-type: none"> <li>• Risk Attitude</li> <li>• Lessons Learned</li> <li>• Emotional Literacy</li> <li>• Heuristics &amp; Biased Behavior</li> <li>• Emotions &amp; Emotional Intelligence</li> </ul>	<ul style="list-style-type: none"> <li>• Risk Exposure &amp; Prioritization</li> <li>• Group Risk Culture</li> <li>• Technology</li> <li>• Religion</li> <li>• Law</li> </ul>

Hillson, 2007, addresses special attention to the internal factors and namely the risk attitude. He argues that risk attitude is the major driver that that triggers and influences risk. An attitude can be defined as a state of mind, a mental view or disposition regarding a fact or state (Hillson, 2006, 2014). In this line of thought, risk attitude can be defined as the adopted position by an individual or group in relation to a given situation (Hillson, 2006). Hillson, argues that risk attitude can be divided in three major categories. They are: (1) Risk Averse, (2) Risk Tolerant, and (3) Risk Seeking. These 3 categories define the well-known Risk Spectrum, or Risk Appetite behaviors, and are illustrated in Figure 8.

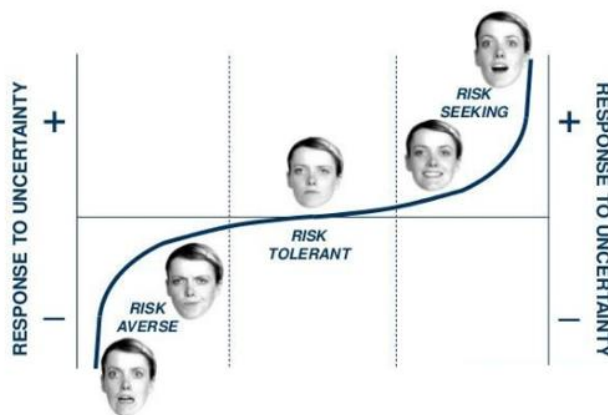


Figure 8 - Risk Attitude Spectrum (Hillson, 2006)

According to Hillson, 2006, a risk seeking person or organization is a person or organization that to some extent can take the risk of losing its investment in the hope of a positive return of an investment. The risk averse one is a person or organization that beyond a certain extent, any

potential gain does not justify taking the risk of losing the initial investment. Risk tolerant, is person or organization somewhere between seeking and averse.

According to Ortwin Renn (professor for environmental sociology and technology assessment at the University of Stuttgart) perception is a personal characteristic that it's built across the life cycle of humans (Renn, 1990). Renn defines risk perception as a function of intuitive heuristics, such as availability, anchoring, and overconfidence. This definition of perception is also in line with other renowned researchers and authors such as Neil D. Weinstein (Weinstein, 1980), Kasperon, Pidgeon, and Slovic (Bodemer, 2015). Renn, 1990, concludes by arguing that risk perception is a function of heuristics, where heuristics in Greek means discover!

A heuristic is a mental shortcut that allows people to solve problems and make judgments quickly and efficiently (Bazerman, 2018). These rule-of-thumb / best guess strategies shorten decision-making time and allow people to work further without constantly stopping to think about their next course of action. According to Herbert Simon, Nobel-prize winning psychologist, 1950's, people are programmed to use heuristic techniques. Heuristics play an important role in both, problem-solving and decision-making (Bazerman, 2018). They are particularly helpful when a fast solution is needed, however can also lead to cognitive biases (Bazerman, 2018).

According to literature there are several types of heuristics. They include (Bazerman, 2018; Bodemer, 2015; Renn, 1990): Availability, overconfidence, anchoring, educated guess, rule of thumb, absurdity, consistency, common, contagion, representativeness and so on. Tversky & Kahneman, 1974, found that three heuristics have a particular importance due to their frequently use in a daily basis. These findings back 1974 were validated by Bazerman, 2018. They are (Kahneman, 1974): (1) **availability**, (2) **representativeness**, and (3) **affect** heuristics. The availability heuristic involves making decisions based upon how easy it is to bring something up to mind. In other words, how easy it is to remember something. The representativeness heuristic involves making decisions by comparing the present situation to the most representative mental prototype. The affect heuristic has to do with making choices or decisions when strongly influenced by emotions one is experiencing at the time of the decision. Usually, positive emotions lead people to emphasize that the benefits will be higher than the non-benefits. The inverse is also true.

Gerd Gigerenzer, a psychologist at the Max Planck Institute for Human Development in Berlin, in his work - Gut Feelings (2011) which resulted in more than a decade of research, explains why intuition is such a powerful decision-making tool, by demonstrating that the so-called *gut feelings* result of an unconscious mental process that apply rules of thumb. Gigerenzer and his team, in 1996, and 1999 demonstrated that circa 90% of critical decisions are made based on intuition. These findings are validated by other renowned related fields authors (Zaltman, 2003; Bibace et al., 2005; Gigerenzer & Kurzenhauser, 2005; Clavien, 2010; Bazerman, 2018).

### 3.3 Risk Management in Organizations

#### 3.3.1 Definitions, History & Evolution

Risk management can be defined as a forward-looking radar that scans the future (Hillson, 2012). Risk management is recognized as an essential contributor to business and project success because it focuses on addressing uncertainties in a proactive manner to minimize threats, maximize opportunities, and optimize achievement of objectives (Hillson, 2006; PMI, 2017; NIST, 2018; ISO, 2021). Although the evolution of risk management and quality management are different, they are strongly connected by the nature of their objective (Hillson, 2006). The evolution of risk management as a science is strongly connected with the advance in the mathematical sciences such as probabilities and statistical models (Crockford, 1982). According to several authors modern risk management began after the Second World War and evolved until the present days (Crockford, 1982; William & Heins, 1989; Naomi, 2008). In Figure 9 is illustrated the evolution of the foundations of modern risk management (Buehler et al., 2008).

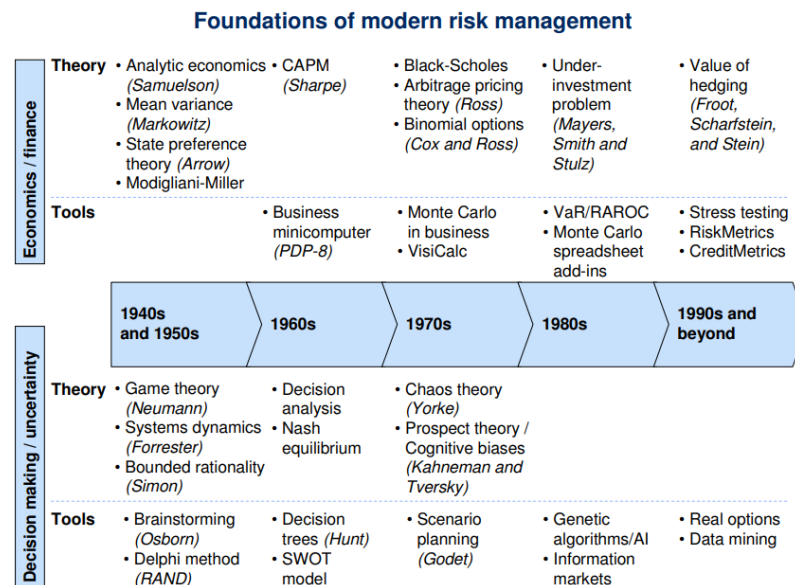


Figure 9 - Foundations of Modern Risk Management (Buehler et al., 2008; Dionne, 2013).

Many years before the World War II, Henry Fayol identified risk management as a critical function among the six basic functions of a business organization (Outreville, 1998). Before 1956 there were no official books registered regarding risk management, and no universities has yet offered courses or training in the risk management field (Outreville, 1998). The first literature published on risk management was in 1963 (Dionne, 2013). In this publication risk was only seen as a bad thing (threats) also known as pure risk (Dionne, 2013). According to Outreville, 1998 one of the first references to the concept of risk management was published in 1956 at the Harvard Business Review. In October 1988, the first world congress in risk management was sponsored by the FRIM

(Federation of Risk and Insurance Management) (Outreville, 1998). Risk management has been since the very beginning of its existence connected with the market insurance, which was essentially concerned to protect individuals and organizations against losses arising from accidents. Only after the Second World War, risk management entered the industrial engineering (Outreville, 1998; Dionne, 2013).

In Table 14 are illustrated some principal milestones in each decade regarding the application of risk management in a financial perspective. Many of these findings, such as the Var (Value at Risk), are still today applied in the most diverse fields, such as project management. (Dionne, 2013).

Table 14 – Major Milestones in the history of risk management (Dionne, 2013)

<b>Milestones</b>	<b>Description</b>
1900	Louis Bachelier’s thesis “Théorie de la Spéculation”; Brownian motion
1932	First issue of the Journal of Risk and Insurance
1952	Publication of Markowitz’s article “Portfolio Selection”
1961-1966	Treynor, Sharpe, Lintner and Mossin develop the CAPM
1963	Arrow introduces optimal insurance, moral hazard, and adverse selection
1977	Interest rate models by Vasicek and Cox, Ingersoll, and Ross (1985)
1980-1990	Exotic options, swaptions and stock derivatives
1987	First risk management department in a bank (Merrill Lynch)
1988	Basel I (Round of deliberations done by central bankers in 1988 in Basel that set a minimum capital requirements for all world banks to better insolvency risks).
Late 1980s	Value at risk (VaR) and calculation of optimal capital
1992	Introduction of Risk Metrics, Integrated Risk Management across literature
2002	New governance rules by Sarbanes-Oxley and NYSE
2004	Basel II (recommendations on banking laws and regulations issued by the Basel Committee on Banking Supervision that were developed after BASEL I).
2010	Basel III (voluntary regulatory framework on bank capital adequacy, stress testing, and market liquidity risk that was developed in response to the deficiencies in financial regulation revealed by the financial crisis of 2007–08)

### **3.3.2 History & Evolution - The State of the Art**

Risk management is strongly connected with quality management (Strategyex, 2017). In Figure 10 are chronologically illustrated the results of an extensive research regarding risk and quality management breakthroughs during three major periods ((1) Classical Theorists, (2) Neo-Classical Theorists, and (3) Recent Theorists) (Crockford, 1982; William & Heinz, 1989; Daft, 1997; Outreville, 1998; Hillson, 2006; Hillson, 2007; Naomi, 2008; Buehler et al., 2008; Pipelow, 2012; Dionne, 2013; Jones, 2013; Szczepańska-Woszczyna, 2014; Cacciattolo, 2014; PM<sup>2</sup>, 2016; Strategyex, 2017; PMI, 2017; APM, 2020; ISO, 2021).

## Early Theorists

*Classical Management Theories*  
*Practicing Managers*  
*Classical or Scientific Managers*

- **Frederick Taylor (1856-1915)**
- **Henri Fayol (1841-1925)**

Reflect upon and theorize about their personal experiences of management aiming to produce a set of rational principles of management which could be applied universally in order to achieve organizational efficiency. The theories are primarily concerned with structuring of work and organizations, rather than with human motivation or organization culture.  
**Key words:** Formal hierarchy, authority, division of work, span of control, are the important things to achieve success.

## Social Scientists

*(Academics)*  
*(Human relationships Theorists and Contingency )*

- **Abraham Maslow (1908-1970)**
- **Elton Mayo (1880-1949)**
- **Douglas McGregor (1906-1964)**

The starting point was research the human behavior at the workplace, and the social relationships. Studying the effects of physical working conditions on employees.  
 Directing the study to individual satisfaction, employee motivation, interpersonal communication and leadership style, and the efficient use of resources. Their work was grounded in the idea of organizations as social systems.  
**Key words:** people's needs - are decisive factor in achieving organizational effectiveness.

## "Recent" Theorists

*Modern Approaches to Management*  
*Academics*  
*Management Consultants*  
*Strategic perspective*

- **Henry Mintzberg (1939- )**
- **Tom Peters (1942- )**
- **Michael Porter (1947- )**
- **Moss Kanter (1943- )**

The starting point was taking a strategic perspective, involving several key organizational factors such as: mission, vision, culture and values, customer satisfaction, organizational structure, leadership, external environment. Their concern has been to predict which conditions are the most likely to produce organizations capable of meeting demands of their various stakeholders.  
 Flexibility in responding to change in its external and internal environment, in order to meet the competing demands of all its various stakeholders - (all the involved directly and indirectly) through strategic measures.  
**Key words:** Organizational effectiveness and excellence.  
**Efficiency:** doing things right (Employee point of view)  
**Effectiveness:** doing the right things (Management point of view)

**References:**  
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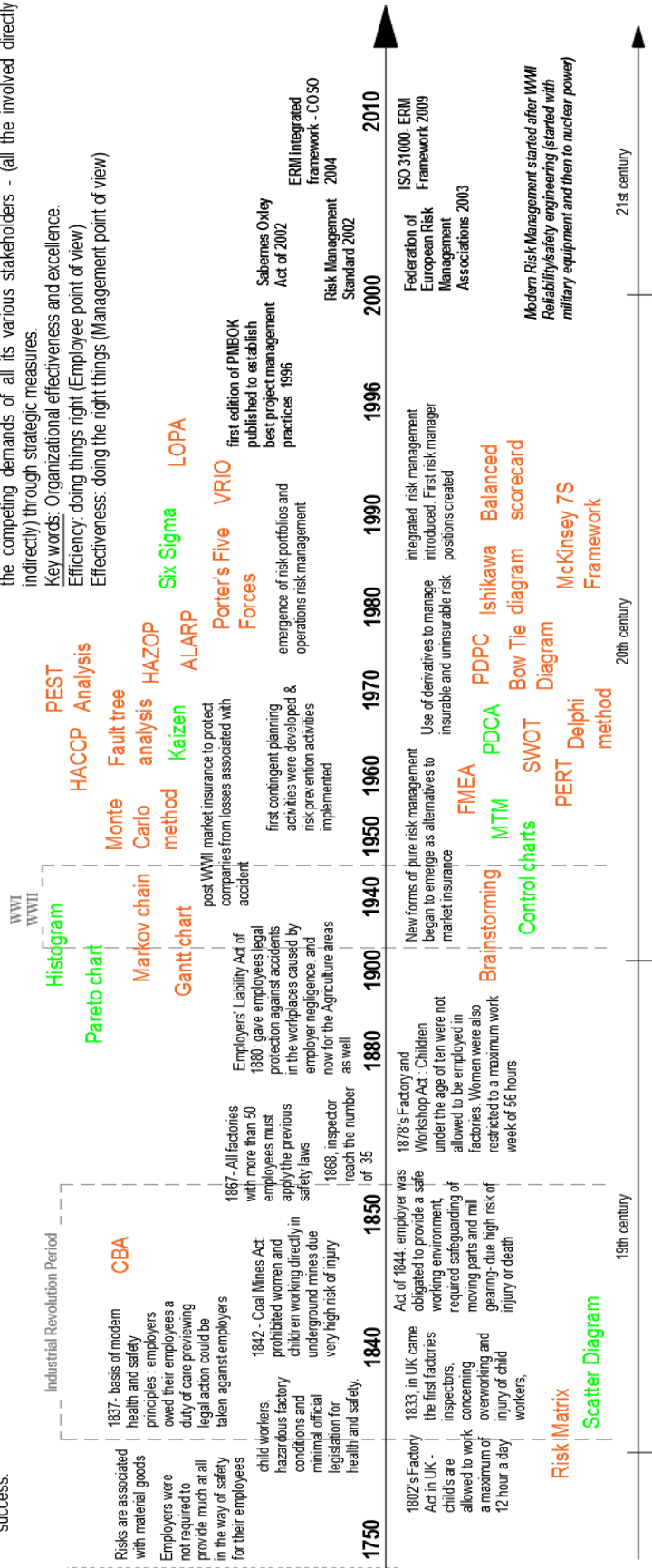


Figure 10- Development of most popular Risk and Quality Management tools across time

According to reviewed literature there are three major fields where actual researchers and practitioners are putting efforts to bring new insights in the field of risk and quality management. They are: (1) The process of risk management, (2) a dynamic risk management approach, and (3) Enterprise Risk Management approach. Terje Aven (Aven, 2015; Aven, 2017) argues that traditional risk assessments are based on causal chains and event analysis. He argues that calculating probabilities based on historical data has strong limitations in analyzing today's complex systems characterized by non-linear components. He argues that a new way of thinking about risks is needed. Aven, 2015 proposes a new way to think about risk based on four pillars: (1) a conceptual risk framework, which highlights uncertainties, (2) new approach regarding risk assessment and management, (3) risk management as quality management with focus on improvements, and the (4) concept of mindfulness as interpreted in studies of High Reliability Organizations (HROs). He also argues that these four pillars must have five major characteristics. They are: (1) preoccupation with failure, (2) reluctance to simplify, (3) sensitivity to operations, (4) commitment to resilience and (5) deference to expertise.

**Dynamic Risk Management (DRM)** is basically understanding the organization risks as relationships between the different departments and identify a potential contagious risk scenario by the application of network theory (Lock & Phillips, 2017). Network theory allows a dynamic, and live view of the risk threats and opportunities as opposition of traditional static tools and techniques (Lock & Phillips, 2017). DRM is the continuous process of identifying hazards, assessing risk, acting to eliminate or reduce risk, monitoring and reviewing, in the rapidly changing circumstances of an operational incident (Lock & Phillips, 2017). The term Dynamic Risk Management is commonly used to describe a process of risk assessment being carried out in a changing environment, where what is being assessed is developing as the process itself is being undertaken. Dynamic risk management models are undergoing namely in the finance fields and air lines industries, where the goal is to increase the robustness and look for alternative hypotheses (Rampini, et al., 2013).

**Enterprise Risk Management (ERM)** is managing risks across all organization throughout its organizational structure in a consistent, continuously, and coherent way. The key point of ERM lays on the interfaces between the different levels of an organization (Bourne, 2010). ERM is a senior risk management function on the top level of the organization, usually reporting to the Board, or CRO (Chief Risk Officer). It must guarantee that everybody in the organization have a share understanding of risk, share risk language, common procedures for managing risk, and risk is consistently identified and described and escalated up and down the organization until it's found the right level to be managed (Bourne, 2010). ERM uses network flows analysis, risk maps, and scenario analysis among others, to manage risk (Bourne, 2010; COSO, 2020). One of the most popular ERM Frameworks was developed by COSO - Committee of Sponsoring Organizations of the Treadway Commission (COSO, 2020). The framework is illustrated in Figure 11. In the framework

illustrated in Figure 11 is illustrated how risk management should be implemented and covers all the organizational structure of a company.



Figure 11 - COSO ERM Framework (COSO, 2020)

As it can be seen in Figure 11 the enterprise risk management process has its basis founded on the organization’s mission, vision and core values that will guide the entire process onwards. After having set the mission, vision, and values, it is time for development of a strategy or strategies that will enable the achievement of sustainable competitive advantages and will help in the formulation of business objectives.

### 3.3.3 Risk Management Culture

Sir Edward Tylor (1832-1917), the founder of cultural anthropology, wrote in 1871 that “Culture is that complex whole which includes knowledge, beliefs, art, morals, law, customs and any other capabilities and habits acquired by man as a member of society” (Tylor, 1871).

Edgar Schein in 1984 wrote that “culture is the pattern of basic assumptions that a given group has invented, discovered, or developed in learning to cope with its problems of external adaptation and internal integration, and that have worked well enough to be considered valid, and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems” (Schein, 2010). Hofstede in 1991 defines culture as “a collective programming of the mind that distinguishes one group or category of people from another”. And he goes further saying that culture is “the used language and empathy, and practice collaboration and inter-group competition. Culture are the unwritten rules of how we do these things (Hofstede, 1991). He added that culture is how we call these unwritten rules about how to be a good member of the group” (Hofstede, 1991). An illustrative way of defining culture and its process is illustrated in Figure 12. The process of culture

building proposed by Lewis in 1996, explains how culture is gained, adsorbed, and later projected (Lewis, 2013).

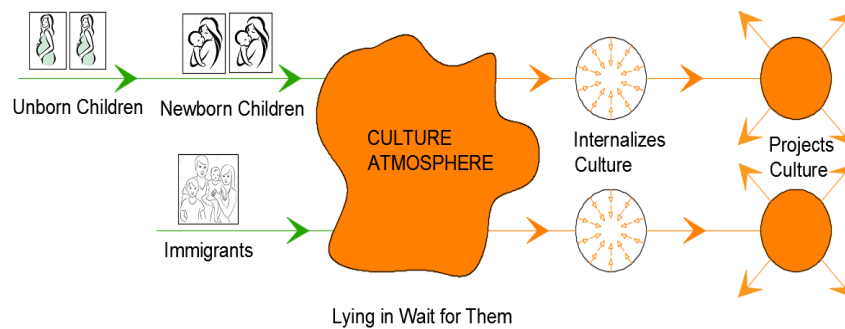


Figure 12 - Culture Definition according Lewis (Adapted from Lewis, 2013)

The culture atmosphere was already there lying wait for them - when the newborn came in to - so the newborn will internalize the existing culture atmosphere. According to Lewis, 2013, psychologists say that it's in a period of 10-12 years - which is called the formative period, after the newborn (staying inside the culture atmosphere) - that one acquires the habits and mentality of a lifetime. He argues that it will never change, no matter how one changes (acquires some new characteristics). According to Lewis the same thing will happen with immigrants. They will be adsorbed in the pre-existing culture atmosphere but depending on how complete the formative period of an immigrant is, the internalizing and projecting culture process will be different. And once again, the same rule applies here – the period of 10-12 years (Lewis, 2006).

According to Hillson, 2002a the biggest critical success factor for effective risk management is the one that most often lacks - an appropriate and mature risk culture (Hillson, 2002a). Because risk management is done by people, this fact introduces an additional layer of complexity into the risk management process, with a multitude of influences both explicit and covert (Hillson, 2006). Risk culture exists at multiple levels, such as different groups with common purposes, for instance in an organization comprised with all different departments, which need to be all aligned in order to have effective risk management. Risk culture is a base pillar on which decision should be taken and monitored (Hillson, 2014). According to research, The Big Five model has proved to be very reliable to predict a variety of important social, occupational, psychological, and health outcomes (Soto & Liang, 2015). Therefore, is often used in people risk management as a monitoring tool (Hillson, 2006).

The Big Five Model, or the Big Five personality traits - one of the most widely used model of personality structure - states that every person will land into one or more the following models of personality. They are: (1) Extraversion, (2) Agreeableness, (3) Conscientiousness, (4) Neuroticism (sometimes named by its opposite, Emotional Stability), and (5) Openness to Experience (sometimes named Intellect). These five personality traits are substantially influenced by both

genetic and environmental factors (Soto & Liang, 2015). Although the different Big Five factors are associated with different behaviors - regardless of the exceptions where some individuals show atypical patterns of change that differ from mean-levels trends -, the rank order of the Big Five tends to remain consistent over time, reaching its stability point (but allowing still some room for additional change) in the middle age period of a person.

In Table 15 are described the five components of the Big Five Model of Personality including core facets and the meaning (Soto & Liang, 2015).

Table 15 - The Big Five Models of Personality traits (Soto & Liang, 2015)

<b>Big Five</b>	<b>Core Facets</b>	<b>Meaning</b>
1-Extraversion	Sociability (instead of shyness). Assertiveness (instead of submissiveness). Activity (instead of lack of energy)	Talkative. Take charge in group situations. Is outgoing in social situations
2-Agreeableness	Compassion (instead of lack of concern for others). Politeness (instead of antagonism). Trust (instead of suspicion of others)	Behave prosaically toward others. Maintain pleasant, and harmonious interpersonal relations. Help and treat others with respect
3-Conscientiousness	Orderliness (instead of disorganization). Self-discipline (instead of inefficiency). Reliability (instead of inconsistency)	High capacity to organize and complete tasks. Goal oriented. Follow rules and norms. Are productive workers
4-Neuroticism	Anxiety (instead of calmness). Depression (instead of contentment). Emotional volatility (instead of stability)	Fear, sadness, and frustration, and frequent mood swings. Low self-esteem
5-Openness to Experience	Aesthetic sensitivity (instead of insensitivity). Imagination (instead of lack of creativity). Intellect (instead of lack of intellectual curiosity)	Broad range of interests and enjoy. learning and trying new things.

As it can be seen in Table 15 the Big Five Model of Personality which comprises extraversion, agreeableness, conscientiousness, neuroticism, and openness experience, cover a wide range of different personalities that co-exist separately or combined in a human being, which contribute to explain why risk and risk management processes are differently precepted and understood.

### **3.3.4 Fields of Application of Risk Management**

Risk management as a science can be applied to all the different areas within the business landscape (Verbano & Venturini, 2011; ISO, 2021). It is a transversal discipline that goes across almost everything that can be subject a change from an actual state to a desired future state, by suffering internal and / or external action or influence (Verbano & Venturini, 2011; ISO, 2021). I

n Table 16 are illustrated some of the principal fields where the risk management science is applied and the major focus for each one of the fields.

Table 16 - Risk Management Fields of Application (Verbano & Venturini, 2011)

<b>Fields</b>	<b>Major Focus</b>
Strategy	Industry, technology, brand, competitor, customer, project, stagnation
Finance	Credit risk, market risk inflation risk, interest rate risk, commodity risk, liquidity risk
Enterprise	Value maximization and risk management
Insurance	Property risks relates, liability, personnel risks
Project Management	Technical or operational risk, organizational risk, contractual risks, financial and economic risk, political risks
Eng. & R&D	Program risk management, environmental risk management
Supply Chain	Outsourcing for production and R&D, globalization, suppliers, delays, product life cycles, physical locations, financial: information, relational, innovation
Disasters	Natural, health, social life, economic, political, environmental, technological
Clinical / Health	Healthcare, patients at risk of harm, errors in the use of pharmaceuticals, surgical errors, errors in the use of equipment, diagnostic exams or procedures, timing errors

### **3.3.5 Risk Management Models, Tools & Techniques**

A risk management model can be defined as a quantitative method, system or approach that applies statistical, economic, financial, or mathematical theories, techniques, and assumptions to process input data into quantitative estimates (Lamas et al., 2014). Risk management models can be defined as guidelines for risk practicioners so that they can orientate themselves when conducting risk management activities (Crespo et al., 2018). Risk Management Models come in all shapes and forms, and they are growing rapidly specially in the Bank sector where they are being developed at a rate of 10-25% per year (Crespo et al., 2018). Most organizations adopt standards that are being continuously developed by specialized Risk Management body of knowledges and institutes such as the ISO. However, function of the nature of an organization’s business – especially in the chemical, oil & gas, and pharmaceutical industries –, they may develop their own or adapt existing specific Risk Management Models.

A typical risk management model lifecycle is comprised of three different phases. They are (Ni, 2016): (1) Development, (2) Validation, and (3) Use. In the development phase important aspects concern the quality, know-how of the team that develops the model, the designing process, and the respective documentation. In the validation phase is when the model will be tested and checked if the results are being those to which the model was designed for. Once the model is ready to be used it is important to be aware of its limitations in order not to extract wrong conclusions (Ni, 2016). In Figure 13 is illustrated a risk management model suggested by one of the most popular private consulting organizations in the risk management field – KPMG (Ni, 2016).

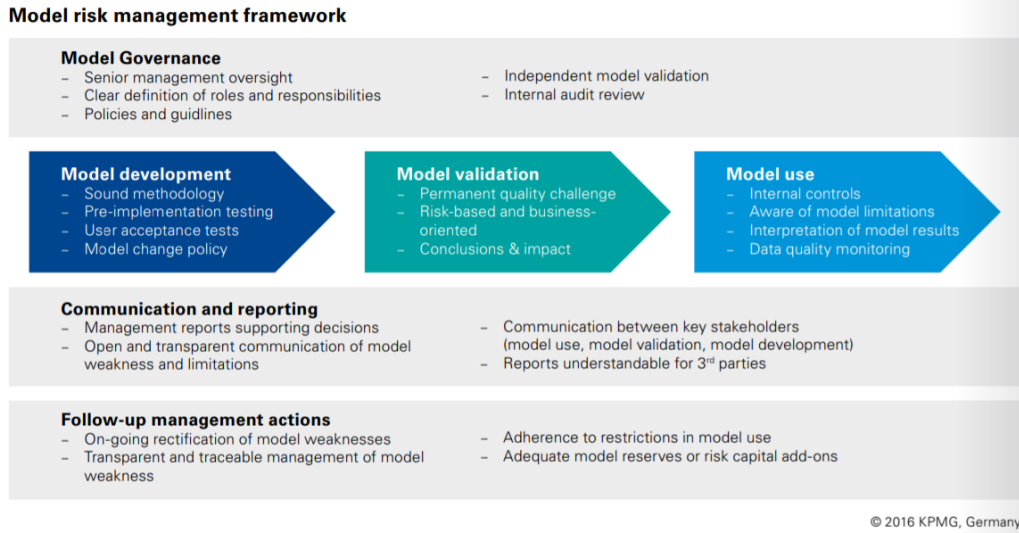


Figure 13 - Risk Management Model example (Ni, 2016)

Risk management models can be classified in two different interrelated types as illustrated in Figure 14 (Bossaerts et al., 2019). They are: (1) complexity (maximum and minimum), and (2) uncertainty (maximum and minimum).

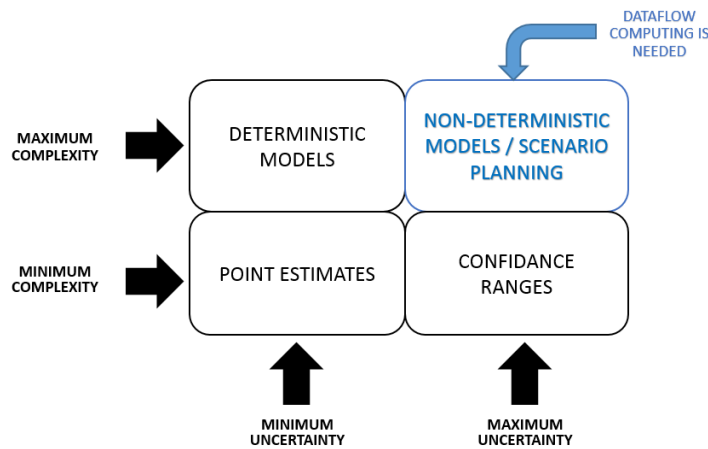


Figure 14 - Risk Management Model: Complexity vs Uncertainty (Bossaerts et al., 2019)

Both, form the interdependent risk model matrix, which comprise four different types of risk management models. They are: (1) deterministic, (2) point estimates, (3) confidence ranges, and (4) non-deterministic models). These are illustrated in Figure 14. There should be a commitment between input and output function of a given situation. In other words, it is not clever to employ time and money in developing and using a Complex Risk Management Model to assess, identify, and treat certain risks that do not need such efforts to output a reasonable result.

Deterministic Models, where the outputs are determined by the relationship among states and events without any space for random variation, have high complexity in the design, develop, and

using phases. The output provided by a deterministic model has lower uncertainty associated than point estimates (Bossaerts et al., 2019). Confidence ranges or intervals, are the models which carry the less complexity in terms of calculation but have the highest uncertainty associated to. Scenario planning is a strategic planning method used to make flexible long-term plans. They are usually associated with military intelligence (Bossaerts et al., 2019). Such model type requires tons of information to be analyzed through non-deterministic models. In scenario planning, for a same input a different output is possible. Scenario planning is believed to be the future of the decision-making process (Bossaerts et al., 2019). In the future, scenario planning tends to replace heuristic models because contrary to heuristic models, scenario planning aims the planning at the long-term rather than the short-term (Bossaerts et al., 2019).

Heuristic models use a practical method or various shortcuts to produce solutions that may not be optimal but are sufficient given a limited timeframe or deadline. Heuristics models are intended to be flexible and are used for quick decisions, especially when finding an optimal solution is either impossible or impractical and when working with complex data (Bossaerts et al., 2019).

Risk management models that comprise cultural aspects are extremely valuable (Goffee & Jones, 1998). Given the importance of culture in risk management one of the most credit institutions in the field of risk management – the IRM (The Institute of Risk Management), developed risk management models for addressing risk based on cultural issues. The most popular one is the A-B-C Risk Culture Model. The original ABC model is credited to Albert Ellis in 1958 (Ellis, 1958 and 1991). He argues that every human attitude has three components: affective, behavioral, and cognitive. The IRM (IRM, 2019), adjusted the ABC model to A-Attitude, B-Behavior, and C-Culture as is illustrated in Figure 15. In Figure 15 (left side) is described the relationship between the three components adjusted by the IRM. The relationships illustrated in Figure 15 are interpreted follows: attitude shapes behavior. If such behaviors become a repeatable pattern over time, it will eventually become culture. Finally, culture directly influences behavior and attitudes.

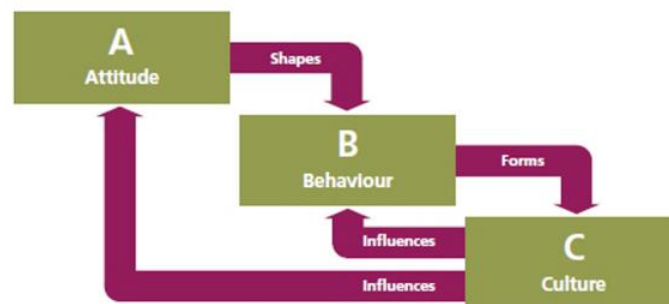


Figure 15 - The ABC risk management model of the IRM (IRM, 2019).

The IRM also defines three components of risk taken into consideration and continuously monitored, while executing risk management activities. They are (IRM, 2019): (1) **risk attitude** - is

the chosen position adopted by an individual or group towards risk, influenced by risk perception, (2) **risk behavior** - comprises external observable risk-related actions, including risk-based decision-making, risk processes, risk communications etc., and (3) **risk culture** - are the values, beliefs, knowledge and understanding about risk, shared by a group of people with a common purpose.

Risk models can be classified according to scientific field, specific application case, and business case (Henschel, 2008; Hillson, 2012). The use of risk models, tools & techniques in the very initial stage of a project is vital to timely forecast opportunities and threats (Henschel, 2008). In project management can be applied different assessment models, such as the Failure Mode Effects Analysis (FMEA), Fault Tree Analysis (FTA), Analytic Hierarchy Process (AHP) and Risk Diagnosing Methodology (RDM), just to name a few (Rosas et al., 2015). The ISO (ISO, 2021) suggests a number of tools & techniques that can be applied in the risk management process. These techniques are divided into seven major groups. Some of the most popular applied in project management are illustrated in Table 17 (Hillson, 2014; ISO, 2021).

Table 17 – Most Popular Risk Assessment Techniques (Hillson, 2014; ISO, 2021).

Risk Assessment Tool		Risk Assessment Steps				
Major Groups	Tool & Technique	Risk Identification	Risk Analysis			Risk Evaluation
			Consequence	Probability	Risk Level	
look-up	Checklists	yes	no	no	no	no
supporting	Brainstorming	yes	no	no	no	no
	Delphi technique	yes	no	no	no	no
	“What-if analysis”	yes	yes	yes	yes	yes
scenario analysis	Root cause analysis	no	yes	yes	yes	yes
	Scenario analysis	yes	yes	yes	yes	yes
	Event tree analysis	yes	yes	yes	yes	no
	Cause/ effect analysis	yes	yes	yes	yes	yes
function analysis	FMEA and FMECA	yes	yes	yes	yes	yes
	HAZOP	yes	yes	yes	yes	yes
	HACCP	yes	yes	no	no	yes
controls	Bow tie analysis	no	yes	yes	yes	yes
statistical	Bayesian analysis	no	yes	no	no	yes
others	Environmental risk matrix	yes	yes	yes	yes	yes
	Decision Tree	no	yes	yes	yes	yes
	Consequence/probability matrix	yes	yes	yes	yes	yes

Research shows that the way Table 17 is illustrated (colored approach) provides organizations benefits when performing risk management (Strategyex, 2017). First, by plotting the colors green, yellow, and black, provides a visual perspective of which tools have or have not the capacity to output measurable results. Second, it provides risk management practitioners a sense of continuously awareness of what tools & techniques are available. Third, it efficiently minimizes the effects of the availability heuristic, which often limits the capacity of see beyond a certain way of doing things.

### **3.3.6 Risk Management Benefits and Limitations**

According to reviewed literature benefits of risk management include (Hillson, 2014; Strategyex, 2017; ISO, 2021; PMI, 2021): (1) Increases the likelihood of achieving objectives, (2) encourages proactive management, (3) improves the identification of opportunities and threats, (4) complies with relevant legal and regulatory requirements and international norms, (5) improves, governance, stakeholder confidence and trust, voluntary reporting, controls, (6) effectively allocates and use resources for risk treatment, (7) improves organizational resilience, operation effectiveness and efficiency and learn, (8) minimizes losses, and enhances health and safety performance, as well as environment protection. On the other side, risk management can be very stressing and time-costuming for employees to adapt to the new risk management model. This essentially happens due to the change in processes, and procedures related to risk management activities, and the difficulty of breaking with old working habits (old working cultures) (Hillson, 2012; Strategyex, 2017).

## **3.4 Risk Management in Project Management**

### **3.4.1 The Importance of Risk Management in Project Management**

Efficient risk management in project management is probably the most important activity across all the phases of a project lifecycle because it enables to manage predicted and unpredicted events minimizing (in case of threats) or maximizing (in case of opportunities) their impacts in project objectives (Hillson, 2002; APM, 2007; Hillson, 2014; PMI, 2017; Arena, 2018; PMI, 2021; Nunes & Abreu, 2020). Some authors argue that doing project management is in fact doing risk management (Baccarini, 1999; Hillson & Murray-Webster, 2007; Hillson, 2014).

Project risk management is the art and science of identifying analyzing and efficiently responding to risk events across the lifecycle of a project and in the best interest of meeting project activities (PMI, 2021). Effective risk management strategies in project management allow an organization to identify in a timely manner project's strengths, weaknesses, opportunities, and threats (Hillson, 2014; PMI, 2021). The importance of risk management in project management can be seen in two

different but interrelated aspects. They are: (1) what is it for, and (2) how can be done (Baccarini, 1999; Raz & Michael, 2001; Hillson & Murray-Webster, 2007; Hillson, 2014). The first aspect essentially regards the objectives of performing risk management in project management. In other words, the benefits that the activity risk management represents in project management. The second aspect essentially concerns the tools used to efficiently perform risk management in project management.

Concerning the *what is it for* dimension, risk management in project management is critical because it aims the overall successful deliver of a project (Hillson, 2014). In other words, risk management is the interrelated activity that aims to ensure that all the project activities such as, planning, delegating, implementing, controlling, meet stakeholder's expectations and are executed as planned (Renn, 1990; Hillson, 2014; PMI, 2021).

Project risk management identifies, and keeps stakeholders fully informed about possible risk events and conditions (Renn, 1990). The major outcome of project risk management is an improved and constantly updated probability that project value realization will be optimal, and the project will be a success (Renn, 1990; Hillson, 2014). Project risk management enables organizations to in a more data-informed way develop preventive plans in the case potential future events take place. By calculating the likelihood of occurrence and impact of a future even, organizations can more efficiently define strategies to manage risks (threats and opportunities) associated to such events in projects objectives. These strategies depend on how an organization is capable to deal with risks in project management and essentially include (Hillson, 2014; PMI, 2021): (1) **risk avoidance** (an organization avoids taking on risks as much as possible), (2) **risk mitigation** (an organization develops measures to minimize or eliminate negative impacts (threats) of risks while maximizing their positive impacts (opportunities)), (3) **risk transfer** or sharing (organizations transfer or share risk with an external party such as insurance companies for example), and (4) **risk acceptance** (organizations accept a potential loss that may arrive from predicted risks, where usually that loss is not great enough to warrant spending money and resources to avoid it).

Concerning the *how can be done* dimension, project risk management comes equipped with several tools and techniques that are critical to perform efficient risk management in projects under a well-defined framework (Hillson, 2014). Such framework consists in a sequential number of stages or steps to efficiently perform risk management in projects. These may include (Renn, 1990; Hillson, 2014; PMI, 2021): (1) understanding the risk concept in projects, (2) agreeing on project risk among all involved project stakeholders, (3) recognizing risk events and their likelihood of occurrence, (4) developing risk management approaches (either a standard or customizable), (5) preparing a risk breakdown structure, (6) defining risk tolerance levels, (7) developing organizational risk processes, (8) estimating risk severity, and (creating and continuously updating the risk register).

After surveying six different international organizations in the fields of food & beverage and cosmetics industry in Germany between 2017 and 2019, a set of 12 most used / popular tools & techniques used in Project Management function of project phase were identified (Strategyex, 2017). They are divided according the four generic phases of a generic project lifecycle (Table 18).

Table 18 - Project Management Risk Tools & Techniques across the PLC

<b>Generic Phases of generic Project Lifecycle</b>			
<i>Phase I - Initiation</i>	<i>Phase II - Planning</i>	<i>Phase III -Execution</i>	<i>Phase IV - Closing</i>
Brainstorming SWOT Risk Matrix Expert Judgement Cost-Risk Analysis PESTLE Analysis	Brainstorming Risk Register Expert Judgement Three Point Estimation CPM / PERT Diagramming Techniques	Brainstorming Check Lists Expert Judgment Diagramming Techniques	Brainstorming Check Lists Risk Register

Brainstorming can be defined as engaging in a stimulating and encouraging free-flowing conversation, by using techniques, to try to ensure that people's imagination is triggered by the thoughts and statements of others in the group, of knowledgeable people, in order to identify potential failure modes and associated hazards, risks, criteria for decisions and/or options for treatment (ISO, 2021). SWOT analysis evaluates the internal strengths and weaknesses, and the external opportunities and threats in an organization's environment (Sammut-Bonnici & Galea, 2015). Risk Matrix combines qualitative or semi-quantitative ratings of consequence and probability to produce a level of risk or risk rating (ISO, 2021). Expert Judgment can be defined as the systematic and structured use of processes to estimate probability, draw upon all relevant available information including historical, system-specific, organizational-specific, experimental, design, etc. The methods available include the Delphi approach, paired comparisons, category rating and absolute probability judgements (ISO, 2021). Cost-Risk Analysis evaluates where total expected costs are weighed against the total expected benefits to choose the best or most profitable option. It can be qualitative or quantitative or involve a combination of quantitative and qualitative elements (ISO, 2021). PEST analysis is the most common approach for considering the external business environment. PEST analysis stands for Political, Economic, Social, and Technological analysis and describes a framework of macro-environmental factors used in the environmental scanning component of strategic management (Gupta, 2013). Check Lists are used to identify hazards and risks or to assess the effectiveness of controls. They can be used at any stage of the life cycle of a product, process, or system (ISO, 2021). Risk Register is a record of information about identified, risks and their status (ISO, 2021). Three Point Estimation is a technique which utilizes an optimistic, most likely, and a pessimistic estimate to determine the ideal estimate value for a project task. CPM / PERT are similar techniques used to assist the project manager in scheduling the activities across a Project lifecycle (ISO, 2021). Bow-Tie Analysis is a simple way to communicate and simplifying the flow of risk thinking. is a methodology that covers all steps in risk management cycle, including hazard identification, risk analysis, risk evaluation, and risk control (Abdi, 2016).

Diagramming Techniques are a set of maps that design the general flow of processes, where risks that may hinder the achievement of objectives, are to be identified as it moves along to the goal or objective. The most common are: The Process Flow Diagram (PFD), The Ishikawa Diagram, Influence Diagrams (ISO, 2021).

### **3.4.2 Risk Management in Project Management – benefits and limitations**

For some authors project management is simply doing effective risk management across all the different phases of a project lifecycle with the aim of conducting all project activities to success (Hillson & Murray-Webster, 2007; Hillson, 2014). However, there are some limitations to be aware of. According to several research, limitations of risk management in project management may include (Renn, 1990; Raz & Michael, 2001; Strategyex, 2017, Nunes & Abreu, 2020): (1) **Risk management standards may not be suitable for all organizations** – not all organizations have the capacity to efficiently implement risk management standards developed by the ISO (international Organization for Standardization) or the COSO (Committee of Sponsoring Organizations of the Treadway Commission), or even the NIST (National Institute of Standards and Technology) essentially due to their complexity or too much simplicity of interrelated processes and systems. For example, in industries with high risk factors such as chemical, oil & gas, or pharmacy a standard approach to risk management such as the one proposed in the ISO 31010 may not be enough to efficiently manage potential risks. (2) **Risk management may become too expensive** – not all organizations have the financial capacities to undertake all the recommended activities with the recommended frequency across all the different phases of a project lifecycle for example. (3) **It may lead to loss of focus on other project activities** - too much focus on risk management activities may lead organizations to miss other important project activities. This may occur as organizations mobilize too many resources to risk management activities (training, participation in brainstorming sessions and so on) lacking resources to other project activities. (4) **Bias arriving from project risk management participants** - often project people (usually project subject matter experts) inadvertently use heuristics while taking decisions that usually arise from experience-based techniques for problem solving problems experienced across many years. These heuristics may include (Hillson, 2014): **anchoring** (it happens when there is a tendency to rely on one trait or piece of information (one anchor) when deciding or planning while moving around that point (anchor), **availability** (people judge the probability of the occurrence of events by how easily these events are brought to mind), **representativeness** (it happens when people make judgements about probabilities and risk based on the category an object, process or person represents), **confirmation bias** (it is the tendency to search for, interpret, favor, and recall information in a way that confirms or supports one's prior beliefs or values). (5) **The calculation of an event likelihood may be under false assumptions** – collected data to be used in likelihood estimations may be biased and generated based on false assumptions. Furthermore, often

such estimations heavily rely on past data, and as the saying goes “you cannot drive a car looking in the rear mirror”. (6) **Subjectivity in the analysis and interpretation of results** - May lead to conflict in the decision-making process. (7) **Typical risk management tools and techniques miss to catch people interactions in outcomes** – very often, the way people dynamically interact across different phases of a project lifecycle may strongly contribute to a certain outcome. Such interactions, as well as a correlation between them and outcomes are practically impossible to be identified using traditional risk management tools and techniques.

However, despite all the limitations above described, efficient risk management in project management drive projects to success minimizing or eliminating threat events and maximizing opportunities events (Baccarini, 1999; Renn, 1990; Raz & Michael, 2001; Hillson, 2002; APM, 2007; Aven, 2017; Hillson, 2018; PMI, 2018; Arena, 2018; NIST, 2018; IRM, 2019; Aven & Marja, 2019; COSO, 2020; Nunes & Abreu, 2020(c); ISO, 2021, PMI, 2021).

Furthermore, according to several literature that the most popular standard adopted by organizations (either in its original or in an adapted version) is the one suggested by the ISO – International Organization for Standardization (ISO, 2021) because it provides a set of best practices and principles that result of the implementation of proven solutions across several years in several different areas such as, engineering, economics, finance, health, and care, just to name a few to evaluate, manage and monitor risks (Hillson, 2012; Aven & Marja, 2019; Nunes & Abreu, 2021; PMI, 2021; ISO, 2021). For this reason, it is worth to analyze in detail the ISO 31010 standard for Risk management which is illustrated in Figure 16.

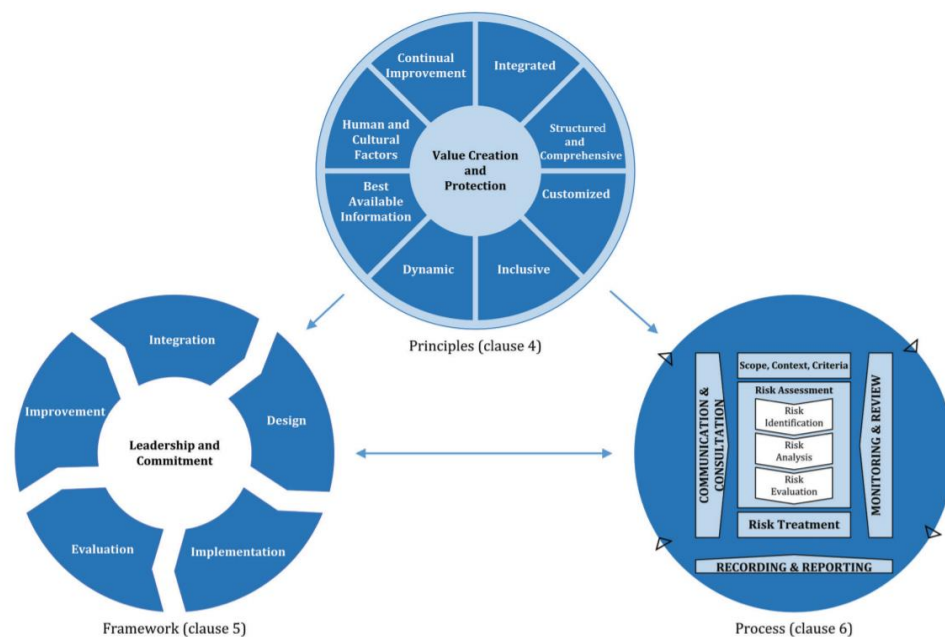


Figure 16 - ISO, Principles, Framework, and Process (ISO, 2021).

In Figure 16 is illustrated the ISO-31010 standard on risk management which comprises three interrelated blocks. They are (ISO, 2021): (1) principles, (2) framework, and (3) process. The principles are the foundation for managing risk and state that risk management is the creation and protection of value, improves performance, encourages innovation, and supports the achievement of objectives. Furthermore, it lays the foundations to guide and understand how the risk management framework and process work. The framework provides guidelines to organizations in risk management, so that they can be able to integrate risk management, into their overall management system in the most successful way possible. The process establishes the steps and stages of what must be done to properly assess and treat risk (threats and opportunities). The process should be an integral part of management, embedded in the culture and practices, and adjusted (tailored) to the business process of the organization. In Figure 16 are illustrated the principles, framework, and the process of the risk management ISO 31000 standard suggested by the ISO committee.

Concluding, risk management is an integral part of all organizational processes, part of decision making, explicitly addresses uncertainty, systematic, structured, and timely based in the best available information, tailored, take human and cultural factors into account, transparent and inclusive, dynamic iterative and responsive to change, and facilitates continual improvement of the organization (ISO, 2021).

To a better understanding of how the process or risk management should be conducted, the suggested steps in the process circle in Figure 16 will be briefly addressed as follows:

**1-Scope Context and Criteria** - establishing the context for risk management is articulating the objectives desired by the organization related to risk management objectives, defining the external and internal parameters to manage risk, and setting the scope and the risk criteria. The context of the risk management process should be established where risk management is going to be applied in the organization. These include in the objectives, strategies, scope, parameters, etc. It should be also justified and specified the use of resources allocated to the risk management, as well as the responsibilities authorities. **2- Establishing the External context** - the external context is the external environment where organizations seek to achieve their objectives. Also, external stakeholder's objectives must be clearly understood when developing risk criteria. **3-Establishing the Internal context** – the internal context is the internal environment where organizations seek to achieve their objectives. The Risk management process should be aligned with the culture of the organization, processes, structure, and strategy. **4-Defining Risk Criteria** - it implies the definition of the criteria to be used to evaluate the significance of risk! The criteria should reflect the organization's values objectives and resources. Some criteria may be imposed by legal or contractual issues. Risk criteria should be consistent with the organizations risk management policy. It should be defined at the beginning of the risk management activity and continuously reviewed. Factors that should be considered when defining risk criteria include nature and type of

causes and consequences that can occur and how they will be measured, how likelihood is defined, the timeframe of the likelihood and consequence, how the level of risk is to be determined, the views of stakeholders, when does risk becomes acceptable or tolerable, define if multiple risks should be considered or not and which combination should be considered. **5- Risk Identification** - in the process of risk identification, the organization should identify sources of risks, identify areas of impacts, identify events (including changes in circumstances) and their causes and consequences, create a comprehensive list of risks (Positives and Negatives) and separate risks that are under control of the organization from those that not. **6- Risk Analysis** - this stage provides information to risk evaluation. Risk analysis are decisions on whether the risk needs to be or not treated and on which most appropriated risk treatment strategies & methods should be followed. These include qualitative, semi-quantitative and quantitative analysis, or a combination of these. The generic steps in this stage are as follows: (1) consequence analysis, (2) qualitative, semi-quantitative or quantitative probability estimation, (3) assessing the effectiveness of any existing controls, (4) estimation the level of risk. **7- Risk Evaluation** - risk evaluation is the process of analysing if risks need to be treated and when, and if there is a need for a new analysis or if nothing should be do except maintaining existing controls. It includes comparing level of risk found during analysis process with risk criteria established when the context was considered and based on this comparison consider the need of treatment. **8- Risk Treatment** – it involves selecting one or more options for modifying risks and implementing options. It is essentially the process of accept, avoid, mitigate, transfer, exploit, enhance, or share treat risks and opportunities (Figure 17). **9- Risk Monitoring, Communication and Recording** – it is the process of recording all significant findings - the hazards, how people might be harmed by them and what exist in place to control the risks and communicate those findings across the organization. Any record produced should be simple and focused on results obtained. It implies also the ensuring that controls are effective and efficient in both design and operation phases.



Figure 17 - Risk Treatment process

Finally, due to the benefits illustrated across this sub-chapter regarding the adoption of the ISO 31010 standard for risk management in project management, the functioning principle of the proposed model in this work is partly influenced by the steps to manage risk above described.

# Chapter 4

## 4 Social Network Analysis (SNA) in Organizations

*“The key to successful leadership today is influence not authority.”*

Kenneth Blanchard

### 4.1 Introduction

It is very hard to find anything that is not to somehow connected (Borgatti, 2018; Nunes & Abreu, 2021). It is through formal and informal networks of relationships how information, flows, advice is given, know-how is shared and so on. In other words, is how things get done (Schoch & Brandes, 2016). In every organization, alongside with an organizational formal chart, an informal network exists, which usually responsible for how the work gets done in an organization (Schoch & Brandes, 2016; Kadushin, 2012; Nunes & Abreu, 2021). This informal network will skip levels and cross organizational boundaries (internal and external) to get the job done. In western democratic countries informal networks are crucial in organizations to get things done. This happens because the formal organizational structure cannot always anticipate all contingencies that an organization needs to execute tasks or activities, especially in today’s disruptive business landscape Schoch & Brandes, 2016; Kadushin, 2012; Nunes & Abreu, 2021).

To understand how things are connected, tools and techniques that can output results in a measurable, logical, and rational manner are needed. Research suggests that the best approach to efficiently study organization informal network is by the application of social network analysis (SNA) (Schoch & Brandes, 2016; Kadushin, 2012; Borgatti, 2016; Nunes & Abreu, 2021). By applying SNA to study organizational informal networks it is possible to map a set of relationships in only one display (picture), whereby means of representative tool (tables, graphs, charts) is possible (if a network is not too large) to draw quantitative conclusions regarding network structure and actor location. Moreover, such conclusion can be then correlated with organizational outcomes (Schoch & Brandes, 2016; Kadushin, 2012; Borgatti, 2016; Nunes & Abreu, 2021)

The way informal networks are organized is of critical importance because they may have great or total influence in decision-making and coordination across all levels of an organization (Jones, 2013).

In this chapter is introduced the third and final scientific pillar that support the development of the proposed model in this work – (3) social network analysis. Across this chapter subjects such as the background of the social network analysis field, the application of social network analysis in organizations, and in particular the application of social network analysis in project management will be detailed illustrated, as well as the mathematical foundations and approaches used by this scientific field.

## **4.2 Social Network Analysis in Organizations**

### **4.2.1 History & Evolution - *The State of the Art***

Several authors credit Jacob Moreno (1889-1974) for the first time ever application of Social Network Analysis tools and techniques with a scientific purpose (Bavelas, 1948; Wasserman & Faust, 1994; Martino & Spoto, 2006; Freeman, 2004; Scott, 2017; Nunes & Abreu, 2020 (a); Nunes et al., 2020). The first time that the term network was used in terms of social representations is credit to Barnes (Wasserman & Faust, 1994). After the work of Moreno, in the 1940's Harvard researchers started to research and develop methods of block structures to understand and compose graphs to apply in the study of social sciences (Wasserman & Faust, 1994). W. Lloyd Warner and Elton Mayo gave to birth the first large use of sociograms and introduced the concept of clique (Martino & Spoto, 2006; Scott, 2017). Harvard professors in late 1940's took the works from Moreno, Warner and Mayo and argued that sociometry could be a valid foundation for social analysis (Martino & Spoto, 2006). At the same time, Siegfried Nadel developed his work in the social sciences directed to the importance of structural analysis in organizations. He was the first to name the social function "role" and proposed the use of algebraic tool for analyzing such roles (Martino & Spoto, 2006). Giving continuity to the work of Nadel, Clyde Mitchell introduced the difference between total network and ego-centered or local network and introduced the concept of density (Martino & Spoto, 2006). In late 1950's Harrison White and his team directed the study to a mathematical-formal aspect of Social Networks and on the real relations among the network nodes and on how these relations structures help to explain the emergent roles (Martino & Spoto, 2006). In 1973 Mark Granovetter highlighted the importance of weak ties (Freeman, 2004). At the same time, Linton Freeman developed several measures of centrality based on betweenness (Martino & Spoto, 2006). The first measure of centrality described by Freeman was "betweenness". He stated that betweenness is a critical characteristic of communication (Bavelas, 1948; Shimbel, 1953). In 1978 Barry Wellman created an international group to bring SNA researchers together to develop new SNA metrics. This group named INSNA (Network Society of Social Network Analysts) is still active in present days (Shimbel, 1953). The next breakthrough happens in 1967 with Stanley Milgram. He proposed a theory called "small world phenomenon" where he demonstrated that no matter how large and how distant people are from each other, the number of intermediaries to reach everybody is relatively small (Shimbel, 1953). This theory was to be found very interesting and

object of several further studies. In 1998 a young physicist, Duncan J. Watts worked with a mathematician Steven H. Strogatz, and together they published an article on the small world phenomenon in the Nature journal (Freeman, 2004). They confirmed the six degrees of separation theory that was proposed in 1929 by Frigyes Karinthy.

Social Network Analysis suffered a boost in the mid 1980's due to the computational technologies. This helped researchers to faster and more accurately develop and test metrics that characterize dynamic social structures (Nunes & Abreu, 2021). The research and development undertaken in the latest regarding SNA essentially concerned on the network formation phenomena (Watts & Strogatz, 1998). The first model to generate graphs with small-world properties was proposed by Duncan J. Watts and Steven Strogatz in their paper in the Nature journal in 1998 (Watts & Strogatz, 1998). They developed the random graph model which essentially is a model to that explains the formation of social structures. Furthermore, the model assume that network formation is based on a probability of attachment between any two dynamic entities (Watts & Strogatz, 1998). The proposed model derives from the Erdős–Rényi model, which was proposed by Paul Erdős and Alfréd Rényi in 1959 (Erdős, 1959). In 1999 a renowned Hungarian-American physicist, Albert-László Barabási proposed an algorithm for generating random scale-free networks using a preferential attachment mechanism (Albert & Barabási, 2002).

The development of Social Network Analysis within the last 20 years suffered another boost, mostly after the 9/11 terrorist attacks in USA. Such boost was essentially motivated by the interest of knowing how terrorist networks forms, emerges, and operates (National Research Council, 2003; Tu et al., 2018). In 2002 the National Research Council and the Office of Naval Research of the US brought together researchers from the behavioral, cognitive, social sciences, initiated the development of models, together to develop models and theories for the national security issues, essentially, to understand and predict how terrorist networks work (National Research Council, 2003). Since then, enormous research in Dynamic Social Network Analysis (DSNA) has been made. DSNA - name by Kathleen Carley & George Davis from the Carnegie Mellon University in Pittsburgh, USA - differ from traditional social network analysis, in that they can handle large dynamic multi-mode, multi-link networks with several levels of uncertainty (Hayden et al., 2009). DSNA, as in quantum mechanics, is a theory where relations between actors are probabilistic (Hayden et al., 2009). Later in 2009 an event patrocinated by the Department of Defense of the United States Government, brought together some of the most renowned researchers in SNA / DSNA with the objective to present new advances in research regarding the development of SNA models (Hayden et al., 2009). Issues, such as how confident can one be in the conclusions based on social network analysis, what kind of long-term understanding does the social network paradigm promote, what might be missing in the application of SNA, and what role does SNA have to play in DTRA's mission for countering Weapons of Mass Destruction (WMD), were discussed (Hayden et al., 2009). In 2016 in a presentation at the Microsoft Research Campus, SNA researcher at the CMU

Eric Xing, states that the research in SNA and DSNA is concentrated in several different areas, with special attention for the development of global topological measures for social network analysis which comprise complex, and very complex models that are used to try to reproduce real life Networks. These are called Models for Meta-Analysis of Networks, Evolving Networks-Dynamics, and Network formation Mechanism (Airoldi et al., 2008; Xing, 2016).

Other SNA renowned names are leading research & development of SNA in other directions. This is the case of Stephen Borgatti, a SNA in Organizations expert, professor, and author, which centrality in organizations (Schoch & Brandes, 2016; Borgatti, 2018). Borgatti states that there have been notable advances in terms of redefining what centrality of a node really means. This opens a new way to define centrality rather the traditional centrality definitions proposed by Sabidussi, and Freeman (Borgatti, 2018). Borgatti argues that node centrality should not only be measured independently with one type of 4 usual centrality metrics, such as degree, closeness, betweenness, and eigenvector, rather embedded in three new perspectives; (1) involvement approach; (2) induced approach; and (3) flow outcome approach (Borgatti, 2018). In Social Sciences research is applying SNA as a method for computing the Frustration Index and Balancing Social Networks (Arena, 2018). Research highlights the relevance and importance of culture in the building of new SNA and DNA models and theories. This represents a new perspective that will bring new factors (based on culture) to the field of social network analysis (Ferguson et al., 2017). In the mathematical field new algorithms based on artificial intelligence to analyze large scale networks are being developed. These are a fundamental tool to understand phenomenon's like, such as structure of societies, information diffusion, link prediction, and the different patterns of communication (Daokun et al., 2017; Compagnon & Ollivier, 2017; Ryan et al., 2018; Li et al., 2018; Nunes et al., 2020).

#### **4.2.2 Social Network Analysis Theory & Principles**

Social Network Analysis (SNA) is the process of studying and analyzing social structures data with a variety of measures developed based on graph theory, that contributes to explain how social structures evolve across time, and how they impact the environment where they do exist (Otte & Rousseau, 2002; Durland & Fredericks, 2006; Carroll et al., 2010; Meisel et al. 2015; Kacanski & Lusher, 2017). SNA simply defined as “a specific set of linkages among a defined set of persons, with the additional property that the characteristics of these linkages as a whole may be used to interpret the social behavior of the persons involved” (Mitchell, 1979). SNA operates by analyzing social data. Such data is strongly rooted in cultural values and symbols which are comprised of meanings, motives, and definitions. There are three different types of Social Data. They are (Scott, 2017): (1) Attribute Data, (2) Relational Data, (3) Ideational Data. For each type of social data, a proper specific analysis technique is recommended. These are illustrated in Table 19 (Scott, 2017).

Table 19 - Social data types (Scott, 2017)

Types of social data	Attribute Data	Relational Data	Ideational Data
Analysis technique	Variable Analysis	Network Analysis	Typological Analysis

**Attribute Data:** data related to the attitudes, opinions, and behaviors of actors, which are considered as properties, qualities or characteristics that belong to the individual or the group. This type of data can be quantified and analyzed through statistical techniques. Therefore, the Variable Analysis is the most appropriated method to analyze this type of data. **Relational Data:** are the connections, contacts, ties, which relate one actor to the other actor or a group of actors with another group of actors. The structure of a network is built from relations between the entities that comprise that Network therefore, Network Analysis is useful for investigations of kinship patterns, community structure, interlocking directorships and so forth. **Ideational Data:** describes the meanings, motives, and definitions themselves, where the Typological Analysis is the most appropriate type of analysis.

SNA has its mathematical foundations based on the Graph Theory. Graph Theory can be defined as mathematical structures used to model and study the study pairwise (directed and undirected connections) relations between objects (Wasserman & Faust, 1994; Borgatti et al., 2009). In the most simply form a network can be formed by only two nodes. This is called a dyad (Wasserman & Faust, 1994). In a dyad there are three different types of connections or states (Table 20). They are (Wasserman & Faust, 1994): (1) Isomorphism type I – null dyad or no connection, (2) Isomorphism type II – asymmetric, or one-direction connection only, (3) Isomorphism type III – reciprocal dyad, or two-direction connection. In Table 20 these types of connections are illustrated (Wasserman & Faust, 1994).

Table 20- Possible states of a Directed Dyad

Isomorphism I	Isomorphism II		Isomorphism III
Null dyad	Asymmetric dyad	Asymmetric dyad	Reciprocal dyad
A ●                  ● B	A ● → ● B	A ● ← ● B	A ● ↔ ● B

The next simplest combination that can form a network is by having three nodes and their possible states regarding to how they can be connected. In this case is named as triade (Wasserman & Faust, 1994). In a triade there are 16 different statuses as illustrated in Figure 18.

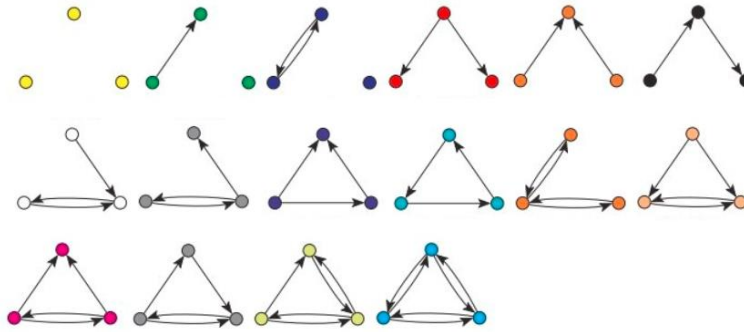


Figure 18 - The Directed Network Triad Isomorphism Classes (Doroud, et al., 2011)

The connections between any two actors within a given network can be either directed (one-way only direction - for example A points towards B but B does not point back to A) or undirected (reciprocal direction - for example A points towards B and B points back to A). These can still be sub-divided into directed and undirected weighted. It represents a connection with a degree of preference associated with an intensity of preference. For example, A loves B but B only likes A. Still the connection between any two given nodes or entities within a network or graph can be signed (which represents a positive or negative connection from A to B or from B to A or both).

Finally, the connections between any two entities within a social network can be one-mode type (connection that relates entities of the same type as for example people with people, or organizations with organizations) or two-mode (connection that relates entities of different types as for example connections between people and know-how, people and outcomes, or people and competencies) (Wasserman & Faust, 1994; Borgatti et al., 2009). In Table 21 are illustrated the directed and undirected connections and their sub-divisions.

Table 21 - Directed vs Undirected Links (Adapted from Wasserman & Faust, 1994)

Undirected	Directed
<p>a)</p>	<p>a)</p>
<p>b)</p>	<p>b)</p>

In Table 21 undirected (a, b) are illustrated the Non-oriented Link between any two Nodes (relationships are always reciprocal between any two Nodes that are connected by a Link). In Table 21 directed (a, b) are illustrated the Oriented Link between any two Nodes where there may or not exist reciprocal relationships between any two Nodes that are connected by a Link)

There are typical networks topologies which allows the comparison between real observed networks with a set of pre-defined network topologies. According to literature the most important pre-defined network topologies that are used to compare and analyze real networks are four networks. They are (Scott, 2017): (1) The Ring network, (2) The Star network, (3) The Line network, and the (4) Fully Connected network. They are illustrated in Figure 19.

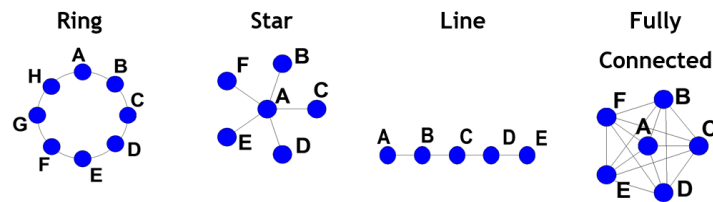


Figure 19 - Network Topology (Adapted from Wasserman & Faust, 1994)

From these networks illustrated in Figure 19 quantitative results – by the application of graph metrics – can be calculated and used to compare to which extent do real networks differ from these four major types (ring, star, line, and fully connected). By doing so it enables the characterization of real networks.

One mode network are networks where only one type of entity or actor is present. A Two-modes network is a network that has two different types of entities (Scott, 2017). A typical two-modes network is illustrated in Figure 20 in the right side.

A two-modes network can be transformed into a one mode network. This can be done when is desired to independently analyze how each type of entity or actor is connected. This enables for example, in an actor vs event two-modes network analyze only the connection between actors related to the participation in events across the time and conclude about the relationship degree that any two actors developed (Borgatti et al., 2018). Networks with more than two different entities are also called of Meta-Networks (Borgatti et al., 2018).

One popular way to mathematically represent the relationships between the actors (either one or two-mode network) of a given network, is by means of a Sociomatrix or affiliation matrix, respectively (Wasserman & Faust, 1994; Nunes & Abreu, 2020 (e)). Matrices for one-mode networks are called of Sociomatrices, and matrices for two-modes networks are called Affiliation Matrices. These are illustrated in Figure 20. The  $n$  represents an actor or entity,  $E$  represents an

event,  $a$  represents a numerical value that characterizes the relationship between  $n1$  and  $ng$  and  $X$  represents a value that characterizes the relationship between  $n1$  and  $Et$ .

	n1	n2	....	ng
n1	$a_{(n1,n1)}$	$a_{(n1,n2)}$	....	....
n2	....	....	....	....
:	....	....	....	....
ng	....	....	....	$a_{(ng,ng)}$

	E1	E2	....	$E_{Et}$
n1	$x_{(n1,E1)}$	$x_{(n1,E2)}$	....	....
n2	....	....	....	....
:	....	....	....	....
ng	....	....	....	$x_{(ng,Et)}$

Figure 20 - Structure of One-Mode (Left side) / Two-Modes Matrix (Right side)

Social Network Analysis uses metrics based on graph theory (Wasserman & Faust, 1994) to quantitatively analyze network structures. Essentially, there are a number of centrality measures that best characterize the single entities of a network structure. They are ((Wasserman & Faust, 1994; Borgatti et al., 2018; Nunes & Abreu, 2020 (d)): (1) Actor degree, (2) Closeness degree, (3) Betweenness degree, (4) Centrality degree, (5) Eigenvector degree, and (5) Peripheral degree. To characterize a network structure, centrality measures, such as density, network average degree, clusterability degree, centralization degree, just to name a few, can be applied. In Table 22 are presented the most common metrics used in SNA for both, directed and undirected network types.

Table 22 – Node Level Metrics (Wasserman & Faust, 1994)

Metric	Description / Meaning	
	Non-Directional	Directional
Actor (Degree) Centrality	<p>The arithmetic sum of lines that are connected to an Actor (Node) in the Network. The Actor with the biggest sum of links is the Actor with the highest CD.</p> <p>Absolute degree:</p> $C_D(n_i) = d(n_i) = \sum_j x_{ji} \quad (1)$ <p>Relative degree (from 0 to 1):</p> $C'_D(n_i) = \frac{d(n_i)}{g-1} \quad (2)$	<p>The arithmetic sum of lines that are pointed to an Actor (Node) in the Network. The Actor with the biggest sum of incoming links is the Actor with the highest CD. Can be called as Degree Prestige.</p> <p>Absolute degree:</p> $P_D(n_i) = d_I(n_i) = x_{+i} \quad (3)$ <p>Relative degree (from 0 to 1):</p> $P'_D(n_i) = \frac{x_{+i}}{g-1} \quad (4)$
Closeness Centrality	<p>It is the average length of the shortest path between one Actor and all the other Actors in a Network. The Actor with the smallest average sum, is the</p>	<p>It is the average length of the shortest path between one Actor and all the other Actors in a Network. The Actor with the smallest average sum, is the Actor with the highest CC. It is the</p>

	<p>Actor with the highest CC. It is the Actor that reaches all the other with the smallest number of steps.</p> <p>Absolute degree:</p> $C_C(n_i) = \frac{\sum_{j=1}^g d(n_i, n_j)}{g-1} \quad (5)$ <p>Relative degree (from 0 to 1):</p> $C'_C(n_i) = \frac{g-1}{\sum_{j=1}^g d(n_i, n_j)} \quad (6)$	<p>Actor that reaches all the other with the smallest number of steps. In this case (Directional Networks), this Index is only mean full if the Network is strongly connected.</p> <p>Absolute degree:</p> $C''_C(n_i) = \frac{\sum_{j=1}^g d(n_i, n_j)}{g-1} \quad (7)$ <p>Relative degree (from 0 to 1):</p> $C'''_C(n_i) = \frac{g-1}{\sum_{j=1}^g d(n_i, n_j)} \quad (8)$
<p>Betweenness centrality</p>	<p>It measures how often an Actor is a bridge between other Actors in a Network across the shortest path. It is the amount of time, that an Actor is present in the shortest path between any two other nodes. The highest the number of times, the highest the CB of an Actor.</p> <p>Absolute degree:</p> $C_B(n_i) = \sum_{j < k} \frac{g_{jk}(n_i)}{g_{jk}} \quad (9)$ <p>Relative degree (from 0 to 1):</p> $C'_B(n_i) = \frac{C_B(n_i)}{\frac{(g-1)(g-2)}{2}} \quad (10)$	<p>It is a measure of how often an Actor is a bridge between other Actors in a Network across the shortest path. It is the amount of time an Actor is present in the shortest path from two other nodes. The highest the number of times, the highest the CB of an Actor. In this case (Directional Networks), this Index is only mean full if the Network is strongly connected.</p> <p>Absolute degree:</p> $C''_B(n_i) = \sum_{j < k} \frac{g_{jk}(n_i)}{g_{jk}} \quad (11)$ <p>Relative degree (from 0 to 1):</p> $C'''_B(n_i) = \frac{C_B(n_i)}{\frac{(g-1)(g-2)}{2}} \quad (12)$
<p>Eigenvector (Prestige) Centrality</p>	<p>N/A</p>	<p>It measures the Prestige of an Actor. The Prestige is measure by the number of in-degrees that one Actor has given from other Actors that are more important (high degree) in a Network. It's like: It does not matter what you know but who you know! The same algorithm is used by Google Page Rank.</p> <p>Can be called as Rank Prestige.</p> <p>Absolute degree:</p> $P_R(n_i) = x_{1i}P_R(n_1) + x_{2i}P_R(n_2) + x_{gi}P_R(n_g)$

		<p>Where <math>\mathbf{P}_R(n_i)</math>, is the Rank of one Actor.</p> <p>In a Matricidal form:</p> <p>Sociomatrix = X</p> <p>Actors Rank indices Vector = P</p> <p>Solving the Matrix:</p> $\mathbf{P} = \mathbf{X}' \mathbf{P} \quad (13)$ $(\mathbf{I} - \mathbf{X}') \mathbf{P} = \mathbf{0}$ <p>Where I, is the identity matrix of dimension g, and P and o are vectors of length g.</p>
Peripheral Degree	<p>The arithmetic sum of lines that are connected to an Actor (Node) in the Network. The Actor with the smallest sum of links is the Actor with the smallest CD.</p> <p>Absolute degree:</p> $C_D(n_i) = d(n_i) = \sum_j x_{ji} \quad (14)$ <p>Relative degree (from 0 to 1):</p> $C'_D(n_i) = \frac{d(n_i)}{g-1} \quad (15)$	<p>The arithmetic sum of lines that are pointed to an Actor (Node) in the Network. The Actor with the smallest sum of incoming links is the Actor with the lowest CD. Can be called as Degree Prestige.</p> <p>Absolute degree:</p> $P_D(n_i) = d_I(n_i) = x_{+i} \quad (16)$ <p>Relative degree (from 0 to 1):</p> $\mathbf{P}'_D(n_i) = \frac{x_{+i}}{g-1} \quad (17)$
Density	<p>It measures how many ties between actors exist (in a directional form) compared to how many ties between actors are possible within a network or graph.</p> <p>Nr of Maximum Possible ties:</p> $NLMAX = \frac{g(g-1)}{2} \quad (18)$ <p>g= number of Nodes</p> <p>Index degree (from 0 to 1):</p> $\text{Density} = \frac{N_{L\text{REAL}}}{N_{LMAX}} \quad (19)$	<p>It measures how many ties between actors exist (in a non-directional form) compared to how many ties between actors are possible within a network or graph.</p> <p>Nr of Maximum Possible ties:</p> $NLMAX = g(g-1) \quad (20)$ <p>g= number of Nodes</p> <p>Index degree (from 0 to 1):</p> $\text{Density} = \frac{N_{L\text{REAL}}}{N_{LMAX}} \quad (21)$
Network Average	<p>The average degree of a non-directional graph is used to measure the</p>	<p>The average degree of a directional graph is used to measure the number of edges</p>

Degree	number of edges compared to the number of nodes.	compared to the number of nodes.
	$D_{Av} = \frac{\sum_{i=1}^g d(n_i)}{g} \quad (22)$	$D_{Av} = \frac{\sum_{i=1}^g d_I(n_i)}{g} \quad (24)$
	$\bar{d} = \frac{2N_t}{g} = \text{Density (g-1)} \quad (23)$	$\bar{d} = \frac{2N_t}{g} = \text{Density (g-1)} \quad (25)$

Continuation of Table 22 – Node Level Metrics (Wasserman & Faust, 1994)

To know more about SNA metrics, their mathematical development, and application, it is recommended the review of the master-work (also known as the SNA Bible) - Social Network Analysis in the Social and Behavioral Sciences". Social Network Analysis: Methods and Applications, written by Stanley Wasserman and Katherine Faust in 1994.

### 4.2.3 Fields of Application

SNA is applied in several disciplines and scientific fields that range from social and behavioral sciences, economics, marketing, industrial engineering, health and care, organizations, terrorist organizations, just to name a few (Wasserman & Faust 1994; Borgatti et al., 2009; Nunes & Abreu, 2020 (d); Nunes et al., 2020).

SNA has a wide range of applications that goes from the classic social behavioral sciences, project management (CPM & PERT Networks), archeology, just to name a few. One of the best ways to describe where SNA is applied is by analyzing published literature across the latest years in reference journals. In Table 23 are illustrated a few examples from several different fields where the application of SNA has shown to be fruitful.

Table 23 - Application of the Social Network Analysis according to various authors

<b>Social &amp; Behavioral Sciences</b>	Churn Prediction in a Real Online Social Network Using Local Community Analysis (Ngonmang et al., 2010)
	Entrepreneurs' Networks: Size, Diversity and Composition Shaped by Cultures of Rationality and Trust (Schøtt & Cheraghi, 2012)
	The Impact of Measurement Time on Subgroup Detection in Online Communities (Zeini et al., 2014)
	An Introduction to Social Network Analysis for Personality and Social Psychologists (Clifton & D. Webster, 2017)
<b>Dynamic Social Network Analysis</b>	Application of Social Network Analysis to the Investigation of Interpersonal Connections (Niewiadomska-Szynkiewicz, 2012)
	Spatial and Temporal Evaluation of Network-Based Analysis of Human Mobility (Coscia et al., 2014)
	Complex networks: Structure and dynamics (Boccaletti et al., 2006)

<b>Agriculture</b>	The Agricultural Community as a Social Network in a Collaborative, Multi-Stakeholder Problem-Solving Process (Simpson & De Loë, 2017)
<b>Health care</b>	<p>Using network analysis for the prediction of treatment dropout in patients with mood and anxiety disorders: A methodological proof-of-concept study (Lutz et al., 2018)</p> <p>An Appraisal of Social Network Theory and Analysis as Applied to Public Health: Challenges and Opportunities (Valente, 2017)</p> <p>Use of social network analysis methods to study professional advice and performance among healthcare providers: A systematic review (Sabot, 2017)</p> <p>Social Network Analysis as a Methodological Approach to Explore Health Systems: A Case Study Exploring Support among Senior Managers/Executives in a Hospital Network (De Brun, 2018)</p> <p>A social network analysis approach to alcohol use and co-occurring addictive behavior in young adults (Meisel, 2015)</p>
<b>Environment</b>	<p>Networking the environment: social network analysis in environmental management and local ecological knowledge studies (Salpeteur et al., 2017)</p> <p>Social network analysis: A useful tool for visualizing and evaluating forestry research (Klenk, 2009)</p>
<b>Law, National Safety, Criminology, Terrorism</b>	<p>Social Network Analysis for Law Enforcement (Fresno State USA, 2019)</p> <p>Monitoring social media: Lessons for Future Department of Defense Social Media Analysis in Support of Information Operations (William et al., 2017)</p> <p>Networks of Cooperation and Conflict in the Middle East (2017-2018). (Maghraoui et al., 2018)</p> <p>Applying social network analysis to security (Phillips, 2015)</p> <p>Using social network analysis to combat counterfeiting (Ting, 2014)</p>
<b>Political Science</b>	<p>Social media analysis during political turbulence (Antonakaki et al., 2017)</p> <p>The potential of Social Network Analysis as a tool for monitoring and evaluation of capacity building interventions (Faulkner &amp; M Nkwake, 2017)</p> <p>Network Analysis and Political Science (Ward, 2011)</p>
<b>R &amp; D</b>	<p>Social Network Analysis: Tools for Effective Evaluation and Research (Carothers, 2016)</p> <p>The use of social network analysis tools in the evaluation of social change communications (Davies, 2009)</p> <p>Analysis of Social Media Influencers and Trends on Online and Mobile Learning (Shen, 2017)</p> <p>Social network analysis in innovation research: using a mixed method approach to analyze social innovations (Kolleck, 2013)</p>
<b>Organizational Science Industry, Management</b>	<p>Linking social network analysis with the analytic hierarchy process for knowledge mapping in organizations (Liebowitz, 2005)</p> <p>The Social Network Ties of Group Leaders: Implications for Group Performance and</p>

<b>Leadership &amp; Innovation</b>	<p>Leader Reputation (Mehra et al., 2006)</p> <p>The Effects of Social Network Structure on Enterprise Systems Success: A Longitudinal Multilevel Analysis (Sasidharan, 2012)</p> <p>Using Organizational Social Networks to Predict Employee Engagement (Guha, 2016)</p> <p>The evaluation of social network analysis applications in the UK construction industry (Ruan, 2012)</p> <p>The Application of Social Network Analysis to Accounting and Auditing (Kacanski, 2017)</p> <p>Applying Social Network Analysis to Identify Project Critical Success Factors (Nunes, Abreu 2020(a)).</p> <p>Managing Open Innovation Project Risks Based on a Social Network Analysis Perspective (Nunes, Abreu 2020(b))</p> <p>A model to support Open Innovation Collaboration Risks based on Social Network Analysis. Springer PRO-VE 2020 - 21st IFIP / SOCOLNET Working Conference on Virtual Enterprises. Boosting Collaborative Networks 4.0. (Nunes, Abreu 2020(e))</p>
<b>Archeology</b>	<p>Social Network Analysis in Archaeology (Mills, 2016)</p>
<b>Communication, Learning &amp; Media</b>	<p>Social network analysis of students' participation and presence in a community of educational blogging (Jimoyiannis, 2013)</p> <p>Social network analysis and festival cities: an exploration of concepts, literature, and methods (Jarman, 2014)</p>

Continuation of Table 23 - Application of the Social Network Analysis according to various authors

#### 4.2.4 Benefits and Limitations

According to several authors the application of SNA in organizations provides valuable and unique insights into how organizations really work (Wasserman & Faust, 1994; Cross, 2004; Cross, 2006; Long et al., 2013; Borgatti et al., 2018). Simply by looking a social network (Sociogram) many conclusions can immediately be outdrawn. The same is not always possible when observing bar charts or circular graphs. Analyzing a sociogram creates awareness of possible issues or problems that would not be uncovered by other tools (Borgatti et al., 2018). Analyzing a sociogram leads to rich discussions fueled by a different perspective regarding organizational performance (Nunes & Abreu, 2021). SNA is effective in promoting effective collaboration between strategically important groups (Nunes & Abreu, 2021). It brings together different knowledges of different departments of an organization. It helps in breaking down organizational silos, that throughout the time emerged between different business units or departments (Nunes & Abreu, 2021).

SNA efficiently ensures the integration within different strategical groups following a strategic restructuring, merges, or acquisitions (Nunes & Abreu, 2021). It actively addresses collaboration issues that naturally emerge due the lack of social & technical skills (Nunes & Abreu, 2021).

SNA often promotes organizational flexibility, innovation, and efficiency, which results in quality improvements of products or services by virtue of effectively identifying unique expertise (Workday, 2018; Borgatti, 2016; Nunes & Abreu, 2021). It proactively addresses the social capital aspects at both, individual and organizational levels, by leveraging individual capacities to be brought into a wide network of connections, creating thus chain-values in both directions – individual towards the collective, and collective towards the individual (Workday, 2018; Borgatti, 2016; Nunes & Abreu, 2021).

However, some limitations include (Cross, 2004; NTNU, 2009; Xing, 2016): (1) complex data & collecting process, (2) unable to make predictions, and (3) ethical and legal issues. SNA data is usually collected through surveys or questionnaires, observations, or data logs such as emails. When collecting data through survey or questionnaires the quality of collected data is entirely dependent of the participant good willingness to provide accurate information. Very often, SNA participants feel uncomfortable to provide information that directly exposes others that to whom a friendship relationship may exist. Still, information provided by SNA participants in surveys or questionnaires may be biased leading to take wrong conclusions. SNA is still unable to accurately predict future events due to the high complexity that human behavior comprises together with the other types of uncertainty already addressed in this work (see Risk & uncertainty). Finally, accessing meaningful data to model social networks to draw conclusions regarding organizational performance and innovation is considered by many confidential which may constitute legal & ethical issues.

#### **4.2.5 Conducting a Social Network Analysis in Organizations**

There are two major approaches to conduct a SNA (Cross & Parker, 2004). They are: (1) Personal (also called as Egocentric), and (2) Group (also called Bounded) assessments. The personal approach demands a person to freely identify (usually by means of a survey) other people who are important for a given function or task. This approach has the advantage of uncovering all relationships that are important to the interviewed person, either if they belong to a work task group or if they are external to the Organization. The Group approach requires first to define a network of interest for a specific task or function that needs to be studied. In this case, a list of pre-defined “key” people is to be presented to the interviewed, as all possible options that he can chose as being important for a given function or task. This approach requires knowledge and preparation on the part of the researcher once he must compile a list. The advantage of this approach is that the survey can be adapted by asking respondents to rank or to rate their connections, and so indicating the intensity or significance of those connections (Buehler et al., 2008). Considered by many as the best approach, this option combines both, personal and group approaches (Cross & Parker, 2004).

After defining the approach strategy regarding the target of the SNA, a set of coordinated steps are necessary to execute the assessment. There are eight well defined steps that must be taken to

conduct a successful SNA. They are illustrated in Table 24 (Borgatti et al., 2009; Nunes et al., 2020; Nunes & Abreu, 2020 (a, b, c)):

Table 24 - Typical Steps in conduction a SNA assessment

Step 1 – Define the Reason	Identify a Problem or issue that needs to be properly addressed, where SNA will better work than other tools & techniques.
Step 2 – Define approach Type	Personal approach, Group approach or combined. They can be either closed (the participant will be constraint to a set of preferences) or open (the participant will freely point out a set of preferences)
Step 3 – Define Boundaries & Target	Define, the assessment extension area. (This step is dependent of the previous step). Define precisely what, who when is to be assessed.
Step 4 – Define collecting Data Method(s)	Define one, or multiple collection data methods. They can be essentially; Free or directed Observations, Questionnaires, Mail's analysis, and Log's consultation (Events participation, or others)
Step 5 –Identify Data to be Assessed	Precisely identify, which type of Data is to be assessed, allowed to extract, and relevant for the SNA assessment.
Step 6 – Conduct the Assessment	Collect the Data
Step 7 – Analyze the Data	Analyze, interpret, and draw conclusions over the collected data. Use appropriated SNA software if the network does not allow to extract clear conclusions, through a visual inspection.
Step 8 – Share and Present Results	Create team or / and individual targeted meetings and display, and explain the results obtained. Conduct follow up sessions to accurate identify the real reasons that took a certain result uncovered by applying SNA.

#### 4.2.6 SNA & Centrality: Key-Roles & Key-Networks

Steve Borgatti – specialist in Network Centrality Metrics -, argues that centrality measures are the ones that most valuable and actionable output give regarding the relationship between dynamic behaviors and outcomes (Borgatti et al., 2009). Node centrality can be defined as the advantage that a node has which arrives by the virtue of his position within a network (Borgatti, 2016). People that are central within a network are not far from everybody else. As an advantage, such people tend to ear things faster than others and thus can take advantage of it (Nunes & Abreu, 2021). Central people are usually connected to a lot of different parts of the network. This allows them to hear things about problems, solutions, facts, and so on, that already did occur in one part of an organizational network and can convey that information to other parts of the network that are not so well connected.

Several authors (Wasserman & Faust, 1994; Borgatti et al., 2009; Brandes et al., 2016; Schoch & Brandes, 2016) argue that there are a set of well-defined positions of single actors within a social network structure that strongly influence how an organization functions, and in turn, characterize the different informal organizational networks that may exist in an organization. In Table 25 are presented the most popular informal roles that actors may play in organizations function of their location within the organization social network. They are (Cross & Parker, 2004): Central connector, Boundary spanners, Information brokers, Peripheral and Energizers. For each one of the informal key-roles a respective SNA metric is associated to. These are described in Table 25.

Table 25 - Informal Role (Actors) Type's Description (Cross & Parker, 2004)

<b>Informal role – types &amp; description</b>			
<b>Type</b>	<b>Definition</b>	<b>Characteristics</b>	<b>Most Revealing Metric(s)</b>
Central Connectors or Hubs	<p>Actors that receive the biggest number of links / preferences, coming from nominees from other actors pointing at it (in-degree). A Central Connector can be:</p> <p>1-The Unsung Hero: Actors that surprisingly are much more central than anyone had imagined. They are often unrecognized by their informal work.</p> <p>2-The Bottleneck: people that become much central that end up by holding the entire group and organization back.</p> <p>Within a given social network, both types may simultaneously co-exist. This means that a particular actor may play different roles (either an Unsung Hero or a Bottleneck) function of a particular subject.</p>	<p>These actors look like they know sometimes everyone around them.</p> <p>They share lots of information and may quickly influence others.</p> <p>They can be anywhere in the hierarchy of an organization.</p> <p>Are most of the times well linked and deeply engaged in the Organization Tasks Events and Developments.</p>	<p>Degree Centrality</p> <p>&amp;</p> <p>Visual Analyze</p>
Boundary Spanners	<p>A node which if removed from a network creates a new component. Boundary spanners are also called Gate Keeper Actors, or</p>	<p>Boundary Spanners are those who connect different “groups” of people, known as well as</p>	<p>Betweenness Centrality</p>

	<p>articulations points of a network (ORA) provide critical links between two groups of people that are defined by affiliation, physical location, or hierarchical level.</p>	<p>a SPOC – single point of contact between different groups.</p> <p>Such groups may be within a particular organization department or group, or between different organizations, clusters or even countries.</p>	<p>&amp;</p> <p>Visual Analyze</p>
<p>Information Brokers</p>	<p>It measures how close one Actor is from all other Actors in the network - even people that they are not directly connected to – or is sitting on the shortest path between many other Actors.</p> <p>Often, they make connections across hierarchies, business units, locations, or other Silos, which means that they can - span boundaries!</p> <p>Brokers are intermediary actors who facilitate transactions between actors lacking access to or trust in one another.</p> <p>A Broker must be seen as a trustworthy intermediary (third person/entity) by the two (two other persons/entities) being brokered actors who are go-betweens and bridges in collaborative advice networks are seen as being more trustworthy than people who are not. Social capital theory would further argue that the power and benefits of brokerage (having access to unique sources of information or resources) would be lost if the</p>	<p>Brokers are Key Players in the sense that they can be vital to the integrity and viability of the network.</p> <p>Brokers bring, by crossing holes or boundaries considerable value. They can generate innovative ideas and increase the quality of innovative work, mediate, resolve conflicts, make advice and knowledge more accessible, and can promote trust and collaboration because they know what each side does.</p>	<p>Closeness Centrality</p> <p>&amp;</p> <p>Visual Analyze</p>

	broker proved untrustworthy so there is social pressure on the broker to maintain trust.		
Peripheral People	The Actors that receive the lowest number of links pointing at it (in-degree). A Peripheral Connector can be: Stuck in the Periphery: people that are newcomers, in the Organization. Intentional Peripheral: they can be specialists, or just people that avoid contribute to the Organizations dynamic.	Overlooked and unconnected with the other members of the Organization.  Talented peripheral can be a high risk for the Organization	Degree Centrality  &  Visual Analyze
Energizers	Create energy and excitement in their interpersonal interactions. When people are around energizers, they tend to learn more, demonstrate greater creativity and innovation, and report more satisfaction with their jobs	Usually, people that have a high level of engagement in almost all the activities of an organization, and a constructive a positive attitude when facing challenges.	Degree Centrality

Continuation of Table 25 - Informal Role (Actors) Type's Description (Cross & Parker, 2004)

Besides key individual roles, there are also informal key-networks in organizations. These are essentially comprised by the structural arrangement of each key individual roles within a given social network where they exist. Some of the most important are illustrated in Table 26 and include: Communication network, Information network, Problem-Solving network, Know-How network, Access network, and Trust network.

Table 26 - Informal Key Networks (Cross & Parker, 2004)

<b>Informal key Networks</b>	<b>Brief description</b>
Communication network	Identifies who communicates with who regarding a given issue or just in general, at the break coffee, cantina, etc. so-called the informal network
Information network	Identifies who goes to whom (regularly, sporadic, etc.) for advice on work-related matters regarding a specific subject
Problem-Solving network	Identifies who goes to whom looking for a problem-solving advice, regarding general, or specific issues
Know-How network	Identifies who knows what, who has skills regarding Task A, B, C, etc....)
Access network	Identifies who has access to whose knowledge and expertise
Trust Network	Identifies who trusts whom regarding a particular subject within a given organizational social network

The informal networks illustrated in Table 26 are amongst the most important informal networks for organizations regarding the execution of tasks and activities. Nevertheless, other informal social networks, such as support, well-being, know-what, energizers, just to name a few more, are also important for the execution of task and activities. The informal organizational networks comprise many interrelated aspects important to task execution, such as directed and undirected links, tie strengths, frequency, stability, reciprocity, multiplexity, degree, range, size, inclusiveness, components, clusters, reach, connectedness, transitivity, centralization, and symmetry, that have a critical role in the way coordination, cooperation and collaboration occurs within and between organizations (Wassermann & Faust, 1994; Nunes & Abreu, 2020).

## **4.3 Social Network Analysis in Project Management**

### **4.3.1 Application of Social Network Analysis in Project Management**

In latest years the application of social network analysis has been extending into the area of project management. However, this extending is so far at a very initial stage (Prell et al., 2009; Chinowsky et al., 2009). In project management environments subjects that may contribute to a success project outcome, such as understanding and measure knowledge transfer, consensus building, the identification of project critical success factors, stakeholder management, just to name a few, are on the top of the list regarding the application of social network analysis (Carlsson, 2008; Newig et al., 2010). This has been a trend across the latest years in project management because latest research highlights that more important than frameworks, processes, and procedures applied to manage projects, are - by far - the countless dynamic mix of informal and formal interactions between project people across the different phases of a project lifecycle (Wasserman & Faust, 1994; Cross & Parker, 2004; Prell et al., 2009; Borgatti et al., 2009; Brandes et al., 2016; Nunes & Abreu, 2020).

The identification of critical project success factors has been a continuous preoccupation within latest years. One of the very first notable works regarding the identification of critical success factors in project management was published by Pinto and Slevin in 1988. By surveying circa 400 project managers from very different industries asking them what major reasons lead to success and unsuccess delivery of project, enabled them to identify a set of common project critical factors that responsible for a successful project outcome. Furthermore, they identified that those critical factors were changing the importance degree function of the project phase (Pinto & Slevin, 1988). They identified ten major critical factors. Three of them are related to how project people work in networks of collaboration throughout the different phases of a project lifecycle. They are (Pinto & Slevin, 1988): 1-top management support, 2-client consultation, and 3-communicating network.

The findings made by Pinto and Slevin in 1988 were revalidated by research conducted in 2005 and 2012 (Müller & Jugdev, 2012). The study conducted by Pinto & Slevin contributed to trigger the interest of the application of network analysis in project management (Nunes & Abreu, 2021).

However, the study conducted by Pinto & Slevin did not include the application of social network analysis to quantify behavioral dynamic patterns, and thus they could not quantitatively demonstrate the relationships between identified critical success factors and project outcomes.

Several studies have been done since then trying to provide valuable insight into some of these critical factors identified by Pinto and Slevin.

In a publication in the Harvard Business Review (HBR) in 1993 professor David Krackhardt and Jeffrey R. Hanson highlighted the importance of managers tapping their informal organizational networks as being a key contributor for success. They suggested that by mapping three networks, managers could better understand how work is executed in organizations (Krackhardt, 2000). The three networks are (Krackhardt, 2000): (1) **advice network**—which reveals the people to whom others turn to get work done, (2) **trust network**—which uncovers who shares delicate information with whom, and the (3) **communication network**—which shows who talks to whom about work-related matters

These three networks would then be mapped with the employee's relational information collected through the application of surveys. Krackhardt and Hanson argued that this approach would get to the roots of many organizational problems, enabling managers to take more informed decisions (Krackhardt, 2000). In 2001 Stephen Mead applied social network analysis in a project environment to visualize project teams (Mead, 2001). This study is considered the first study where SNA tools and techniques were applied in project management (Zheng et al., 2016). Mead identified and analyzed an informal project stakeholder's communication network and identified isolated and central stakeholders regarding the informal communication network. This enabled him to elaborate a corrective plan in order to improve the performances of those that were isolated.

In the latest 30 years remarkable research has been done by Professor Rob Cross, a renowned researcher and developer who applies social network analysis to study organizations. In one of his works, "The Hidden Power of Social Networks," published in 2004 he presents a set of ten-year research cases in the study of organizations where he highlights the many benefits of the application of SNA in organizations, especially in project environments (Cross & Parker, 2004). Cross found that in every organization, behind the formal chart there is an informal organizational network that is responsible for how the work is done (Cross & Parker, 2004). Furthermore, he argues that in every informal organizational network there are a set of common actors who are responsible for most of interactions within an organization. These actors include: the central connector, the boundary spanner, the information broker, the peripheral expert, the peripheral intentional, and the energizer. These names were coined to describe their informal role within the organizational informal network structure (Cross & Parker, 2004).

Social network analysis has been applied in health projects is illustrated by a study conducted by the U.S. department of health and human services. Here SNA methods and measures were applied to understand the multidimensional determinants and complexity of tobacco use (Maddox et al., 2014). Prell et al. (2009) applied SNA to analyze stakeholder networks in a natural resource management. He identified which individuals and categories of stakeholder played more central roles in the project network and which were more peripheral. He then used this information to guide stakeholder selection.

Another notable work regarding the application of social network analysis in projects was published in one of the most credited project management institutes (PMI, 2017) in 2012. It details the importance of four key social network analysis terms, showing that those key terms are directly related to project management performance (Toomey, 2012). They are centrality, structural holes, boundary management, and tie strength.

Other recent studies regarding the application of social network analysis in project environments, go from the development of models based on SNA to analyze communication, collaboration, and knowledge networks in project meta-networks (Fitsilis et al., 2009), to the analysis of mega projects networks from the perspectives of different important project stakeholders that help to develop proper long-term project governance policies (Uddin, 2017). In 2017 Mok et al. (2017) applied SNA centrality measures to identify key challenges in major engineering projects (MEPs) based on interdependencies between stakeholder concerns This resulted in the identification of a set of key challenges that that occurred in such MEPs and helped to properly develop a set of recommendations to alleviate those challenges. Yu et al. (2017) (Yu et al., 2017) used social network analysis to investigate social risks related to housing demolition from a stakeholder perspective in China.

A recent work in the field of organizations developed by Michael Arena, Ex-Chief Talent Officer for General Motors, concluded that, after years of investigation in several organizations, successful organizations operate in a networked way enjoying what he called of an *adaptive space*. This space enables a proper connection between the operational and entrepreneurial pockets of an organization in a virtual space—adaptive space—where employees explore new ideas and empower the most creative people to spread their ideas across the organization. This adaptive space is built, managed, and maintained using social network analysis (Arena, 2018). Arena argues that such adaptive space enables organizations to work in a more agile way, which ultimately contributes to outperforming the competition in a disruptive way.

Research and development in SNA extend to other areas as for example the research conducted by Professor Eric Xing, researcher, and professor at the CMU (Carnegie Melon University, Pennsylvania, USA). Xing conducted several investigations on dynamic predictive models built on social network analysis theory. These models which have as objective forecasting how people will

interact and react when facing different future events (Xing, 2016). Such predictive models integrated into a risk management process of an organization, may strongly help organizations to prepare projects or operations better, and more accurately, this could be possible because organizations could better estimate the evolution of future events, and thus, prepare proper plans to respond to those events. In the field of project management, such dynamic predictive models will bring critical help, namely, in the stage of choosing elements to form a project team that better will adapt to certain upcoming project events.

Finally, an indicator of the growing trend regarding the importance of the application of social network analysis in organizations to analyze the influence that the informal organizational network may have on performance, innovation, employee retention, and so on, is visible in renowned consultancy organizations such as, but not limited to, Deloitte (Deloitte, 2016) and Mckinsey (Cross et al., 2007) as they continuously keep integrating social network analysis in their people analytics portfolios.

#### **4.3.2 The Importance of Centrality in Project Management**

Centrality in a social network refers to the structural location of an actor (Nunes & Abreu, 2021). In other words, it refers to where an actor is located within the structure of a social network and not to the actor's own inherent attributes such as age, tender, expertise, and so on (Borgatti, 2016; Workday, 2018; Nunes & Abreu, 2021). Researchers have found that actor centrality can be a measure importance, influence, prestige, control, and prominence (Freeman, 1977; Ove, 2002), and these can be quantitatively measured by applying graph theory centrality metrics, such as degree, betweenness, and closeness (Wasserman & Faust, 1994). According to Freeman (1977) for each of these metrics a respective social direct implication exists, and it goes as follows: (1) **degree** can be an index of a network's activity potential, (2) **betweenness** is an index of communication control by serving as bridge between two different subgroups of a network, (3) **closeness** is an index of the potential independence from network control.

Network centrality can be seen as a source of informal power in a social network (Freeman, 1977; Monge & Eisenberg, 1987; Ove, 2002; Nunes & Abreu, 2021). Informal power derives from the advantageous position of an actor within an organizational social network regarding the facility which interaction occurs, such as communication, collaboration, information exchange, and so on (Monge & Eisenberg, 1987). Informal power is sometime opposite to formal power, which is defined by the position of an actor in the organizational formal chart (Monge & Eisenberg, 1987; Freeman, 1977; Ove, 2002; Nunes & Abreu, 2021).

As previously shown, several studies have focused on the centrality role in informal networks as a special location within a structure of an informal project network (Cross & Prusak, 2002; Cross & Parker, 2004). In fact, further research has been showing that centrality in informal project

networks plays a key role regarding project coordination and decision-making (Cross & Prusak, 2002; Cross & Parker, 2004; Nunes & Abreu, 2021).

Liaquat et al. (2006) applied network analysis to explore the correlation between actor centrality and project-based coordination, concluding that, in projects actors that are central and well connected in informal project networks can exercise greater coordination within the project social network structure. Dogan et al. (2014) reinforced the idea of the importance of centrality in informal networks as he applied social network analysis to measure coordination performance in building and construction projects. He concluded that coordination scores are highly correlated with centrality indices. Wen et al. (2018) applied social network analysis to investigate the determinants of timely decision-making from the perspective of collaboration network dynamics. He also concluded that network tie strength characterized by familiarity and network position strength characterized by centrality have a positive effect in decision-making.



# Chapter 5

## 5 Proposed Model to Monitor Risk in Project Management

*“All models are wrong. But some are useful.”*

K George P. Box

### 5.1 Introduction

In this chapter it will be introduced the proposed model in this work which was developed to answer the research question presented in sub-chapter 1.2.1. The proposed model essentially addresses two critical risk types that may occur as organizations deliver projects. They are (Hillson, 2014; Nunes & Abreu, 2021): (1) **collaborative risks**, which include, behavioral, and collaborative network management risks, and (2) **ambiguity risks**, also known as “epistemic uncertainty”. These types of risks arise from lack of knowledge or understanding and can be managed by applying simulations and lessons learned (Cross et al., 2006; Hillson & Murray-Webster, 2007; Ballinger et al., 2011; Kadushin, 2012; Hillson, 2014; Cross et al., 2016; Workday, 2018; Abreu et al., 2020; Nunes & Abreu, 2021). This is exactly what the proposed model in this work offers: quantitative lessons learned regarding the identification of project critical success factors and a simulation process to guide ongoing or upcoming projects. The risk management pillar assumes particular importance in the structure of the application of the proposed model in this work because the process adopted by the proposed model in this work is strongly based in the process or risk management steps suggested by the ISO. In Table 27 is illustrated the relationship between the ISO steps for risk management and the proposed model in this work functioning principle or approach.

Table 27 - Relationship between the ISO steps for risk management and the proposed model in this work functioning principle or approach.

<b>Steps (ISO, 2021)</b>	<b>Proposed model process steps</b>
“Scope, context & criteria”	Step 1-Select, collect, and prepare collaborative data from successfully, and unsuccessfully delivered projects
“Risk identification”	Step 2-Identification of unique repeatable behavioral patterns associated with successfully, and unsuccessfully delivered projects
“Risk analysis”	Step 3-Identify and quantify project CSFs
“Risk evaluation”	Step 4-Quantitatively measure the deviation between actual status of ongoing project and desired status regarding CSFs
“Risk treatment”	Step 5-Apply (quantitatively) actions to align ongoing project evolution with

	identified CSFs
“Monitoring, and reviewing”	Step 6-Continuously update the CSFs identification process (continuous improvement cycle – self learning system)

Continuation of Table 27 - Proposed model risk assessment process (adapted from (ISO, 2021))

As it can be seen in Table 27 the standard steps suggested by the ISO (International Organization for Standardization) serve as a guide across the different stages that comprise the application of the proposed model in this work. This fact is in line with what researchers suggested about what doing project management is - which according to several authors – efficient project management is executing risk management across the different project’s tasks and activities (Kwak, 2003; Hillson & Murray-Webster, 2007; Hillson, 2014; PMI, 2017; APM, 2020).

## 5.2 Proposed Model Development & Application

### 5.2.1 The proposed model in a nutshell

In a nutshell, to address the research question the proposed model is designed to identify repeatable behavioral patterns that are associated to a given project outcome (success, or failure). In other words, the proposed model in this work will analyze how project people did behave across the different phases of successful and unsuccessfully delivered projects. If the model identifies that in projects that were successfully delivered project people clearly behaved differently from project people that participated in project that were unsuccessfully delivered, then project critical success factors have been found. If so, identified project critical success factors will be used in ongoing in and upcoming projects as a guidance regarding the behavioral patterns that lead to successful project outcome. For this the proposed model in this work will analyze data collected in project Meetings, Mails, and Questionnaires. This data will then be analyzed and used to characterize five different global collaboration types (5-GCT) that often emerge as project are delivered. They are (Nunes & Abreu, 2021): (1) **Communication and Insight**, (2) **Internal & Cross Boundaries-Collaboration**, (3) **Know-how Sharing & Power**, (4) **Clustering (variability effect)**, and (5) **Teamwork Efficiency**. For the characterization process, the proposed model in this work will apply social network analysis centrality metrics. The application of SNA centrality metrics will enable the quantification of behavioral patterns in each one of the five different global collaboration types.

### 5.2.2 Model Key concepts

Before drilling down on how the model is built and operates, important subjects need to be introduced. **Project Definition:** In the context of the proposed model in this work, a project is defined according to the PMI, which defines a project as temporary endeavor undertaken to create a

unique product, service, or result (PMI, 2017). **Project Outcome:** The proposed model in this work needs as input two different classifications of project sets. These could be for example characterized as successful or unsuccessfully delivered. However, the criteria that dictates the two different classifications are out of scope of the proposed model in this work. The successful and unsuccessful project outcome criteria could be for example adopted by the PMI definitions which essentially says that a successfully delivered project is a project that was delivered on time, scope, budget, and under the agreed quality standards (PMI, 2017). **Number of Projects:** The proposed model is not constrained to a given number of projects that were successfully, and unsuccessfully delivered to be analyzed. However, to be able to the model, at least information from two projects (one successfully delivered, and one unsuccessfully delivered) must be available. **Project People:** Project people is any person that directly or indirectly participated in a project across the different phases of its lifecycle. These are for example, the internal stakeholders from both interacting parts – Service Provider, Customer and Suppliers for example, that are contractually engaged for the demand/supply of resources, services and/or end products (Tsai & Ghoshal, 1998; PMI, 2017). Project people is any person that has participated in project meetings, email project information-related exchange, and questionnaires. The model studies the dynamic interactions between any two different Teams (Team A: Service Provider and Team B: Customer for example), across a project lifecycle. There are no restrictions to the number of teams to be analyzed by the model. **Project people-roles:** Across a project lifecycle is usually expected that several different project people-roles with own and specific responsibilities take part on project activities. Also called as important stakeholders, project people-roles, for the proposed model's version, are the Project Manager(s), Engineer(s), Expert(s), other(s), and Outsourcers. **Project Phases and Lifecycle:** Any project that has been successful, or unsuccessfully delivered must have a finite number of project-phases. The number of phases may be given by the PMI standard. Usually there are between four and five project generic phases according to the PMI. They are: Starting the Project, Organizing and Preparing, Carrying Out the Work, and Ending the Project (PMI, 2017). However, the user may decide the number of phases that the project to be analyzed have. Important is that all project that will be analyzed must have the same number of project phases. **Dynamic Interaction:** The dynamic interaction of project people (DIPP) refers to how project people communicate, direct and cross boundaries collaborate, shares know-how, exerts power, cluster (create and / or lose relationships), provide advice or help, and so on within the mix of formal and informal project network relationships. The DIPP across the different phases of a project lifecycle are captured with several observations within a given project phase. These dynamic interactions comprise the mix of formal and informal networks of relationships that emerge and evolve as project people collaborate to deliver a given project. The DIPP is analyzed by measuring meetings participating degree, rate and intensity of email project information-related exchange, and degree of importance and influence of some project people over other project people. **Project Informal Network:** The project informal network or Project Social Network (PSN) refers to all the project people dynamic interactions that occurs out and in the pre-defined formal structure of the project organization. This

includes the mix of all the formal and informal dynamic interactions. For example, in the project email network, the communication between a project people A and a project people B will be analyzed and considered part of the project informal network regardless of the official relationship between A and B.

### 5.2.3 Model Functioning Principles

The proposed model in this work will look for repeatable behavioral patterns (RBP) regarding the dynamic interaction of project people across the different phases of a project lifecycle in both, successful and unsuccessfully delivered project. If the model identifies unique RBPs that are associated with a certain project outcome (success, or failure), they are classified as critical factors. Unique RBPs means that there are things that repeat themselves only in one of the two possible project outcomes (success or failure). By being unique, they are immediately considered project critical success factors. To better illustrate the above description a theoretical example will be explained using Figure 21 in as support. In Figure 21 are represented the lifecycles of two real delivered projects – project 1 and project 2 – that were delivered to a Customer C (not present in Figure 21) and accomplished by the Organizations A and B (both present in Figure 21). Both projects 1 and 2, comprise the development, and application of technical solutions in the food & beverage industry. Customer C, a market leader in the food & beverage industry, invited first, several Organizations that deliver projects in the mentioned area, such as Organizations A, and B, to show its plans / ideas, to develop and commercialize a new product, and second, to create two project proposals that meets its needs, namely building two new production lines.

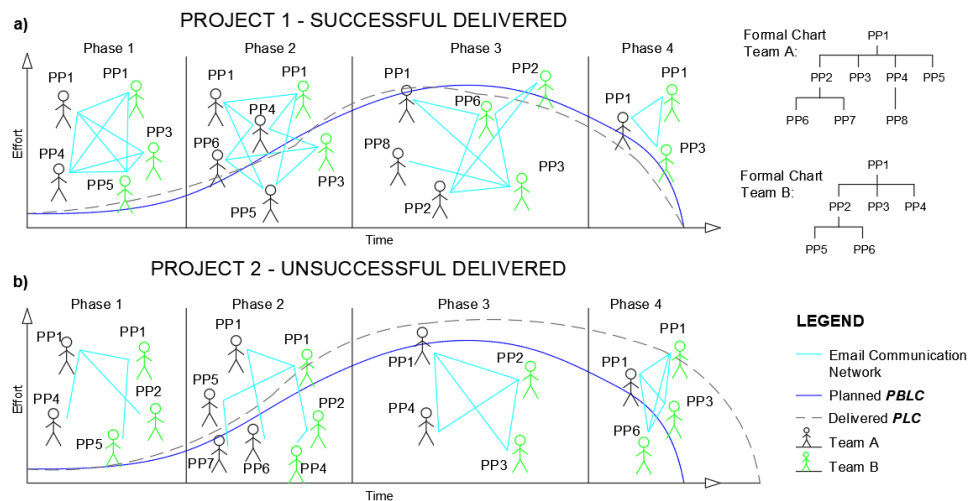


Figure 21 - Project lifecycles for Project 1 and Project 2 (Nunes & Abreu, 2020).

Organizations A and B won both project proposals and delivered both projects 1, and 2. Project 1, and project 2 were delivered in different points in time, but within the same year in Europe. Both projects, were delivered across the year of 2019, with the average duration of 5 months each. Organization A delivered the engineering and mechanical installation parts, and Organization B

delivered the automation and programming services. Project 1 had a budget of circa 8 M€, and project 2, had a budget of circa 5 M€. For both projects 1, and 2, the same formal structure was used regarding Organization A, and B respectively, according to Figure 21. Due to protection reasons, further projects information, and Customer C, and Organizations A, and B identification, will not be disclosed in this work. Employees (project people) from Organization A are represented with the black color (Team A), and from the Organization B, with the green color (Team B).

In Figure 21 is also illustrated the project people location within the project formal structure, which is valid for both projects 1 and 2, where for example for Team A, PP1 is the project manager, and PP2, PP3, PP4, and PP5, are their direct subordinates (Functional managers), and PP6, PP7, and PP8, are project staff (engineers, programmers, and so on). The project people represented at the formal chart, are those project people that have been assigned at the very beginning of phase I to deliver the project throughout all the project phases. Concretely, Figure 21, represents the collaboration network between Organization A and B, while delivering Projects 1 and 2 to a Customer C. The blue line (project planned curve) represents how the projects were planned to be delivered. The grey line represents how the projects were delivered. Project 1 was successfully delivered, and project 2 was unsuccessfully delivered. For this illustrative case, and according to the PMI, a successfully delivered project, is a project delivered on time, scope, budget, and the agreed quality (PMI, 2017). On the other side, an unsuccessfully delivered project, is a project where at least one of the mentioned constraints (time, scope, budget, or quality) was not delivered according to the plan. Both projects have four different phases: phase I, 2, 3, and 4 throughout their lifecycles.

In each of the four phases of both projects, the blue light lines represent the email communication network between the project people. Such network mirrors the direct communication (email sent directly to, or received directed from) pattern, results of the analysis of all emails project-information related exchanged at any given project phase. For example, after consulting the email exchange logs for project 1 in phase I, there has been a direct communication between project people 4 and project people 5. This means that PP4, sent and or received an email from PP5, and vice versa, at any given time within the phase I of project 1. On the other side, for example, on project 2 in phase I, PP3 and PP5 never had a direct contact regarding email exchange.

Each blue light line between any two-project people, represents an email communication channel regardless of the number of emails exchanged. When analyzing how the email communication occurred in the first two phases (phase I, and phase II) of both projects, it is clear, that the project that was successfully delivered (Project 1) the email communication network is by far denser than the email communication network in project 2. For these two phases, and not considering any other factors, it can be concluded that a denser email communication in phase I of a project, is correlated to a project success outcome. Means this, that the email network communication is a critical success

factor, and project success outcome is correlated with a dense email communication network in phase I of a project.

However, one still needs to define what a dense, and sparse email communication network is. This means, they need to be quantified. It is now, that the Social Network Analysis provides critical help. SNA uses the graph theory, that can be used to characterize and measure a social structure. The constellation that results from linking project people through emails sent and received, perfectly mirrors a typical graph structure. Therefore, the direct application of graph theory metrics is adequate. For this case a centrality measure – the density (18) metric, will be used to quantify what a dense and a sparse communication network is. The density is the ratio of existing links between project people inside each phase of each project lifecycle, to the maximum possible number of links (when everybody is linked) between project people, and is given by the formula (1):

$$d = \frac{2L}{n(n-1)} \quad (18)$$

Where:

L = number of existing lines between project people

n= total number of project people

Applying (1) for phase I of project 1:

$$d = \frac{18}{5(5-1)} = 90 \%$$

Applying (1) for phase II of project 1:

$$d = \frac{20}{6(6-1)} = 67 \%$$

Applying (1) for phase III of project 1:

$$d = \frac{16}{6(6-1)} = 53 \%$$

Applying (1) for phase I of project 2:

$$d = \frac{8}{5(5-1)} = 40 \%$$

Applying (1) for phase II of project 2:

$$d = \frac{12}{7(7-1)} = 29 \%$$

Applying (1) for phase III of project 2:

$$d = \frac{10}{4(4-1)} = 83 \%$$

After analyzing the results, of the above presented equations, it can be concluded that the density value, for example, for project 1 in phase I is of 90%, and for project 2 in phase I is of 40%. This means that, at project 1 in phase I, there are more 50% of direct channels regarding the email communication network, than at project 2 for the same phase. In other words, means that for project 1 in phase I, almost everybody, directly communicated with everybody through the email network, at a certain point in time.

There may be several interpretations for this. One for example, is that, according to the legend, PP1 for both, projects 1 and 2, are the Project Managers of Teams A, and B, and PP4 is a direct subordinate, it can be concluded that the email communication network at project 1 follows a more informal pattern, than the one at project 2. This is because at project 1 in phase I, one Project Manager subordinate (PP4), has had direct contact with all the other project people in opposition to the PP4 at project 2, where the email communication network follows a more formal pattern, where the email communication between Organization A and Organization B is exclusively done through the project Manager of Organization A. For example, in project 1 in phase II, the direct email communication channels drop to 67 %, which means that from all the possible direct email communication channels, only 67 % of them exists. Now when analyzing phase IV of both, projects 1 and 2, it can be seen at naked eye, that all the project people is directly connected through an email communication channel. In fact, when applying (1) for both project as phase IV:

Applying (1) for phase IV of project 1:

$$d = \frac{6}{3(3-1)} = 100 \%$$

Applying (1) for phase IV of project 2:

$$d = \frac{12}{4(4-1)} = 100 \%$$

In this case, for the phase IV of both projects, there is no difference between the density results on both projects. However, project 1 was successfully delivered, and project 2 was unsuccessfully delivered.

So, it can be concluded that, the email communication network for phase IV of both projects is no longer considered a critical success factor, because there is absolutely no difference between the results for both projects, regarding the density metric. These results are in line, with findings from Pinto & Slevin in 1988, as they found that project critical success factors, change the importance degree or even disappear, function of project phase. Therefore, for phase IV, there is a need of

another SNA metric, that may identify a pattern regarding the dynamic interaction of project people, that can be correlated to a certain project outcome.

Finally, when comparing project 1 with project 2, regarding the email communication network, it can be concluded that for phases 1, 2, and 3 tends to be denser in project 1 than in project 2. This means that there is a repeatable behavior pattern (RBP) in phases 1, 2, and 3, of project 1 (successful outcome), which is characterized by having a dense email communication network, of values 90%, 67%, and 53 % respectively.

#### **5.2.4 Project Success Profile & Project Failure Profile**

Now let's assume that the collaboration between organization A and organization B had resulted in 20 successfully and 20 unsuccessfully delivered projects to the imaginary customer C. In total organizations A and B had delivered 40 projects to customer C. Still let's also assume that the project lifecycle of project 1 in Figure 21, no longer represents the project lifecycle of one single successfully delivered project rather the averaged lifecycle of all those 20 successfully delivered projects within the latest year. The same goes for project 2 in Figure 21, where now represents the averaged lifecycle of all those 20 unsuccessfully delivered projects within the latest year.

Now, the blue lines in the lifecycles of Figure 21 represent the average repeatable behavioral pattern regarding the email communication network. That means that in average, all the 20 successfully delivered projects had in phases 1, 2, and 3 a denser email communication network than in the 20 unsuccessfully delivered projects for the same project phases. The average results of the email communication network represent one aspect of the so-called project success profile (PSP), and project failure profile (PFP), for successfully and unsuccessfully delivered projects, respectively.

A project success profile, and a project failure profile represent all the different SNA metrics that were used to analyze and quantitatively measure the dynamic interaction of project people across a project lifecycle. Until now, only one metric has been used to characterize and measure one type of dynamic interaction that occurred in the project informal network, which is the email communication network.

Concluding, a project profile is then the collection of all averaged SNA metrics results, obtained by the application of the proposed model in this work for each individual successful and successfully delivered project.

### **5.2.5 Model Application Span**

The proposed model in this work is not limited to a any fixed number of project phases. However, usually is adopted the suggestion of the PMI institute which defined between 4 and 5 project phases (PMI, 2017). The proposed model is designed to applicable regardless of project size and complexity. The project people-roles are not limited to those previous mentioned in the previous sub-chapter, as long they are well defined for both project success and project failure outcomes. The project Teams A and B that will be analyzed by the model do not necessarily are limited to a relationship Service provider – Customer. This means that, regarding project teams, Teams A and B, can be any two different Teams in a project organizational context (between any two business units of an organization or between any two different organizations, for example). However, the analysis must be always done between any given two teams to be possible quantitatively to compare dynamic interactions. These on turn, may be agglomerated, or delayed into several other “sub” Teams. As for example, if in a project there is a service provider (Team A), a customer (Team B), and supplier to A (Team C), and so on, the model will analyze the dynamic interaction between A and B, A and C, and B and C separately. In other words, the analysis is always to be done between any two different entities, internal – (if for example are business units, or departments of a given mother organization), or / and external (if are different organizations, for example supplier and customer) that directly or indirectly participates in the delivery of projects.

### **5.2.6 POL Model Part 1 & Part 2**

The proposed model in this work (POL Model) has two parts. Part 1 essentially consists in the creation of a knowledge base regarding the critical success factors that may lead projects to a successful outcome as illustrated in the previous sub-chapters (5.2.3, 5.2.4). If critical success factors have been identified in Part 1, then Part 2 of the proposed model in this work can be executed. If not, then Part 2 of the proposed model cannot be executed.

In a nutshell, Part 2 of the proposed model estimates an ongoing project outcome likelihood. Part two of the model can only be run if in Part 1 of the model critical success factors have been identified. In Part 2 of the proposed model an actual state of an ongoing project *AP* will be compared to a desired state for that ongoing project. The proposed model will be applied to identify if there are any deviations between the actual state and the desired state regarding the dynamic interaction of project people across a project lifecycle for an ongoing project. A framework for both parts, Part 1, and Part 2 of the proposed model, is illustrated in Figure 22. To get a full picture of the functioning of the proposed model in this work, Figures 22 and 23 must be simultaneously analyzed.

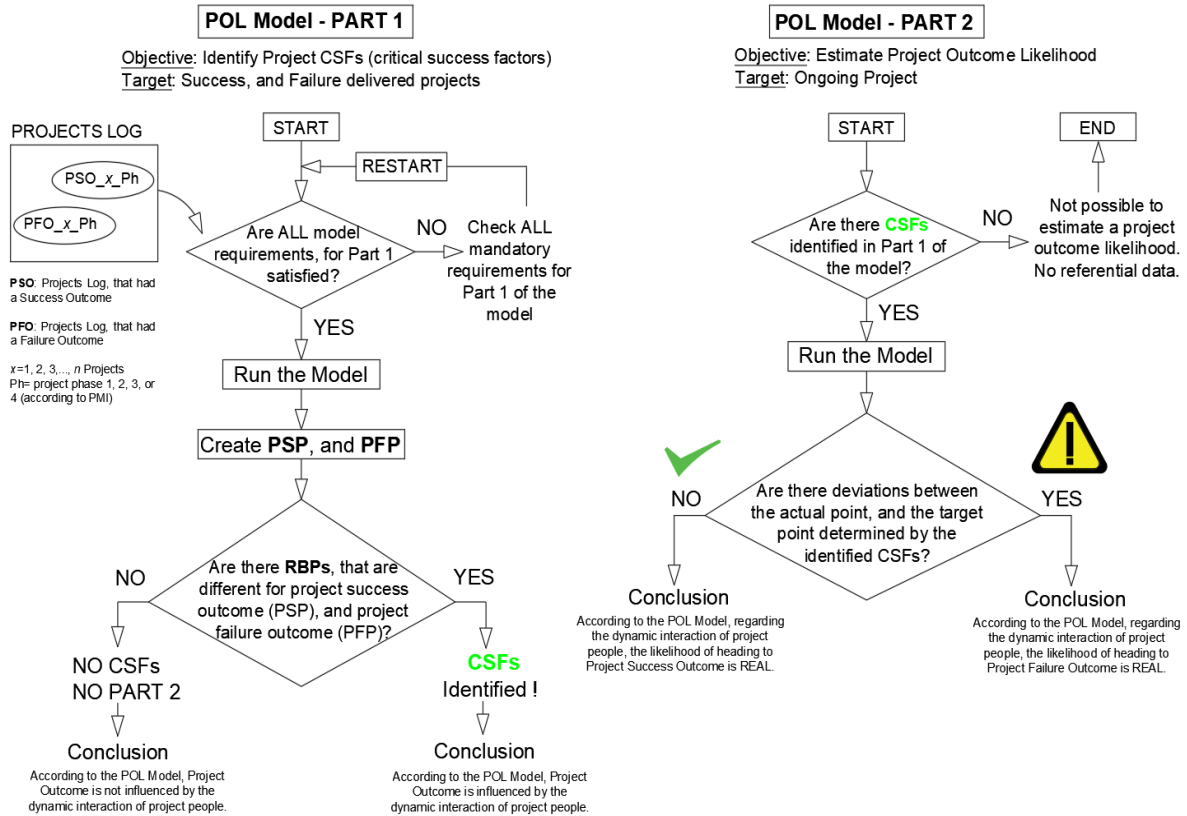


Figure 22 – POL Model Framework - Part 1 and Part 2 (Nunes & Abreu, 2020).

In Part 1 of the POL Model (Figure 22, left) data arriving from number of selected successful (PSO) and unsuccessful (PFO) delivered projects according to Table 29 will be supplied to the model. The model will analyze, and measure inputted data from all the different phases of the projects through the application SNA centrality metrics (Figure 23). The input data can be collected in project emails, project surveys, and project meetings.

After all selected projects have been analyzed, an averaged profile characterizing all the successful (PSP), and unsuccessful (PFP) delivered projects will be created (Figure 22, Figure 23). The content in each of the created project profiles is an averaged result of the repeatable behavioral pattern (RBPs), regarding how project people dynamically interacted throughout the different phases of the selected project lifecycles for both, successfully, and unsuccessfully delivered projects (Figure 22, Figure 23).

It follows a comparison process between the RBPs that characterize the PFP and the PSP. Throughout this process, if crystal clear differences (opposite results regarding the PSP and PFP values) are identified, then project critical success factor(s) have been identified (Figure 22, Figure 23). At this point, if project critical success factors have been identified the characterization of the five global collaboration types is concluded. If critical success factors have not been identified, then it is to be concluded that according to the proposed model the dynamic interaction of project people

across the different phases of the analyzed project lifecycles do not influence a project outcome (Figure 22, left, bottom).

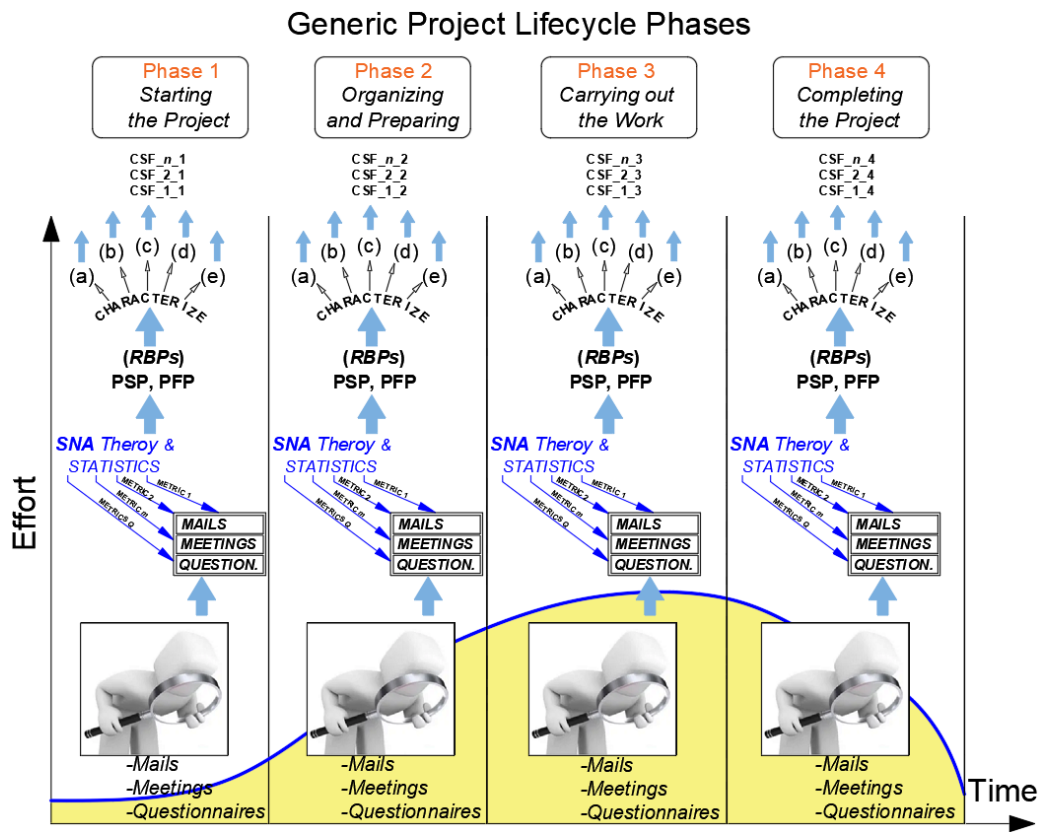


Figure 23 - POL Model - Part 1 & 2 Process. Source: Adapted PMI, 2017 (Nunes & Abreu, 2020).

In Part 2 of the model (Figure 22, right), and if critical success factors have been identified in Part 1 of the proposed model, for an ongoing project, such critical success factors will be used to guide the dynamic interactions of project people for the respective project phase. In Part 2, the model will analyze available relational data produced in the ongoing project from its start until a certain point (actual point in time) *AP*. The model then creates an ongoing project profile which will be compared with the *PSF* and *PSF*. Then if the model finds a deviation between the actual status and the “should be” status (which are the values of the critical success factors identified in Part 1 of the model) can be concluded that according to the proposed model the likelihood of heading to project failure outcome is real (Figure 22, right, bottom). The contrary is also true. Finally, the outcome likelihood will then be estimated by applying a simple rule. This rule is based on the highest percentage of metrics indicating success or failure outcome. In other words, the more metrics - for an ongoing project - are aligned with the critical success factors identified in Part 1 of the model, the highest is the success outcome likelihood of the ongoing project. For a full understanding on the functioning of the proposed model in this work, a case study is presented in chapter 6, covering Parts 1 and 2 applied in a real case.

## 5.2.7 Model Requirements

In Table 28 are illustrated the requirements for Part 1 and Part 2 of the proposed model in this work (Nunes & Abreu, 2020).

Table 28 – Requirements for Part 1 and Part 2 of the POL Model

<b>Part 1</b>	<b>Part 2</b>
<p><b>Objective:</b> Identify project-phase critical success factors.</p> <p><b>Method:</b> Analyze projects that were successfully, and unsuccessfully delivered to create a project success profile (PSP), and a project failure profile (PFP), to identify RBPs.</p> <p><b>Requirements:</b> Project data-related from projects that were successfully and unsuccessfully delivered, must be available for each project phase according to Table 29. The number of projects that were successfully delivered, must not exactly be the same, as the number of projects that were unsuccessfully delivered. There are no restrictions to the number of organizations as well as the number of project people that the model can simultaneously analyze. However, one possible arrangement could be: The Organization that delivers a project (service provider) and the Organization that ordered a project (customer). They can still be simply named as Team A, and Team B respectively. The criteria that define successfully and unsuccessfully delivered projects is not to defined by the proposed model in this work. This must be an input given to the model. All projects must have the same number of phases across their lifecycles for a given analysis.</p>	<p><b>Objective:</b> Estimate an outcome likelihood for an ongoing project-phase.</p> <p><b>Method:</b> Measure the deviation between the evolution of an ongoing regarding the 5 key dimensions, and the critical success factors identified in part 1.</p> <p><b>Requirements:</b> Critical success factors must have been identified in Part 1 of the model. There are no restrictions to the number of organizations as well as the number of project people that the model can simultaneously analyze. However, one possible arrangement could be: The Organization that delivers a project (service provider) and the Organization that ordered a project (customer). They can still be simply named as Team A, and Team B respectively. All information regarding the way project people dynamically interacted, for the respective project-phase where an outcome estimation likelihood is to be calculated, needs to be available according to Table 29.</p>

The necessary information regarding the dynamic interaction of project people will be collected through three different Social Interaction Tools (SIT). This necessary information is illustrated in Table 29. Meetings, refers to F2F or Web project meetings that occur in each phase of a project lifecycle. Mails, refers to all the project related information mails, that were exchanged between the project people, in each phase of a project lifecycle.

Questionnaires will only be used in the phases of the project lifecycle where a third organization is outsourced to accomplish project activities. Usually, Questionnaires are applied in the execution phase of a project lifecycle. The data collected through these three SITs will then be analyzed using a set of tools & techniques based on Social Network Analyses centrality metrics.

Table 29 – Necessary information regarding each of the Social Interaction Tools.

<b>SIT</b>	<b>Necessary Information (Projects Logs)</b>
Meetings	Total number of project meetings in each project phase, across a project’s lifecycle. Total number of participants in each project meeting, in each project phase, across a project’s lifecycle. Name, Project Official Role, and belonging Team from each of the participants
Mails	Total number of emails sent/received in each phase of a project, across a project’s lifecycle that relate to project information matters. Name, Project Official Role, and belonging Team from each participant that sent / received emails project related information. Categorize emails according to: (1) Mails sent in seeking for help, or advice regarding project information related matter. (2) Mails sent, providing help, or advice, regarding project information related matter. (3) Mails need to be accessed and identified either by their subject or content, as being seeking, or providing help type.
Questionnaires	To be applied, case a third Team (possibly called as Team C) takes part at one, or more than one phase, of a project lifecycle, and usually works on behalf (outsourced) of one of the main Teams, A and B. Conduct a SNA by applying following two questions to the third Team members: Question 1: If you have a problem, or question regarding (x)*, that is important to execute your project activity, who do you usually go for help, among the project people of Team A and Team B? Question 2: If you are just about to start the execution of a project activity or task, but you want to make a double check before you go ahead, or even present what you consider to better solution, whom do you turn to, to get approval and final decision among the project people of Team A and Team B?

The quantitative results outputted by the application of SNA centrality metrics will be used to characterize the five global collaboration types (5-GCT). These usually emerge and evolve in all project phases of any project lifecycle. They are, a) Communication & Insight, b) Internal & Cross - Collaboration, c) Know-how Sharing & Power, d) Clustering (variability effect), and e) Team Efficiency. In Table 30 is illustrated a detailed description of the five global collaboration types (5-GCT) that usually emerge across all project phases of a project lifecycle.

Table 30 – The Five global collaboration types (5-GCT) of the POL Model.

<b>Communication &amp; Insight</b>	<p>Description &amp; Objective: How does important project stakeholders (Project Managers and Experts for example), are conducting the project-phase global communication, and the impact for a certain project outcome? How is the feedback level between the different teams that work in networks of collaboration?</p> <p>Regarding Meetings: How the presence of those important stakeholders in project</p>
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	<p>Meetings, triggers communication and insight on what is ongoing throughout the different projects of a project lifecycle, namely in the transitional phase of the different project phases.</p> <p>Regarding Mails: How does the internal and external mail communication is being made regarding cohesion? How is the feedback rate? How is the feedback rate regarding mails communication network?</p>
<b>Internal &amp; Cross Boundaries- Collaboration</b>	<p>Description &amp; Objective: To which extent is one Team (service provider for example), more dependent, or less dependent on project-related information provided from other Team (customer for example), and the impact for a certain project outcome?</p> <p>Regarding Mails: How is the volume of mail communication seeking and providing project-related information between any two Teams (internal to Team A – sub-team of Team A, or cross boundaries, between any two different Teams, as Team A and Team B)?</p>
<b>Know-how sharing &amp; Power</b>	<p>Description &amp; Objective: To which extent, does the project-related information, provided by one Team (service provider), or other Team (customer), is recognized as important &amp; decisive, and the impact for a certain project outcome?</p> <p>Regarding Questionnaires: Apply a SNA assessment, to an Outsourced Organization, to find out on which side (service provider, or customer), lays the major know-how &amp; decision-making power, on site.</p>
<b>Clustering (variability effect – PSNVar)</b>	<p>Description &amp; Objective: To which extent, does the variability (changing the project team set) of the project social network cohesion, across all phases of a project lifecycle, contributes for a certain project outcome?</p> <p>Regarding Meetings: How frequent do changes on the project team set occur, across the different phases of a project outcome, and how is reflected in project people social cohesion?</p>
<b>Teamwork efficiency</b>	<p>Description &amp; Objective: To which extent, does a project outcome is associated to the speed of feedbacking project information-related between project teams?</p> <p>Regarding Mails: To which extent does the Email Feedback Speed, when answering a question or providing project information-related between different project teams, impacts project outcome?</p>

Continuation of Table 30 - The Five global collaboration types (5-GCT) of the POL Model

### 5.2.8 Application of the POL Model

The number of phases adopted in this work will be four. They are (PMI, 2017): (1) starting the project, (2) organizing and preparing, (3) carrying out the work, and (4) completing the project. These phases are adopted by the recommendation of the PMI – Project management institute. To the demonstration of the application of the POL Model in organizations, a real case of application will be used. The application of the POL Model will be explained in the four different phases of a

project lifecycle as illustrated in Figures 25, 27, 28, and 29. For this illustrative purpose a generic project with four different phases has been chosen, where Teams A and B, are expected to collaborate to successfully deliver the project. In each project phase, meetings, email-exchange communication, and questionnaire data (in this case only in phase III) have been recorded according to Table 29. The five application process steps are as follows:

#### 5.2.8.1 Defining the Official Project Formal Structure

First, the proposed model needs to learn the Formal Organizational Chart (Figure 24) in the very beginning of the first phase of a project lifecycle, or even before. The Formal Organizational Chart must be defined one time only before any of the project phases initiates.

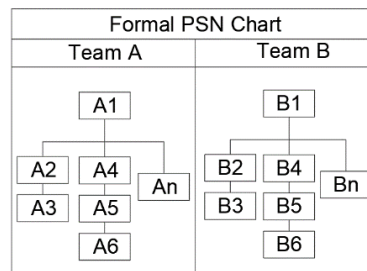


Figure 24 - Organizational Formal Chart - Model application (Nunes & Abreu, 2020).

In Figure 24 is illustrated the Formal Organizational Chart of two Teams – Team A, and Team B - that are collaborating across all the different phases of a Project Lifecycle to deliver the project illustrated in Figures 25, 27, 28, and 29.

The formal importance degree – known as the official line of command of both Teams A, and B - are represented in the formal organizational chart in Figure 24. It is top-down (from A1 down to A6, as an example of Figure 24) ranked, being at the top the “most” important project roles, and at the bottom the “minor” important project roles. In the formal chart displayed in Figure 24 is illustrated who plays what role, and who does what, throughout the project lifecycle.

Furthermore, for the POL Model it is expected to be defined at the beginning of phase I of a project the team that is expected to deliver the project throughout all the phases of the project lifecycle.

#### 5.2.8.2 Application of the model in Phase I – Starting the Project

In Figure 25 is illustrated the application process for project phase I - Starting the Project. In this phase (as well for the following project phases) there must be two well-defined points in time, representing where the phase starts and where the phase ends. This is represented by the points in red **START** and **END** in Figure 25.

Across this phase a set of project meetings occurred and the information regarding those meetings is to be collected according to Table 29. Project meetings are named Events (E) and are coded as: E1\_t, where for example: E\_1=Event of phase I, and \_1= event, or meeting number one. There may exist E1\_t Events in this phase, as for all the other project phases. For example, at Event 1 (E1\_1) illustrated in Figure 25 participated the project people A1, A2, and A5, from Teams A, and B3, B4, B5, and B6 from Team B. The same interpretation to be made for the remaining Events E2, E3, E4, and E5 (E1\_t).

In Figure 25 under the project lifecycle curve is illustrated a table representing the PSNVar\_1. This is a list of: the actual participants, who left, who came new, and who re-came, at any given project meeting of project phase I. As an example, let us consider meeting E1\_2 as the present (actual) meeting for an instant. In meeting E1\_2 (the second project meeting form phase I of the project illustrated in Figure 25) project people A1, A3 from Team A, and: B1, and B2 from Team B, were present. This information is displayed in the box above the red **START** point.

In the table where - Teams A, B, IN, OUT - is displayed (under the project lifecycle curve), for meeting E1\_2 project people A3 from Team A is categorized as IN. This means that project people A3 is present at meeting E1\_2 (present meeting) and was not present at the previous meeting (E1\_1). The categorization IN, means that project people A3 just came into this meeting (E1\_2) and at the same time did not attend the previous meeting (or previous meetings). As it can be seen in Figure 25 project people A3 was not present in meeting E1\_1.

In meeting E1\_2 (the present meeting for this case) project people A2, and A5 are categorized as OUT. This means that they were in the previous meeting (E1\_1) but are not at the actual meeting (E1\_2). The same interpretation is to be made for project people of Team B. Let us now consider meeting E1\_3 as present meeting. In this meeting project people A1 from Team A is the only element present at the actual meeting. From Team B, project people B1 and B4 are present. In this present meeting (E1\_3), project people B4 is categorized as IN, which means that B4 was not present at the previous project meeting E1\_2.

Project people A3 is now categorized as OUT, meaning that A3 was present at the previous project meeting (E1\_2), but is not present at the actual meeting E1\_3. The same goes for project people B2 of Team B. Still at the present meeting (E1\_3), no project people of Team A, is categorized as IN. This means, that at the present meeting (E1\_3), there are no project people from Team A, that simultaneous, did not participate at the previous meeting and participates at the actual meeting. In other words, this means that there are no new arrived project people from team A to the present meeting since last meeting.

Considering now meeting E1\_4 as present the meeting, there are no project people categorized as OUT from both Teams A, and B. This means that from the previous meeting up to the present

meeting, no project people left the meetings circuit from both Teams. In other words, this means that the project people that participate at meeting E1\_3 also are participating in meeting E1\_4.

Considering now meeting E1\_t as the present meeting (which is as well the last meeting from the phase I of the project lifecycle) project people A1, A2 from Team A, and B1, B4, from Team B participated at the actual event. In this case, for Team A there is no project people categorized as IN or OUT. This means that the project people that participate in the actual meeting (last meeting of phase I) is the same project people that participated in the previous project meeting E1\_4.

In such cases, the variability from one meeting to another meeting is zero regarding the project people attendance.

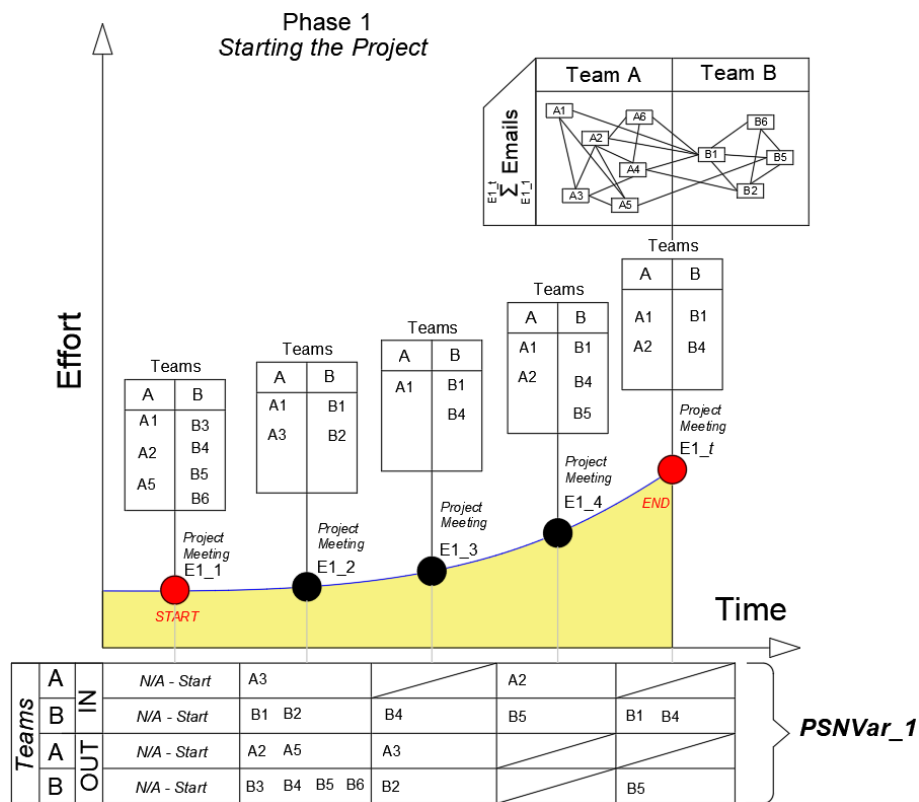


Figure 25 - POL Model application for Phase I, for both, Success and Failure project Outcomes. Example with 5 Meetings (Nunes & Abreu, 2020).

For a given actual meeting, project people categorized as IN are considered *new* in that given meeting. This *new* categorization has two different interpretations and is related with the restart (R) step as illustrated in Figure 26. The first interpretation is related to be new to a given actual project meeting as being new for the very first time to take part in any project meeting. The second interpretation is related to be new to an actual given project meeting as being new relating to the

previous project meeting. This concept is detailed explained at the dynamic variability cycle illustrated in Figure 26.

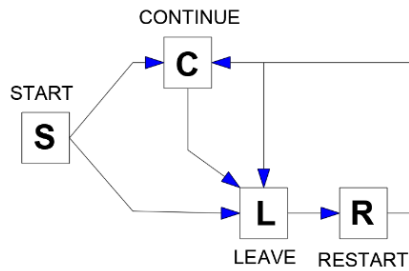


Figure 26 - SCRL dynamic variability cycle meetings participation assiduity (Nunes & Abreu, 2020).

The PSNVar is based on the project people variability cycle illustrated in Figure 26 and aims to understand to which extent does the project social network variability impacts a project outcome. In other words, the PSNVar will quantitatively capture the variability of project people regarding meetings attendance cycle which consists in project people starting the participation in a meeting (S), leaving (L), or continue (C) at the successor meeting. The cycle closes in the case of restarting (R) the meeting attendance after having left the previous meeting. Still in phase I of Figure 26 the POL Model collects all email project-related exchanged information between the participating Teams (in this case Team A and B) according to Table 29. This is illustrated in the box above in the upper right corner of Figure 25.

### 5.2.8.3 Application of the model in Phase II – Organizing and Planning

In Figure 27 is illustrated the application process of the proposed model in this work for project phase II – Organizing and preparing. The process is the same as for phase I, excluding the part of defining the initial formal project chart, which is only defined in phase I.

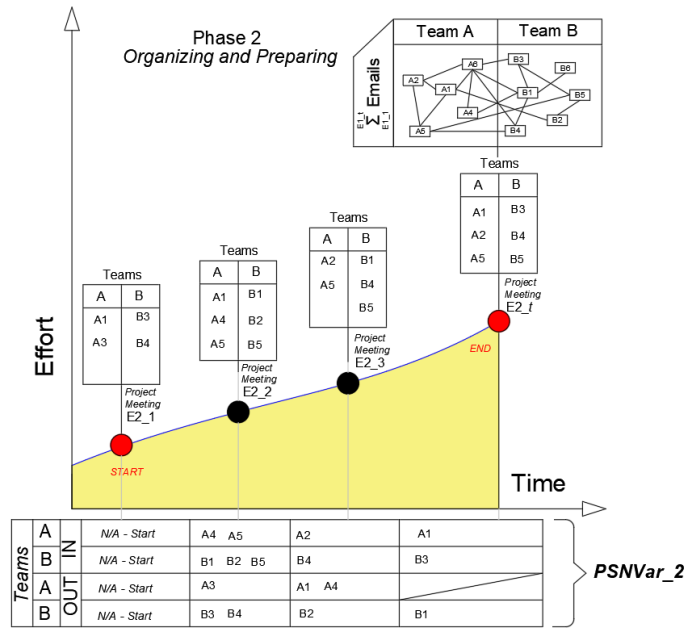


Figure 27 - POL Model application for Phase II, for both Success and Failure project Outcomes. Example with 4 meetings (Nunes & Abreu, 2020).

#### 5.2.8.4 Application of the model in Phase III – Carrying out the Work.

In Figure 28 is illustrated the application process for project phase III – Carrying out the Work.

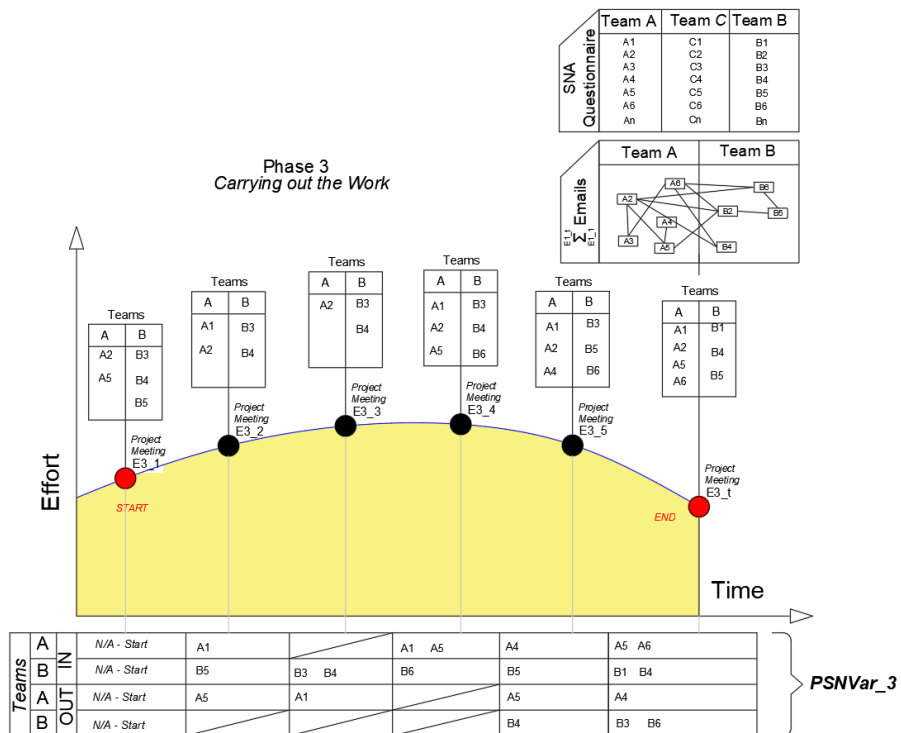


Figure 28 - Model application for Phase III, for both Success and Failure project Outcomes. Example with 6 meetings (Nunes & Abreu, 2020).

The process for phase III illustrated in Figure 28 is exactly the same as for phase II illustrated in Figure 27. However, in this phase a new Team (Team C) is taking part at the Carrying out the Work project phase. The data to be collected regarding the third team is to be according to Table 29 in the questionnaires line.

#### 5.2.8.5 Application of the model in Phase IV – Completing the Project

In Figure 29 is illustrated the application process for project phase IV – Completing the project. The process is the same as for phase II.

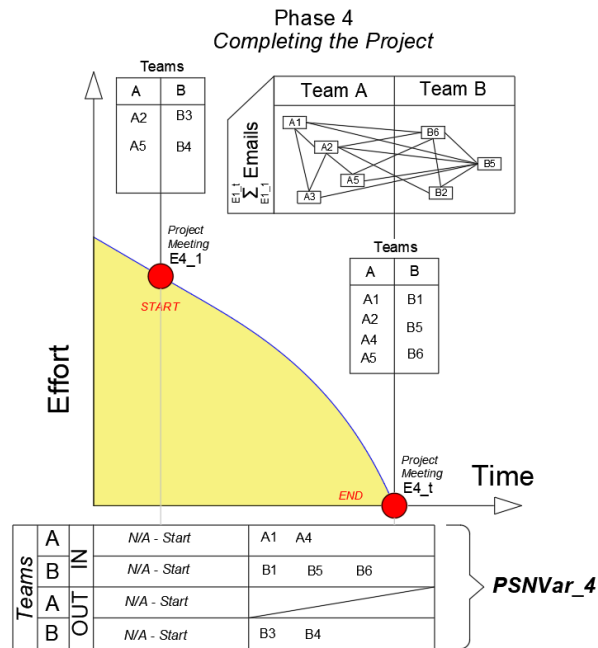


Figure 29 - Model application for Phase IV, for both Success and Failure project outcome types. Example with 2 meetings (Nunes & Abreu, 2020).

The process for phase IV illustrated in Figure 29 is exactly the same as for phase III illustrated in Figure 28.

### 5.2.9 Legal & Ethical Considerations

The proposed model in this work accesses, and analysis project related information that flows across the different project teams across a project lifecycle, that may be considered confidential, and not desired to be accessed, or / and exposed. Therefore, the application of the model is totally dependent on the acceptance of authorities, at the organizational and ultimately nation level, that administer the legal and ethical respective issues. All the project people that participate in a project that is to be monitored by the proposed model, should be aware of it before the project starts.

### 5.2.10 POL Model Metrics

The proposed model aims the application of seven centrality-based metrics. They are presented in Table 31. Although is not objective of this work to extensively detail the metrics applied in the model, a brief description is presented in Table 31. In Table 31 for each metric is indicated the source of information (SITs) as well as the respective global collaboration type associated.

As for example, the global collaboration type Communication & Insight will be characterized and measured for both project successful and unsuccessfully delivered, by analyzing meetings and mail exchange project-related information. For this collaboration type - Communication & Insight -, the model foresees the application of three metrics. They are: (1) **Role attendee degree** (which will analyze project meetings information), (2) **Internal mail cohesion degree** (which will analyze project mail exchange information), and (3) **Feedback degree** (which will analyze project mail exchange information).

The model foresees two types of analysis. They are: (1) **Individual**, and (2) **Collective**. Individual concerns the analysis directed to one give project role, such as project managers, engineers, experts, or other. Collective concerns the analysis directed to a group of project people, such as team, department, or even organization. In Table 31 are illustrated and described the metrics comprised in the proposed model in this work – the POL model.

Table 31 - POL Model proposed Metrics

Metrics	Brief Description	5-GCT
1-Role attendee Degree	Individual Analysis Type - Meetings	Communication & Insight
	Analyze the project meetings-participation rate, from Official Project Roles of the Teams that take part in the accomplishment of a given project. The participation rate will be outputted by an average variation (linear regression) across a project phase, foreseeing four different results.	
	Objective: To find out if project success outcome is somehow correlated with:	
	High participation rate of Official Project Roles in project-meetings, in the first half (beginning) of a given project phase?	
	High participation rate of Official Project Roles in project-meetings, at the second half (at the ending) of a given project phase?	
Constant participation rate of Official Project Roles in project-meetings, in the first half of a given project phase?		
If a) - evolution is characterized by a negative (-) evolution across time, within a		

	<p>given project-phase.</p> <p>If b) - evolution is characterized by a positive (+) evolution across time, within a given project-phase.</p> <p>If c) - evolution is characterized by a constant (o) evolution across time, within a given project-phase.</p> <p>Case 1 c) - Constant Full (when the Official Project Roles participated in all project meetings)</p> <p>Case 2 c) - Neutral Constant, (when the Official Project Roles did not participate in all project meetings)</p> <p>All evolution across time to be calculated through the application of simple linear regression</p>	
<p style="writing-mode: vertical-rl; transform: rotate(180deg);">2- Mail cohesion Degree</p>	<p>Individual Analysis Type - Meetings</p> <p>Analyze the Centrality Structural degree from Official Project Roles from the participating Project Teams, regarding the email communication network.</p> <p>Objective: To find out if project success outcome is somehow correlated with:</p> <p>High, or Very High Centrality in the email communication network of Official Project Roles.</p> <p>Low, or Very Low Centrality in the email communication network of Official Project Roles.</p> <p>This is outputted by the SNA In-degree metric according to (/Wasserman &amp; Faust, 1994). The result for this metric is a numerical value (index), varying from 0 (minimum), to 100 % (maximum) for the two cases.</p>	
	<p>Collective Analysis Type - Mails</p> <p>Analyze the Cohesion degree from all Official Project Roles from the participating Project Teams, regarding the email communication network.</p> <p>Objective: To find out if project success outcome is somehow correlated with:</p> <p>High, or Low Centrality in the email communication network of All Official Project Roles.</p> <p>This is outputted by the SNA centrality metric density (1) (Wasserman &amp; Faust, 1994). The result for this metric is an absolute numerical value, varying from a minimum of zero (0) up to a maximum of 100 %.</p>	

3-Feedback Degree	<p>Collective Analysis Type - Mails</p> <p>Analyze the Reciprocity degree (Feedback) between the different participating Project Teams, regarding the email communication network.</p> <p>Objective: To find out if project success outcome is somehow correlated with:</p> <p>High, or Low Email project-related information Feedback between different project Teams regarding the email communication network (All Official Project Roles)</p> <p>This is outputted by the SNA reciprocity metric (Wasserman &amp; Faust, 1994), which is based on the difference from Out against the In-degree (Wasserman &amp; Faust, 1994). The result for this metric is an absolute numerical value, varying from 0 (minimum), to 100 % (maximum).</p>	
4-Information Seeking / Providing Degree	<p>Collective Analysis Type - Mails</p> <p>Analyze the seeking / providing, of project information-related between the Teams that take part in a project accomplishment. This is outputted by the SNA in-degree metric, respectively seeking, and providing.</p> <p>Objective: To find out if project success outcome is somehow correlated with:</p> <p>High or Low Project-related Information seeking degree?</p> <p>High or Low Project-related Information providing degree?</p> <p>This is outputted by the SNA In-degree, and Out-degree metrics [43]. The result for this metric is an absolute numerical value, varying from 0 (minimum), to 100 % (maximum).</p>	Internal & Cross-Collaboration
5-Action Key Players	<p>Collective Analysis Type - Questionnaire</p> <p>Analyze the Centrality Structural degree from the project social network formed by all Teams that take part in a project accomplishment, from an external point of view. It concerns the analysis regarding know-how sharing and informal power over the project social network.</p> <p>Objective: To find out if project success outcome is somehow correlated with:</p> <p>High or Low Centrality regarding power and know-how share of involved teams at the accomplishment of a project.</p> <p>This is outputted by the SNA in-degree metric [43]. The result for this metric is the project team that is more, voted, by the external point of view.</p>	Know-how sharing & Power

6-Meetings Cohesion Degree	<p>Collective Analysis Type - Meetings</p> <p>Analyze the variability evolution within a project phase, regarding the participation rate of all Official Project Roles (project team set) in project meetings, for each of the project teams that take part in a project accomplishment. This is outputted by the SNA PSNVar an original developed metric, based on weighted average-degree (Wasserman &amp; Faust, 1994).</p> <p>Objective: To find out if project success outcome is somehow correlated with:</p> <p>Constant (=0) no change on the project set team across a project phase</p> <p>Non-Constant Positive (= +) tendentially, are entering new project people across a project phase</p> <p>Non-Constant Negative (= -) tendentially, are leaving project people across a project phase.</p> <p>The output for this metric is an evolution across time (within a project phase time period), calculated by a simple linear regression from all the individual results of the metric PSNVar for each project meeting within a project phase. The formula is illustrated as follows:</p> $V_{(Et)} = \frac{WL_{(Et)}}{TPP_{(Et)} \times Et}$ <p>Where:</p> <p>V = Variability of the Project Social Network</p> <p>Et = Event number (Project Meeting), where Et= 1,2,3, ..., TE</p> <p>TE = Total number of events (Project Meetings) occurred within a project phase</p> <p>TPP = Total number of project people that participated in an Event Et.</p> <p>WL= Total cumulative value of weighed links, from each project people's total degree in each Event Et.</p> <p>For example, if in an Event X, project people 1, and 2 participated in, the link between them is of value 1. If at Event X+1, project people 1, and 2 participated in, the link between them is of value 2.</p>	Clustering (variability effect – PSNVar)
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7- Transferring Speed	Collective Analysis Type - Mails	Teamwork efficiency
	<p>Analyze, in average, the project information-related transferring speed, when requested all Official Project Roles in all projects related email exchange.</p> <p>Objective: To find out if project success outcome is somehow correlated with:</p> <p>Feedback Speed when answering a question or providing project information-related through the email network communication.</p> <p>The output for this metric is an average value displayed in hours, ranging from “100%” (meaning an instantaneous answer reply has been made &lt; 1 hour) up to a maximum of the project time duration “0%”, for cases where feedback is not finding during the lifetime of a project. The metric to be used in this case is the Out and In-degree (Wasserman &amp; Faust, 1994), for each single pair (question vs answer) time-attached.</p>	

Continuation of Table 31 - POL Model proposed Metrics.

The seven proposed metrics will be explained in a project management scenario using collected data of a real case according to Table 29. The project to be analyzed is project P1 (Figure 30) and was carried out and delivered by two different Teams (Team A, and B) which collaborated across the P1 project’s four different project phases across its lifecycle.

The Official Project Roles designated to accomplish the project P1 are displayed in the upper left corner of Figure 30 (Formal PSN Chart) and briefly described in the Legend above the project lifecycle of P1. These roles are project managers, experts, and outsourced team members.

All the non-disclosed official project roles are in this case considered as All as it is defined in Table 32. There are six official project people from both teams that are designated to accomplish the project P1 across its lifecycle (A1, ..., A6 and B1, ..., B6). In project P1 phase III, a third party - outsourced Team C – took part at the respective project’s activities. The elements of the outsourced organization Team C (c1, c2, c3, and c4) are identified in Figure 30 (Team C).

In each project phase a number of project meetings (Events *E*) occurred and are illustrated in Figure 30. For example, in Phase I there were 5 Events, and in Phase II there were 4 events. In the end of each project phase of project P1 all the email project related data exchanged is collected according to Table 29. For the demonstrative purpose only data from phase I, phase II, and phase III of project P1 will be used for the demonstration of the calculation process of the seven proposed metrics. At this point, for the purpose of this work, any other information about the project P1 is not relevant.

## Project Lifecycle Phases of Project P1

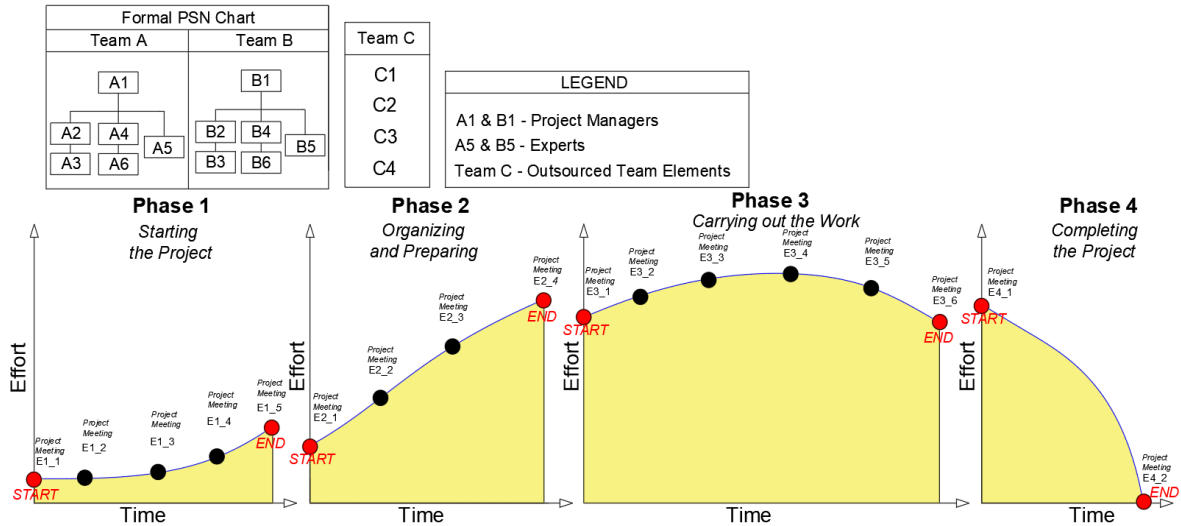


Figure 30 - Project Lifecycle phases of Project P1

In project P1 four different official project roles (OPR) will be considered. They are Project Managers, Experts, Outsourcers, and All (include all the categories already named). The OPR will be analyzed independently, and collectively according to Table 32. Independently, means that some official project roles will be analyzed isolated across all the different phases of a project lifecycle. Collectively, means that either all, or a combination of certain official project roles will be analyzed throughout all the different phases of a project lifecycle. For example, for metric Internal mail Cohesion degree displayed in Table 32 there are two types of analysis planned. The first one is an independent analysis regarding the project managers and the experts in isolated mode. The second is a global analysis (collectively) to all the project people that participated in a project, which includes all the official defined project roles.

Table 32 - Project Official Roles adjusted to a project management scenario

SNA Metrics	Independent PSN stakeholders			Global PSN Stakeholders
	Project Managers	Experts	Outsourcers	All project roles (Team A, and Team B)
Role attendee Degree	✓	✓		
Internal mail cohesion Degree	✓	✓		✓
Feedback Degree				✓
Information Seeking / Provide Degree				✓
Action Key Players			✓	✓
Meetings Cohesion Degree				✓
Teamwork efficiency				✓

#### 5.2.10.1 M1-Role attendee Degree

**Description:** This metric captures the presence of two important stakeholders (Project Managers, and subject matter Experts) in project meetings across a project lifecycle. It outputs an evolution over time, (across a phase of a project) positive, negative, or constant, regarding the participating rate of the desired OPR. For this case project managers and experts from both teams will be analyzed.

**Method:** The presence of the OPR across a project phase will be recorded and plotted in a cartesian graph (Figure 31 b), where to a presence at one project meeting will be given a value of 1, and a no-presence will be given a value of 0. After that a linear regression will be calculated and the respective evolution signal. There are four possible evolution types (Figure 32). They are:

1. **Increasing** (positive evolution across a project phase),
2. **Decreasing** (negative evolution across a project phase),
3. **Full** (constant evolution across a project phase, where the chosen OPR participated at all project meetings across a project phase) and
4. **Neutral** (constant evolution across a project phase, the chosen OPR did not participate at all project meetings across a project phase)

**Uncovers:** What type of evolution (increasing, decreasing, full, or neutral) based on the Role attendee degree in project meetings within a project phase is to be seen with more frequency in projects that were successfully, and non-successfully delivered? To what extent does the variation of the presence of these two OPR in project meetings across a project lifecycle, influences a project outcome?

In Figure 31 a) is illustrated phase I of the project P1. In this phase there were five project meetings (E1\_1 up to E1\_5) where project people of two teams (Team A and Team B) worked together from the beginning until the end of phase I.

From Team A project element A1 is the project manager and the element A5 is the expert. In this case there is only one expert in each of the teams A and B. However, multiple roles, as for the expert's case, are supported by the proposed model. The other elements are engineers from different areas such as Processing, Designing, Automation, and so on. In Team B project element B1 is the project manager and the B5 is the expert. The same goes for the rest of the elements as in Team A.

In Figure 31 b) is represented how the metric Role Attendee Degree is calculated. As an example, project element A1 participated in 4 out of 5 meetings that occur in phase I of project P1: A1 participated at the E1\_1 (value =1), E1\_3 (value =1), E1\_4 (value =1), and the E1\_5 (value =1) meeting. Project element A1 did not participate only at the E1\_2 (value =0) meeting.

This evolution is illustrated in Figure 31 b as the black line indicates the real evolution regarding the element A1, and the blue line is the resulting evolution across time calculated by applying linear regression across the meetings that element A1 participated and did not participate.

In this case the resultant evolution is positive (+). This means that element A1 has a more constant participation in project meetings in phase I as the phase I was heading towards its end. The same analysis principle applies for the other three OPRs – A5, B1, and B5.

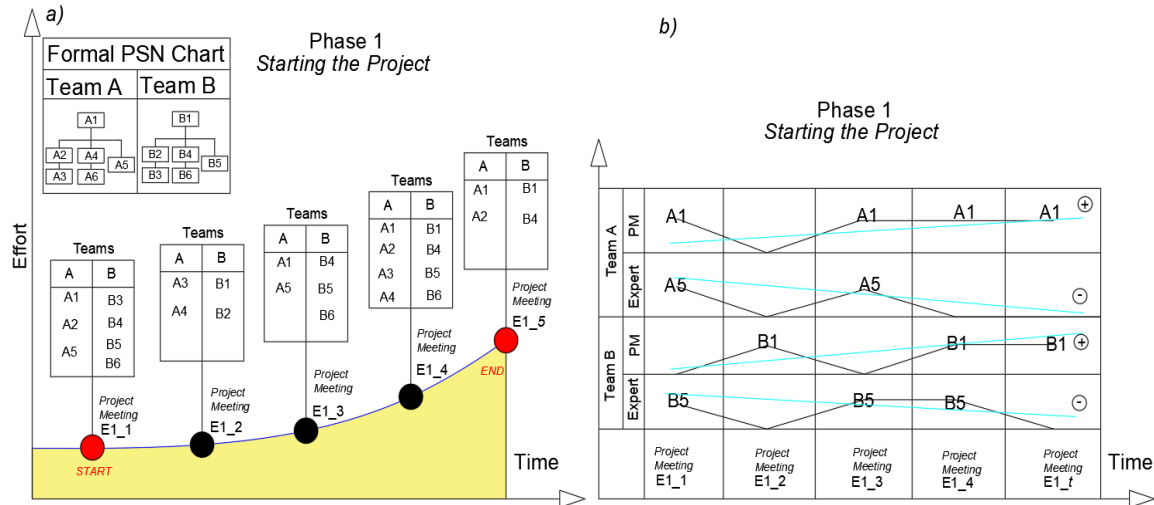


Figure 31 - Role Attendee Degree Calculation for Project P1

There are four possible outcome types for this metric (Figure 32). They are Increasing (positive evolution), Decreasing (negative evolution), Constant Full (participation in all project meetings) and Neutral Constant (participation in some project meetings).

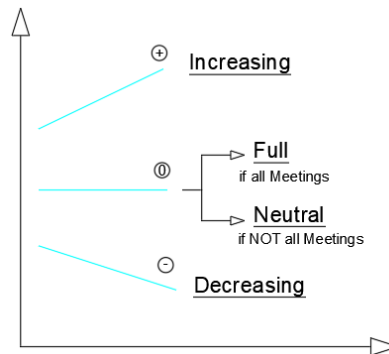


Figure 32- Role Attendee Degree Evolution Types

For the case of project P1 (Figure 31) phase I the project manager of Team A (A1), had a positive evolution (+), whereas the expert of Team A (A5) had a negative evolution (-). For Team B, the project manager B1 had a positive evolution (+) and the expert B5 had a negative evolution (-) throughout phase I of project P1.

### 5.2.10.2 M2- Mail cohesion Degree

**Description:** On the first approach this metric captures the percentage of project people from both, Teams A and B, that were involved in all email communication that relates with project information across a project phase of a project lifecycle. For this metric all mails that were sent / received directly to, forwarded to, or in CC to, will be used as input for the metric.

As an example of application, in the first approach, this metric aims to calculate the email communication cohesion degree within the project Team A. On the second approach it will analyze the Total Degree (in-degree + out-degree) of the two already named OPR (Project Managers and Experts).

**Method:** In the first approach it will be calculated the density value of the email communication network. All emails that contain project matter information related, sent, and received by elements of Team A will be collected and analyzed.

A graph will be created illustrating the mail communication, and the density metric, and will be calculated according to (18) (Wasserman and Faust, 1994) (adapted).

$$d = \frac{2LM}{NM(NM-1)} \quad (1)$$

Where:

LM = total number of existing links in the email communication network

NM = total number of project people connected, within the email communication network

**Uncovers:** To which extent does not being in all email communication network that relates project information across a project phase of Team A project people that officially (according to formal chart) belong to a project, influences a project outcome?

In Figure 33 is represented the phase I of project P1. In the upper right corner, the graph inside the box that contains Team A and Team B, represents the email communication network that contains all the exchanged project related emails across the phase I of project P1.

For the first approach the cross-boarded (from Team A to Team B, and within Team B) emails exchanged, will not be analyzed.

For example, it is visible that there is not a link between A1 and A2. This means, that across phase I of project P1 there was no single email directly exchanged between A1 and A2 concerning project information related matter. The same happens for example, between elements A6 and A1. This

represents, according to the email communication network, that there has been information that might have been not fully shared with all the elements of project Team A.

If there was a link between all elements of Team A, it would mean that all email project information exchanged had been shared with all the project people of Team A.

However, this does not necessarily mean that all information has not been shared across all the elements of Team A. For example, the information that flown in the links between A1 and A3, A1 and A5, and A1 and B1, might have been forwarded by A3, to A2, A5, and A4. However, that might, or might not had occurred, and if yes, it may still had occurred with a certain time delay. In this case, the proposed metric, due privacy, and legal constraints, is not able to look deeper.

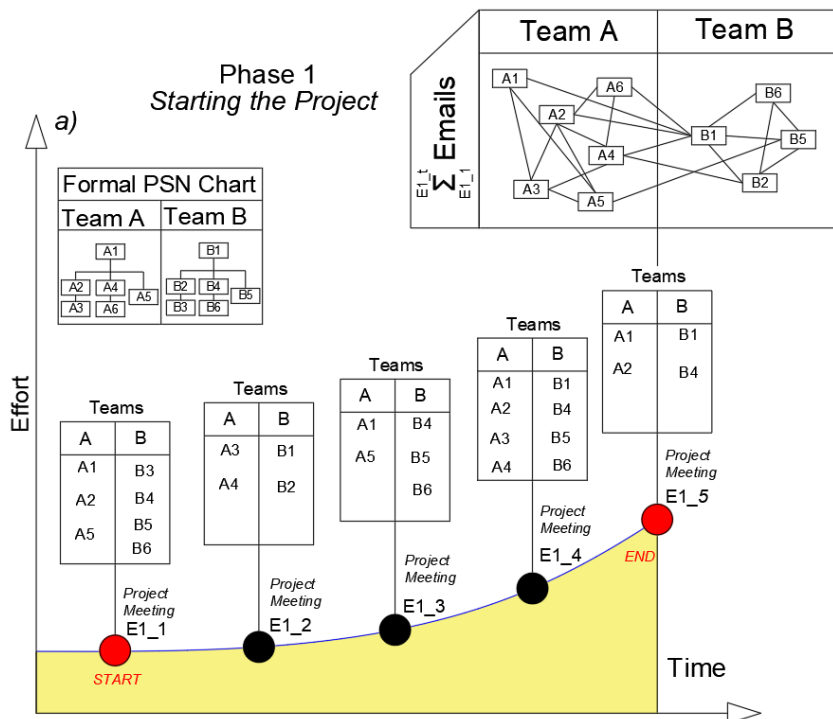


Figure 33 - Internal mail cohesion degree Calculation for Project 1

*First Approach*

To measure the email communication network cohesion degree the density (Wasserman & Faust, 1994) will be used. The maximum value for the density is when all elements of Team A have a link between them. Applying (18):

$$d = \frac{2 \times 9}{6(6-1)} = 60\%$$

These results show that, through the mail communication network 60 % of all possible connections are present in phase I.

*Second Approach*

In the second approach the total degree (3) will be calculated for two OPR – project managers and experts. This is illustrated in Table 33. The Total degree, which represent all the links (incoming, and outgoing) that one project person has, is given by (3) (Wasserman and Faust, 1994) (adapted).

$$T_D(NM_i) = \sum NM_{-1_i} \quad (3)$$

Where:

$T_D$  = total degree in the email communication network

$NM$  = total number of project people connected, within the email communication network

$i$  = project person = 1,2,3,...,NM

$NM_{-1}$  = total number of existing links attached to project person  $i$

Table 33 - Total Degree for Project Managers , and Experts

	Team A		Team B	
	Project Manager	Expert	Project Manager	Expert
	(A1)	(A5)	(B1)	(B5)
<b>Total Degree</b>	3	4	7	4

In Figure 33 element A1 has 3 links, and element A5 has 4 links. For Team B the B1 has 7 links and the B5 has 4 links. In this case is clear to conclude that the Team B has an advantage regarding the Project Manager total-degree, and there is a draw regarding experts of both Teams.

In other words, this means that the project manager from Team B holds advantage regarding the centrality in the email communication network, making him, probably, a more “informal” powerful stakeholder than the project manager from Team A because he has more information about project P1 than the project manager of Team A. Regarding the experts, both have the same “informal” power.

It can be concluded that the project manager from the customer side holds a privileged position regarding the email communication network. The following step would be to analyze to which extent that this privileged position is correlated with project failure or project success.

### 5.2.10.3 M3-Feedback Degree

**Description:** This metric uncovers the percentage of all email project-related information that have been replied from one Team to another Team. In this case, from Team A to Team B. It does not look exactly if one particular mail has been replied (based on its content), rather the overall number of exchanged emails. This metric aims to uncover from which side (Team A or Team B) does the email communication network is more intense, which in turn could reflect more, or less control over the email network, and ultimately more, or less feedback.

**Method:** For this purpose, the metric reciprocity metric will be calculated, which simply is the ration between the emails sent from one Team to the other Team.

**Uncovers:** To which extent does a high or a low project related information email exchange, from a certain project Team, is associated to a certain project outcome?

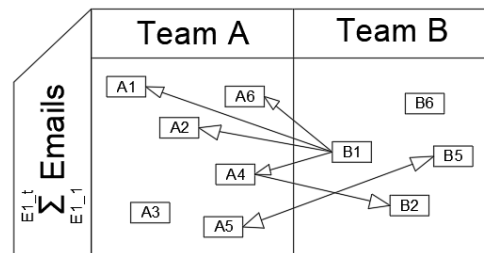


Figure 34 - Feedback Degree Calculation for Project P1

In Figure 34 is represented the mail communication from phase II of project P1, between Team A and Team B. To calculate the feedback degree, the emails sent / received from to needs to be identified. For this case, the in-degree (representing an email received) and the out-degree (representing an email sent), musts to be first calculated. The In-degree metric, which are all the links that one project person receives, is given by (1) (Wasserman and Faust, 1994) (adapted):

$$I_D(NM_i) = \sum NM_{l_i} \quad (1)$$

Where:

$I_D$  = Indegree in the email communication network

$NM$  = total number of project people connected, within the email communication network

$i$  = project person = 1,2,3,...,NM

$NM_{l_i}$  = total number of existing in-links attached to project person  $i$

Applying (4) for elements of Team A, and Team B respectively.

$$I_D(A1)=1 \quad I_D(B1)=0$$

$$I_D(A2)=1 \quad I_D(B2)=1$$

$$I_D(A3)=0 \quad I_D(B5)=1$$

$$I_D(A4)=1 \quad I_D(B6)=0$$

$$I_D(A5)=1$$

$$I_D(A6)=1$$

The Out-degree, which are all the emails that one project person sends to other, is given by (3) (Wasserman and Faust, 1994):

$$O_D(NM_i) = \sum NM_{_1i} \quad (3)$$

Where:

$O_D$  = Outdegree in email communication network

$NM$  = total number of project people connected, within the email communication network

$i$  = project person = 1,2,3..., $NM$

$NM_{_1i}$  = total number of existing out-links attached to project person  $i$

Applying (5) for elements of Team A, and Team B respectively:

$$O_D(A1)=0 \quad O_D(B1)=4$$

$$O_D(A2)=0 \quad O_D(B2)=0$$

$$O_D(A3)=0 \quad O_D(B5)=1$$

$$O_D(A4)=1 \quad O_D(B6)=0$$

$$O_D(A5)=1$$

$$O_D(A6)=0$$

Concluding, Team A sent 2 mails to Team B, and Team B sent 5 mails to Team A. Total mails sent between Teams were 7. The Feedback degree will be calculated by applying the reciprocity given by (18) (Wasserman and Faust, 1994) where:

$$RM = \frac{\text{Sent Mails low}}{\text{Sent Mails high}} \quad (18)$$

Where:

RM= Reciprocity in email communication network

Sent Mails low = sum of the lowest number of emails sent by one given Team

Sent Mails high = sum the highest number of emails sent by one given Team

Applying (6):

$$RM = \frac{2}{5} = 40 \%$$

There is a 40% reciprocity in the mail communication network between Team A and Team B in phase II of project P1. This means that only about 40% of all emails send between Team A and Team B during phase II of project P1 were replied. In this case, three emails have not been replied, and the Team B has the highest number of emails sent and emails non-replied.

#### 5.2.10.4 M4-Information Seeking / Providing Degree

**Description:** This metric uncovers which Team (Team A, or Team B) is more, or less dependent on project related information. Only the mails that contain a project related matter-information will be analyzed. This specific type of information has to be related with seeking and providing help, regarding project related activities.

**Method:** For this purpose, all mail communication will be assessed and filtered according to seeking and providing help. This means that the email content will have to be disclosed. After that, it will be calculated a ratio between mails seeking for help, and those providing help.

**Uncovers:** Which Team is more information dependent to execute project related activities? To which extent does the dependency of a certain team is associated to a certain project outcome?

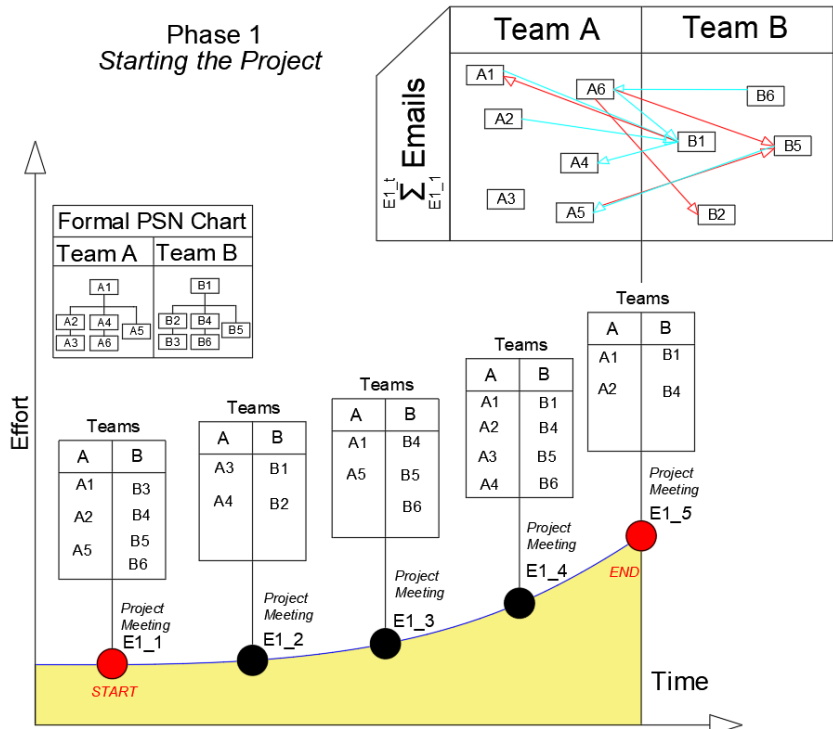


Figure 35 - Information Seeking / Provide degree Calculation for Project P1

In the upper right corner of Figure 35 is illustrated the email communication network between Team A and Team B. It represents the emails sent seeking for help and mails sent providing help, regarding needed project related information to accomplish project activities across phase I of project P1. Mails sent asking for help are identified with the blue color (Table 34). Mails providing information are identified with the red color (Table 34). The results regarding emails sent / received, are presented at the following Tables 34 and 35. For this case, In-degree and Out-degree will be applied according (4), and (5), to both Teams, A and B.

Table 34 – Mails sent Seeking for help:

Blue color	Team A	Team B
Team A	-	3
Team B	3	-

Table 35 – Mails sent Providing help:

Red color	Team A	Team B
Team A	-	3
Team B	1	-

In this case, Team A sent three mails looking for help and only received one mail providing help from Team B. Team B sent three mails asking for help and Team A sent back three mails providing help.

It can be concluded that in this case that both teams have same dependency degree (seeking), but different providing degrees. The seeking and providing reciprocity can be calculated applying (6), for both, seeking, and providing as follows:

$$\text{Seeking } R = \frac{3}{3} = 100 \%$$

$$\text{Providing } R = \frac{1}{3} = 33 \%$$

This concludes that both Teams A and B, are equally information dependent, but Team A has a disadvantage because not all information requests were satisfied through the email communication network. This makes Team A more information dependent than Team B.

There are two possible outcomes for this metric. Either both teams are equally dependent, and in that case the Seeking and Providing reciprocity degrees are 100%, or one of the Teams is dependent, as for example in the case of Figure 35.

Results that are equally dependent, are considered neutral and therefore no conclusion can be taken.

#### 5.2.10.5 M5-Action Key Players

**Description:** This metric is to be applied when a third party was outsourced by one of the Teams (A or B) to execute project activities in any given project phase. This metric uncovers what are the key players among the elements Teams A and B, that share know-how, and provide guidance to the third team to execute project activities. In other words, aims to identify who has the power to delegate and take decisions, and to which extent the way these decisions are taken influence project outcome.

**Method:** A simple SNA assessment will be conducted to the elements of the third Team (usually called as Team C, or TC) to find out who the most important project stakeholders are for the Team TC, regarding support (know-how and decision making) so that Team TC can execute project activities which was outsourced for. Two questions are planned to be done to the Team TC in the SNA assessment. These questions are illustrated in Table 29. They will be here transcript as follows:

**Question 1:** If you have a problem, or question regarding  $x^*$ , that is important to execute your project activity or task, who do you go for help, among the project people of Team A and Team B?

\* $x$  is a project related activity or task, to be named as the project execution phase occurs.

**Question 2:** If you are just about to start the execution of a project activity or task, but you want to make a double check before you go ahead, or even present what you consider to be a better solution, whom do you turn to, to get approval and final decision among the project people of Team A and Team B?

After the SNA assessment is complete, key players will be identified. They will be essentially identified by using In-degree, and Out-degree. It will be searched for Central Connectors and Peripheral people within Teams A, and B.

**Uncovers:** To which extent does the know-how transfer and decision-making power coming either from Team A, or from Team B, influence a project outcome in project phases where a third Team is needed / outsourced to execute project related activities?

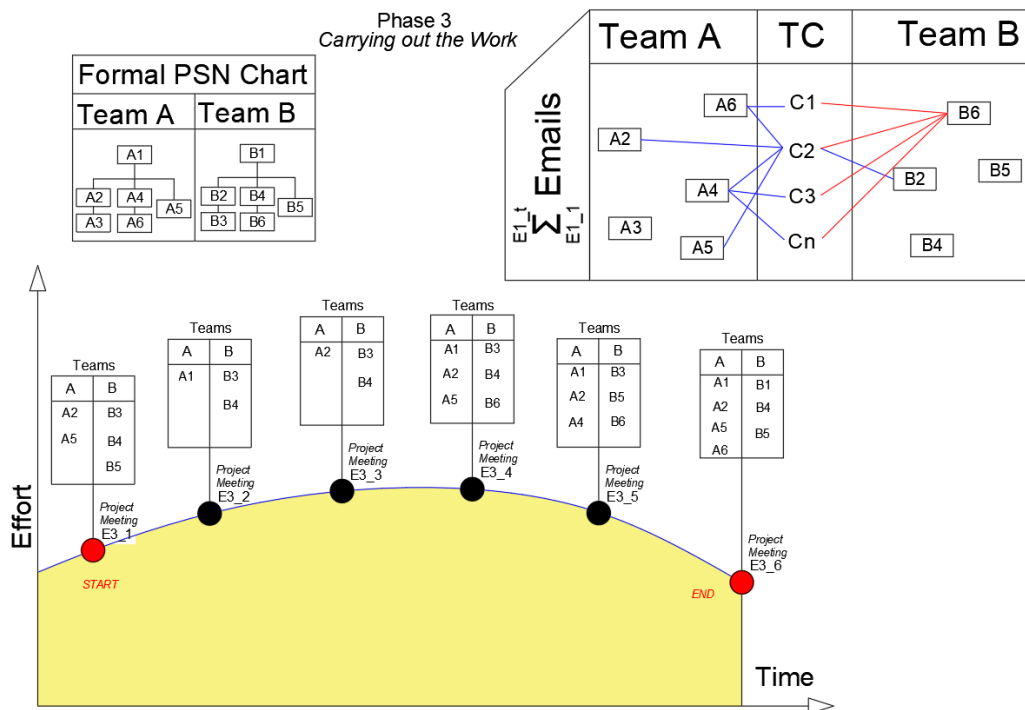


Figure 36 - Action Key Players Calculation for Project P1

In Figure 36 is represented the phase III of the project P1. In this phase (carrying out the work), a third Team (Team C) was outsourced to execute project related activities.

A SNA (Social Network Analysis) with the two strategic questions was conducted to the elements of the outsourced team (c1, c2, c3, c4), and the results are displayed at the upper right corner box in Figure 36. In this case blue lines are answers to Question 1, and red lines are answers to Question 2. The quantitative results for both questions are illustrated in Table 36 by applying (4).

Table 36 – SNA Questionnaire results (In-degree) for Project P1

<b>Question 1</b>		<b>Question 2</b>	
	In degree		In degree
A2	1	A2	0
A3	0	A3	0
A4	3	A4	0
A5	1	A5	0
A6	0	A6	0
B2	1	B2	0
B4	0	B4	0
B5	0	B5	0
B6	0	B6	4

In Table 36 can be seen that Team A holds a privileged position regarding providing help and sharing know-how to execute project related tasks, but Team B takes control of the decision-making process.

For this metric three different possible results for each question are possible. They are illustrated in Figure 37.

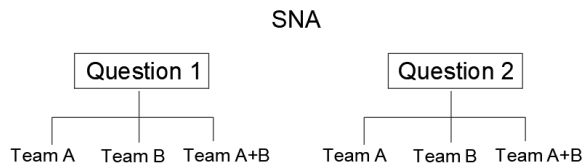


Figure 37 - SNA Questions possible outcome for metric Action Key Players

#### 5.2.10.6 M6-Meetings Cohesion Degree

**Description:** This metric was designed to quantitatively capture the complex project people variability (PSNVar – Project Social Network Variability – Figure 38) regarding the participation in F2F project meetings across a given phase of a project lifecycle.

The variability is function of the project people that start at the very first project meeting of each project phase - usually are at the formal chart. These are characterized as people that are designated to accomplish a project. It includes the project people that start, leave, restart, project meetings across a project phase. This metric measures the project network social cohesion degree variation, regarding meetings participation of project people, across a project lifecycle based on the relationships that dynamically evolve across the project meetings of a project phase.

In other words, if the same project people (project people that are officially designated to accomplish a project phase where usually is defined in phase I of a project) participate in all the

project meetings that occur in a given phase of a project lifecycle, a certain relationship type (project social cohesion) between them may start to emerge and evolves until the end of a project phase. This relationship can be translated into friendship, or simply awareness (who knows who), trust, or other, and may or may not affect a project outcome. This is what this metric is design for.

**Method:** For this purpose, a metric was developed based on graph theory based on the average in-degree metric (Wasserman and Faust, 1994). After the calculation of a variability for each project meeting, a linear regression will be calculated to find out the sign of that line (positive, negative, or constant).

**Uncovers:** To which extent does the variability (change of project people set) of project people that participate in project meetings in a project phase influences a certain project outcome?

Does having an unchangeable project Team set (same elements of a project Team from the beginning until the end of a project phase) across a phase of a project lifecycle, regarding meetings participation, influences a project outcome?

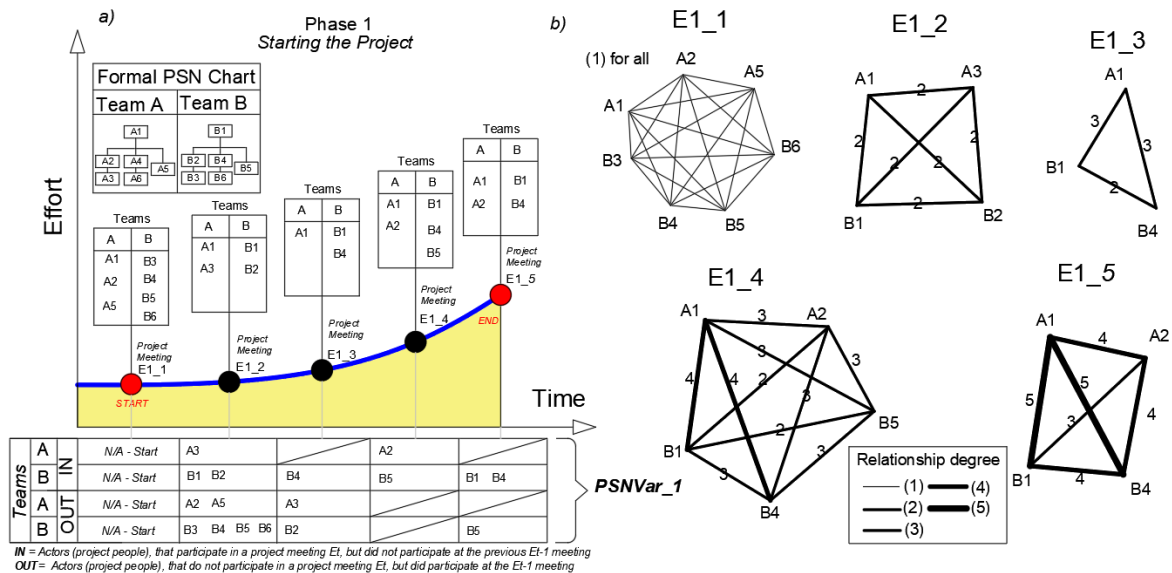


Figure 38 - Meetings Cohesion degree Calculation for project P1

In Figure 38 a) is illustrate the phase I of project P1. In this phase there were 5 project meetings (5 Events). In the first meeting elements A1, A2, A5 from Team A and elements B3, B4, B5, B6 from Team B were present. This is illustrated in the boxes above the large red and black dots that represent the different project meetings in Figure 38 a)). This means that for this metric all these elements did meet each other personally in the project P1 phase I for the very first-time regarding phase I of project P1. To be noted, past relationships between project elements are not to be taking into consideration in this metric.

Thus, all the project people that participated in meeting E1\_1, have developed a link (relationship) between each other. As an example, A1 has a link to B6. This means that they were together in the first meeting of project P1 in phase I. The first meeting is represented in a network in Figure 38 a), in the middle-left corner named as E1\_1. In the first meeting all the participants get a link from all the other participants. This is illustrated in Figure 38 b). This means that for example, A1 has a link of value 1 with all the other elements that participated in the first meeting of project 1 in phase I (A2, A5, B3, B4, B5, B6). This value one represents that they meet each other for the first time in a project meeting environment. So, for A1, as for all other participants, the total indegree in the first meeting will be 6 (all the links directed to A1).

In the second meeting, new elements are in and some elements that participated at the meeting 1 are out now. The only element that is in both meetings (meeting 1 and meeting 2) is the A1. This means, that A1 is for the very first time in a project meeting with all the other three (A3, B1, B2). Thus, A1 as one link of value 1 from each of the others, which makes a total sum of three.

In the third meeting A1 reencounters B1 and B4. A1 and B1 were already together in the first meeting. Now, the link between them is of value two and represents that it is the second time that they are together in a project meeting. The same happens with A1 and B4.

On the other hand, B1 and B4 meet each other for the first time in the third meeting. Therefore, the link between them is of value 1. The same principle is applied for all the other meetings.

In Figure 38 a), under the project curve (blue line) is represented a matrix which contains the project people variability regarding project meetings participation degree. Let's consider meeting E1\_3 as the present meeting. In this third meeting participated elements A1, B1 and B4. Element B4 is in the matrix categorized as IN. This means that B4 did not participate in the previous meeting. Element A3, for example, is categorized as OUT. This means that he participated in the previous meeting but is not taking part in the present project meeting. This matrix represents the PSNVar. The metric (7) developed to measure this variability (PSNVar) measures exactly the number of times that the same project people were together across the project meetings of a project phase.

If the same people were always together in all the project meetings, that metric will output a constant value across time.

If a change in the set has been made, then the metric will immediately react and output a non-constant value for each project meeting.

$$V_{(Et)} = \frac{WL_{(Et)}}{TPP_{(Et)} \times Et} \quad (7)$$

Where:

$V$  = Variability for Project Social Network

$E_t$  = Event number, where  $E_t = 1, 2, 3, \dots, TE$

$TE$  = Total number of events occurred in a project phase

$TPP$  = Total number of project person that participated in an Event  $E_t$ .

$WL$  = total value of weighed links, from each project person total degree in each Event  $E_t$ .

Applying (7), to all the meetings (Events):

$$V_{E_1}(\text{Teams A, B}) = \frac{6+6+6+6+6+6+6}{7 \times 1} = 6$$

$$V_{E_2}(\text{Teams A, B}) = \frac{3+3+3+3}{4 \times 2} = 1,5$$

$$V_{E_3}(\text{Teams A, B}) = \frac{4+3+3}{3 \times 3} = 1,11$$

$$V_{E_4}(\text{Teams A, B}) = \frac{10+7+7+9+7}{5 \times 4} = 2$$

$$V_5(\text{Teams A, B}) = \frac{11+8+10+9}{4 \times 5} = 1,9$$

This metric outputs three different possible results (evolutions across time). They are non-constant evolution positive (+), non-constant evolution negative (-), and constant evolution (o).

- Non-Constant Positive (+): Change in the project teams set (possible increasing of new project elements)
- Non-Constant Negative (-): Change in the project teams set (possible decreasing of project elements)
- Constant evolution (o): No change in the project teams set (constant across all project meetings)

The evolution illustrated in Figure 39 represents the values illustrated in Figure 38 a). It shows that a negative evolution as occurred. This means that the resulting project team (Team A and Team B) has been not the same set since the beginning of that phase until its end. Furthermore, this evolution indicates that the participants number have generally been decreasing across the different project meetings of that project phase of project P1.

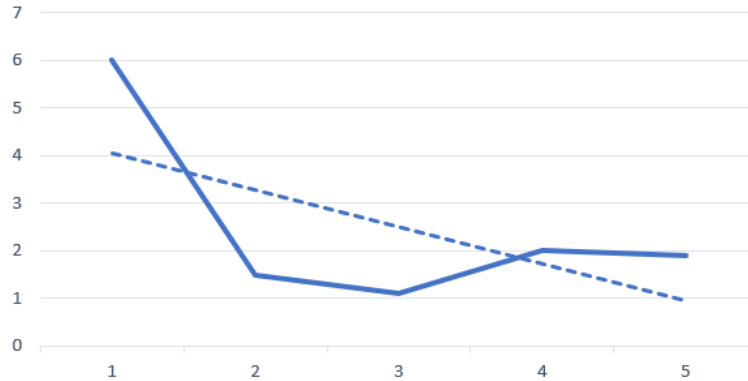


Figure 39 - Linear regression evolution for Meetings Cohesion degree Calculation for project P1

### 5.2.10.7 M7- Transferring Speed

**Description:** This metric analyzes, in average, the project information-related transferring speed (Feedback Speed when answering a question or providing project information-related), when requested all Official Project Roles in all projects related email exchange. It is used to quantify the teamwork efficiency degree.

**Method:** Average value of all feedback times of replied emails within a project phase. The result for this metric is an average value displayed in hours ranging from “100%” (meaning an instantaneous answer reply has been made < 1 hour) up to a maximum of the project time duration (0%), for cases where feedback is not finding during the lifetime of a project phase.

**Uncovers:** Feedback Speed when answering a question or providing project information-related

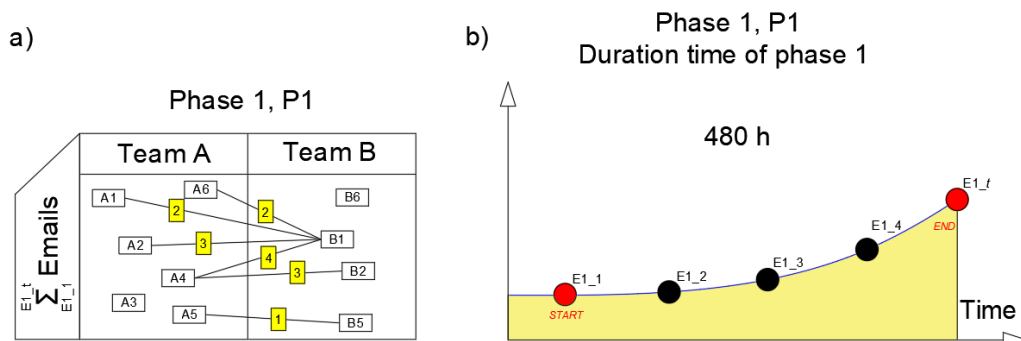


Figure 40 - Teamwork efficiency Calculation for project P1

In Figure 40 a) is illustrated the cross-email communication network, for the phase I of project P1 (a), and its duration in hours (b). Only emails sent between different teams are illustrated by the

links between the different project people. The number of emails sent and received regarding a certain project related subject are marked at yellow.

For example, in phase I of project P1 project people A1 exchanged two emails with project people B1. This means that A1 asked B1 two times for project information related, and B1 replied to him two times. For this case, if an email has not been replied within 480 hours, it has a value of 0, which means that no reply was made within the email network communication.

If an email has been replied in less than 1 hour, it has a value of 100 % (1). For each email interaction presented in Figure 40 the resulting feedback time is displayed in Table 37. For example, the two mails that A1 sent to B1 asking for information project related, had both, a feedback time of 1 (100%).

This means that B1 replied to both emails from A1 in less than 1-hour period. Another example, the feedback first email time (0,3), between A2 and B1 is of 0,3 hours, which means that took 336 hours to be replied.

Instantaneous answer (1, or 100%): Email has been replied in less than 1-hour period time. Infinite answer (0): Email has not been replied within a project phase period time.

Table 37 - Interaction time feedback

	B1			B2				B5
A1	1	1						
A2	0,3	0,4	0,8					
A4	0,1	1	0,3	1	0,3	1	0,8	
A5								0,1
A6	0,2	0,8						

To calculate the Tarnsfer average speed, following formula is to be applied (9):

$$T_s = \frac{\sum t_{a-b}}{TCMs} \quad (9)$$

Where:

$\sum t_{a-b}$  = Sum, of all times, form all replied to emails within a project phase.

TCMs= Total of emails sent and replied within the email network communication.

Applying 9) for Table 37:

$$T_s = \frac{1+1+0,3+0,4+0,8+0,1+1+0,3+1+0,3+1+0,8+0,1+0,2+0,8}{15} = 0,61$$

This means, that in average all the emails that have been replied within the email communication network between the two different teams, have had an average of 187 hours respecting phase I of P1 with a duration of 480 h.

## Chapter 6

# 6 Model Application & Validation – A Case Study

*“If you tell me, I will listen. If you show me, I will see. If you let me experience, I will learn!”*

Lao-Tse

### 6.1 Introduction

In this chapter will be illustrated a step-by-step application case of the proposed model in this work. It will be detailed the process of identification of project critical success factors, and how these can help to guide and monitor an ongoing or upcoming project.

For the demonstration of the benefits of the application of the proposed model in organizations a case study has been conducted in a real project environment and it will be in this chapter presented. The case study comprises the analysis of the collaborative relationship between two organizations – the Service provider and the Customer and the identification of project critical success factors.

A market leader in the Food & Beverage field organization A (named in this work as organization A due to confidentiality reasons) delivers projects to several customers (named in this work as Customer C1, C2, ..., and so on) in different geographical locations. Organization A has been chosen to pioneer the application of the proposed model in this work (the POL Model) in its daily-working culture because it fulfills all the major requirements demanded by the proposed model in this work.

First, and as a very decisive factor, organization A has a diverse customer portfolio spread across the globe which enriches and refines the process of identification of critical success factors (CSFs) proposed by the model in this work by analyzing the different dynamic interactions that emerge in the huge number of collaborative projects, across different working cultures worldwide. This fact alone is a huge advantage in the sense that enables the validation of the proposed model in this work in different cultural environments. In other words, being able to apply the proposed model across different working cultures will enable the identification of unique critical success factors contributing thus for the future optimization process of the proposed model in this work regarding specific technical aspects, such as the collection process of information, the improvement and development of new adequate SNA centrality metrics to be applied in each dimension, just to name a few.

Second, organization A has implemented a business intelligence architecture that enables an efficient information collecting and treatment process of required data for the effective functioning of the proposed model in this work. This implies the recording and collection of project information from project meetings, project email exchange, and project surveys, according to Table 29, for both project outcomes - successful, and unsuccessful.

Third, organization A has implemented a system of data protection according to the GDPR (General Data Protection Regulation) standard that enables a legal and ethical free-issues collecting process, regarding project sensitive information that flows across the three collecting methods used by the proposed model in this work (the POL model) - project meetings, project emails exchange, and project surveys. This fact enables an efficient application of the proposed model in this work because it enables the proposed model to get all the necessary and meaningful information to the process of identification of project critical success factors.

Fourth, organization A has incorporated a project management standard that is aligned with one of the most respectful and important worldwide institutes of project management – The Project Management Institute (PMI). This fact is also of great importance once organization A is already used to manage projects according to the most used worldwide process & framework in physical projects. This is characterized by the application of a waterfall or stage-gate methodology, according to the PMBOK 2017 (PMI, 2017).

In a nutshell, the waterfall or stage-gate methodology clearly divides a generic project into well-defined, however interrelated phases across its lifecycle. This fact enhances the capacities that the POL model has in identifying unique interactions in different project phases. This contributes to a more refined process of identification of project critical success factors (CSFs) which in turn contributes to a more efficient correlation process between dynamic interactions observed and quantified in different tasks or activities (relative to a given project phase), and how these, impact projects outcomes (successful and failure). Concluding, due all the principal mentioned reasons, makes organization A, the perfect candidate for the application of the proposed model in this work.

Finally, the data used for the present case study has been collected during a two-years period time (between 2018-2019 and 2018) in projects that organization A delivered to several different customers in mid-Europe.

## **6.2 Application & Validation of the *POL - Model***

### **6.2.1 Organizational Project Context**

Organization A is the service provider and delivered several projects to seven different customers (C1, to C17) in the period between 2018 and 2019. For this case study twelve projects were chosen (six of which had a successful outcome and the other six had an unsuccessful outcome) as it is illustrated in Figure 41.

The classification of successful and unsuccessfully delivered projects was agreed by both, the service provider, and the customer. The criteria adopted by Organization A and the customer was the triple constraint approach proposed by the project management institute (PMI, 2017). This approach argues that a project is considered unsuccessfully delivered if one of the 3 project constraints ((1) scope, (2) time, or (3) budget) has not been met.

The twelve projects (six unsuccessfully delivered, and six successfully delivered) delivered by organization A to customers C1, C2, C3, C4, C5, C6, and C7 (Figure 41), will be the object of study by the proposed model in this work (the POL model).

For the purpose of this case study organization A will be named as Team A, and all the customer organizations will be named Team B (Figure 41). For all twelve projects in phase III (also known as the execution phase) a third team (Team C) was outsourced to provide support in task execution (mechanical installation works) as illustrated in Figure 36.

The average duration of each delivered project was about 1 year. Several projects were delivered simultaneously. Some employees of organization A (service provider) simultaneously worked in more than one project. The number of elements in the project teams (which includes the service provider employees and the customer employees) were between 5 and 20 elements. These elements do not include on site personal from the customers side, which often informally (not defined in the hierarchical project chart) helped in all the different phases of all delivered projects.

All twelve chosen projects were divided in four distinct project phases (phase I = starting the project, phase II = organizing and planning, phase III = carrying out the work or execution, and phase IV = closing, or completing the project) as suggested by the project management institute (PMI, 2017) as illustrated in chapter 5 in the model application section.

The twelve delivered projects, which comprise the six successful and the six unsuccessfully delivered projects, are illustrated in Figure 41, as well to which customer which project was delivered to.

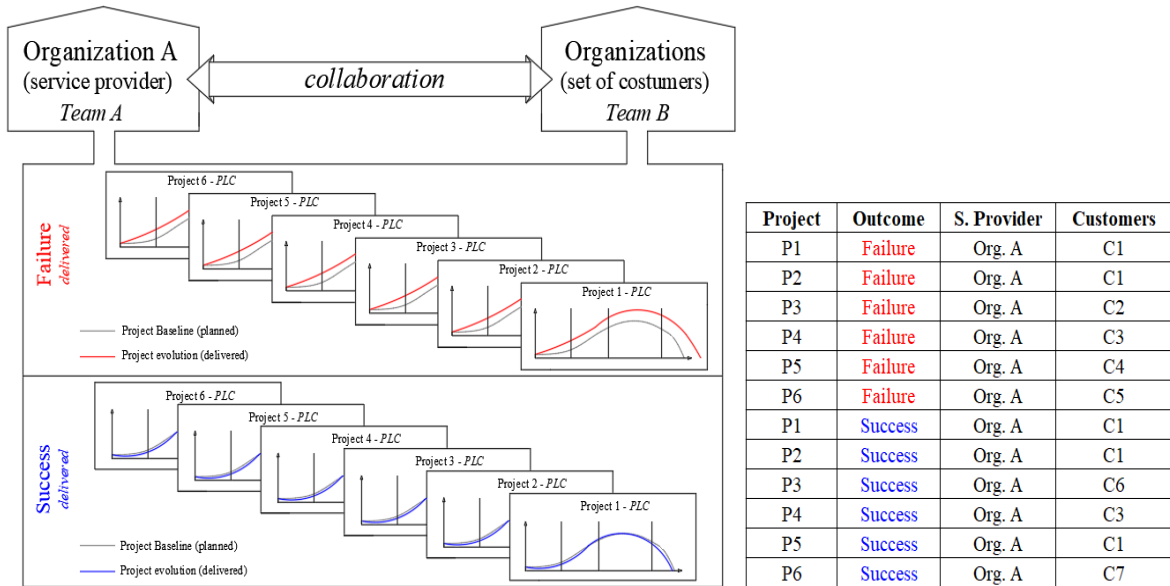


Figure 41 - Projects delivered through networks of collaboration between Organization A and B

As it can be seen in Figure 41 from the twelve chosen projects, organization A delivered two unsuccessful projects to customer C1 and three successful projects for the same customer C1. For customer C2 organization A delivered one unsuccessful project and zero successful projects. For customer C3 organization A delivered one unsuccessful project and one successful project. For customer C4 organization A delivered one unsuccessful project and zero successful projects. For customer C5 organization A delivered one unsuccessful project and zero successful projects. Finally, for customers C6 and C7 organization A delivered one successful project. In the left side of Figure 41 are illustrated the symbolic project lifecycles for all six successful (blue line) and all six unsuccessful (red line) delivered projects.

### 6.2.2 Creating Success, and Failure Project Profiles

The metrics, their mathematical development, as well the criteria that is used to identify the project critical success factors are illustrated in Table 38.

Table 38 - Criteria to create Success, and Failure Project Profiles

Metrics	First Major Measurement	Second Major Measurement	Output Type	Output Value Range	Criterion for PSP vs PFP
1-Role attendee Degree	SNA: In-degree	Statistics: Linear Regression	Evolution on time (slope)	+ = (Positive)	Most observed value (Mode)
				- = (Negative)	
				o (Neutral / Full)	
2-Mail cohesion degree	SNA: Total degree & Density degree	Statistics: Average	Absolute value	[0 - 100 %]	Arithmetic Mean (Average)

					& diff > 25%
3-Feedback degree	SNA: In-degree & Out-degree & Reciprocity	Statistics: Average	Absolute value	[0 - 100 %]	Arithmetic Mean (Average) & diff > 25%
4-Information Seeking / Providing degree	SNA: In-degree & Out-degree	Statistics: Average	Absolute value	[0 - 100 %]	Arithmetic Mean (Average) & diff > 25%
5-Action Key Players	SNA: In-degree	Statistics: Mode	Absolute value	Project Team(s)	Most observed value (Mode)
6-Meetings Cohesion degree	SNA: Average weighted Total-degree	Statistics: Linear Regression	Evolution on time (slope)	o = C	Most observed value (Mode)
				+ = NCP	
				- = NCN	
7-Transferring Speed	SNA: In-degree & Out-degree	Statistics: Speed Average	Absolute value	[0 - 100 %]	Arithmetic Mean (Average) & diff > 25%

Continuation of Table 38 - Criteria to create Success, and Failure Project Profiles

To understand how the table 38 is to be interpreted, the metric Role attendee degree will be used as an example.

According to Table 38, the metric Role attendee degree has two types of major measurements. The first major measurement results from the application of the SNA centrality metric In-degree. This is detailed in chapter 5 of this work.

The second major measurement consists in the application of a basic statistical operation - linear regression - to the results obtained by the application of the first major measurement. In this case, the result obtained by the second major measurement is an evolution on time (also known as trend) that can assume three different values throughout a given project phase. They are positive (+), negative (-), and constant (o).

The criterion that classifies if the role attendee metric is or not a project critical success factor, is the most observed value (in mathematical terms is represented by the Mode). In other words, when comparing the metric Role attendee degree results (which are obtained by first apply the first major measurement, and latter applying the second major measurement) for a set of successful and unsuccessfully delivered projects, the most often observed value (case there exists) will determine a project critical success or failure factor.

For example, for metric Mail cohesion degree the output value is bounded between any value from 0 up to 1. In this case the criterion for defining a critical success factor is that the difference between the average result for all analyze successfully delivered projects and all unsuccessfully delivered project musts differ in 25% or more. The same principle of analysis applies to all other metrics displayed in Table 38.

### **6.2.3 Part 1 – Identify Critical Project Success Factors**

The process of identifying critical success factors is essentially the comparison between the dynamic averaged behaviors (dynamic repeatable patterns) of a set successfully delivered project, and a set of unsuccessfully delivered projects.

First, successfully delivered projects are separated from unsuccessfully delivered projects. Then, each successful and unsuccessfully delivered project will be independently analyzed by the application of the SNA centrality metrics illustrated in Table 38. Second, the individual results of all successfully delivered projects, and the individual results of all unsuccessfully delivered projects will be averaged. Finally, each of the respective successful and unsuccessful metric 's values (results) will be compared one-to-one, and project critical success factors identified (if there are any).

The process of identifying critical success factors is essentially based on the comparison between the dynamic averaged behaviors (dynamic repeatable patterns) of a set successful and unsuccessfully delivered project. First a set of successfully delivered projects (PS(i)), will be separated form a set of unsuccessfully delivered projects (PF(i)) as it is illustrated in Figure 42.

The results of all projects that were as successfully delivered will undergo a selection process (criterion for PSP and PFP according to Table 38) that results in a project success profile (PSP). This characterizes in average and in mode all the six successfully delivered projects. The same is to be done with the projects that were unsuccessfully delivered, resulting in a project failure profile (PFP) as illustrated in Figure 42. Then, according to the criterion defined in Table 38, (the achievement of at least 25% difference regarding the results of some particular metrics values (between successful and unsuccessfully delivered projects) must be present to be able to say that critical success factors are identified (CSF?). Finally, each SNA metric will be classified as YES or NO to distinguish successful from unsuccessful l project critical factors as illustrated in Figure 42.

METRICS RESULTS FOR DELIVERED PROJECTS AT PHASE <i>pha</i>																
Delivered Projects	Role Attendee Degree		Mail Cohesion Degree				Feedback Degree	Information Seeking / Providing Degree		Action Key Players		Meetings Cohesion Degree		Teamwork Efficiency		
	OPR (g)		OPR (g)				All	Team Te <-> Te	Seeking	Providing	Question 1	Question 2	Team (Te)	Team (Te)	Team (Te)	Team (Te)
	Team (Te)	Team (Te)	Team (Te)	Team (Te)	Team (Te)	Team (Te)			Team (Te) & Te							
PS(i)																
PF(i)																
PSP																
PPF																
diff																
CSF?	YES	NO														

Figure 42 - Identifying Project Critical Success Factors Process

All the four different project phases of the twelve delivered projects were analyzed by the POL Model. However, for the present case study illustrated in this work, only the analysis regarding phase III will be addressed. The results of applying the metrics illustrated in Table 38 for phase III are illustrated in Figure 43.

METRICS RESULTS FOR DELIVERED PROJECTS AT PHASE 3																			
Delivered Projects	Role Attendee Degree				Mail Cohesion Degree				Feedback Degree	Information Seeking / Providing Degree		Action Key Players		Meetings Cohesion Degree		Teamwork Efficiency			
	Project Manager		Expert		Project Manager		Expert		All	Team A <-> B	Seeking	Providing	Question 1	Question 2	Team A	Team B	Team A	Team B	
	A	B	A	B	A	B	A	B			Team A & B								
	P1	+	+	-	NEUTRAL	33	85	66	12	55	56	56	89	A	B	C	C	33	98
P2	FULL	-	-	-	65	66	87	25	88	16	22	99	A	B	C	NCN	NCN	45	85
P3	NEUTRAL	+	FULL	NEUTRAL	88	78	65	65	100	55	18	100	A	A	NCP	NCP	88	76	
P4	+	+	NEUTRAL	-	92	26	85	76	100	64	56	87	A	B	NCP	NCP	95	45	
P5	+	+	-	+	56	88	36	1	86	77	88	59	B	A	C	NCN	NCN	74	25
P6	+	+	-	-	77	98	88	12	95	23	12	68	A	A	NCN	NCN	100	31	
P1	-	-	-	NEUTRAL	36	100	12	35	33	12	26	31	A	B	NCN	NCP	18	68	
P2	+	+	NEUTRAL	+	55	88	8	16	10	88	77	15	B	A	NCP	NCP	68	58	
P3	FULL	+	+	NEUTRAL	32	65	15	23	80	15	56	25	B	A	NCP	C	62	66	
P4	-	-	NEUTRAL	NEUTRAL	46	75	6	22	100	10	64	44	A	A	NCN	NCN	43	35	
P5	FULL	-	-	NEUTRAL	33	77	15	84	12	7	66	57	A	B	NCN	NCN	25	67	
P6	-	-	NEUTRAL	+	25	85	20	16	35	56	87	18	A	B	NCN	NCN	45	22	
PSP	+	+	-	-	69	74	71	32	87	49	42	84	A	INCONCLUSIVE	C	NCN	73	60	
PPF	-	-	NEUTRAL	NEUTRAL	38	82	13	33	45	31	63	32	A	INCONCLUSIVE	NCN	NCN	44	53	
diff					31	-8	59	-1	42	17	-21	52					29	7	
CSF?	YES	YES	YES	YES	YES	NO	YES	NO	YES	NO	NO	YES	NO	NO	YES	NO	YES	NO	

Figure 43 – Metric’s results for delivered projects by Organization A in phase III

In Figure 43 is illustrated the twelve projects that were analyzed by the POL Model. Projects P1 to P6 (blue marked) were successfully delivered, and projects P1 to P6 (red marked) were unsuccessfully delivered. Project Managers and Project Experts from both Teams (teams A and B) have been defined as the Official Project Roles for this case. These two actors (Project Managers and Project Experts) will be individually analyzed by the POL Model.

The results displayed in Figure 43 origin from the application of the POL model to the data collected from all twelve delivered projects in Phase III. Some raw data regarding the projects illustrated in Figure 43 that was analyzed by the POL model is illustrated in appendix. For example, for project 1

successfully delivered there were 21 project meetings across phase III. For project 1 unsuccessfully delivered, there were 13 project meetings across Phase III. Because the collected raw project data is of a very high volume the detailed pre-processing steps are not displayed in this work.

Nevertheless, as mentioned before, some of the collected project raw data is illustrated in appendix. This enables the reader together with metric's detailed description illustrated in chapter 5 to calculate results and identify project critical success factors.

In Figure 43 are illustrate the Project Success Profile values (PSP) and Project Failure Profile values (PFP). For the POL Metrics that use the > 25% diff value as a project critical success factor criterion, the line with the name *diff* in Figure 43 contains the differences between the PSP and PFP calculated values. The last line (CSF?) in Figure 43 indicates which of the POL Metrics are project critical success factors.

As an example, for the metric Role Attendee Degree four CSFs have been identified regarding the Project Managers (PMs) and Subject Matter Experts (SME) project roles. Regarding the PMs, it shows that a positive project meetings participation evolution along phase III (which means that the participation of PMs in project meetings is becoming more constant as phase III evolves towards closing), is a behavior found with more frequency in projects that were successfully delivered for both teams, A and B, than in projects that were unsuccessfully delivered for both teams, A and B.

Regarding the Subject Matter Experts, the calculated evolution is opposite to the PMs evolution across phase III. The conclusion is that as the projects in phase III come to an end, the participation of Experts in project meetings do not need to be so constant as it is for the beginning of phase III. This means, that for upcoming projects, organizations A and the respective customers should be aware that in the first project meetings of that upcoming project in phase III, the Subject Matter Experts should be always present. Furthermore, the presence of those Subject Matter Experts in the latest project meetings of that upcoming project in phase III is not so important.

According to Figure 43 for the metric Mail Cohesion degree three CSFs have been identified. For the Metric Feedback degree zero CSFs has been identified. For the metric Information Seeking / Providing degree one CSF has been identified. For the metric Action Key Players zero CSFs have been identified. For the metric Meetings Cohesion degree one CSF has been identified. And finally, for the metric Teamwork Efficiency one CSF has been identified.

For the metric Mail Cohesion degree illustrated in Figure 43 the density degree regarding the email communication network (where the values are displayed in the column *All*) is considered a CSF. This metric refers to the first approach as defined in 5.2.10.2 of chapter 5.

For example, in project P1 successfully delivered the value for the column All is 55 %. This means that from all possible email communication channels between all project people assigned to deliver project 1 in phase III, only 55 % of those channels were found. This means that not everybody that was assigned for project 1 (successfully delivered) had a direct email communication channel to all the other assigned project people. In other words, it means that for example a given project people 1, never had directly exchanged one email regarding project 1 matters with a given project people 2, across phase III of project 1 (successfully delivered). For example, in project p4 (successfully delivered), all assigned project people (according to the official project hierarchical chart) exchanged at least one email between them. In other words, there is one direct connection between all assigned project people for project p4 (and p3) regarding the email communication network.

According to Figure 43 in for successfully delivered projects (PSP), the average centrality degree of the project manager of team A in the email network communication is higher (almost twice more) (69) than in projects that were unsuccessfully delivered (38). This metric refers to a variation of the second approach as defined in 5.2.10.2 of chapter 5. These values represent the number of exchanged emails in each of the existing emails communication channels. For example, the value 69 represents that in average, the organization's A project managers in phase III from all successfully delivered projects, exchanged (sent and received) 69 project emails.

On the other side, in projects that were unsuccessfully delivered project managers of organization A, exchanged in average a total of 38 emails in their email communication direct channels. These results clearly indicate that there is a difference in the number of exchanged emails between successfully delivered projects and unsuccessfully delivered projects. It can be concluded that the number of emails exchanged by the project manager of organization A in phase III of a given project, strongly contributes for the success or the success of the project outcome. More concretely, a high number of exchanged emails by project managers in phase III of projects delivered by organization A, seems to contribute to a successful project outcome. This means that a high centrality degree (around 69%) of the project manager of Team A regarding the email communication network is a project critical success factor, and this value (around 69%) should be used as benchmark in future projects that organization A will deliver.

For the feedback degree it can be seen in Figure 43 that no critical success factor has been found. In fact, when analyzing the results having as criterion the diff of 25% as illustrated in Table 38, the difference between the average results for all successfully delivered project and all unsuccessfully delivered projects is much less than the adopted criterion (25% diff). This means that regarding to any project related matter across phase III, there was not observed a particular difference in the behaviors that characterize this metric (feedback degree).

Regarding the action key players metrics illustrated in Figure 43, it can be said that no critical success factor has been identified. In this case, it seems that the way that support or guidance is

provided to external teams (in this case team C), is not related with success or failure project outcome. In fact, there is no tendency to be observed regarding the results for this metric.

The results of the Meetings Cohesion degree metric illustrated in Figure 43 are considered as a critical success factor for team A, however, not for team B. This metric measures the variability effect regarding participation in project meeting of official designated project people across a given project phase (in this case for phase III of all 12 analyzed projects). More concretely, this metric captures the effects of the change of the project team set by analyzing who starts as project meetings set, who leaves, who reenters, and so on. As it can be seen in Figure 43 in the successfully delivered projects, the value C stands for constant evolution which means that there was no change in the project team set. This includes project managers, subject matter experts, and all the remaining project people across all project meetings of phase III.

On the other side, in projects that were unsuccessfully delivered it can be seen in Figure 43 that the most observed value regarding the Meetings Cohesion degree is the NCN. This stands for non-constant negative which means that there has been a change in the project team set, possibly a decrease in the number of elements across a finite period of time across all project meetings of phase III. This result is in fact aligned with software project management theory (agile methodology), which argues that for a successful project outcome, the project team set should remain the same from the beginning until the end of the project (PMI, 2019). Although the 12 analyzed projects concern the delivery of physical projects, the results illustrated in Figure 43 represent also that the unchanged project team set is not only beneficial in software projects, but as well in physical projects.

The results for the metric Teamwork Efficiency according to Figure 43 show that within Team A, having a shorter mail-answering time (in other words, being fast in reply / answering project related emails) is a critical success factors that may strongly contribute to a successful project outcome. This means that in projects that were successfully delivered, project email information-related questions were faster answered than in projects that were unsuccessfully delivered.

Finally, the critical success factors illustrated in Figure 43 are project people behaviors that project Teams should replicate in the future to enhance the chances of achieving a successful project outcome.

#### **6.2.4 Part 2 – Estimating an ongoing-Project Outcome Likelihood**

Organization A is “at the present moment” delivering a new project (called P7), to customer C1, and wants to monitor the outcome likelihood of the that ongoing project. Project 7 is currently in phase III and in each point AP. Organization A has already successful run Part 1 of the POL Model as

illustrated in Figure 43. This means that it has already identified project critical success factors for phase III.

If Organization A had not identified critical success factors in Part 1 of the POL Model for phase III, then Part 2 of the POL Model could not be run. This would mean that it would not be possible to guide and monitor ongoing project 7.

METRICS RESULTS FOR ONGOING PROJECT AT PHASE 3																		
Derived Projects Profiles	Role Attendee Degree				Mail Cohesion Degree				Feedback Degree	Information Seeking / Providing Degree			Action Key Players		Meetings Cohesion Degree		Teamwork Efficiency	
	Project Manager		Expert		Project Manager		Expert		All	Team A <-> B	Seeking	Providing	Question 1	Question 2	Team A	Team B	Team A	Team B
	A	B	A	B	A	B	A	B			Team A & B							
	PSP	+	+	-	-	69	74	71	32	87	49	42	84	A	INCONCLUSIVE	C	NCN	73
PFP	-	-	NEUTRAL	NEUTRAL	38	82	13	33	43	31	63	32	A	INCONCLUSIVE	NCN	NCN	44	53
CSF?	YES	YES	YES	YES	YES	NO	YES	NO	YES	NO	NO	YES	NO	NO	YES	NO	YES	NO
OP	+	+	+	+	55		22		61			19			NCP		23	
	1/4	1/4	1/4	1/4	1/3		1/3		1/3			1			1		1	
Status																		

Figure 44 - Results for ongoing Project phase III

In Figure 44 is illustrated the results of the application of the POL Model (OP) for phase III of the ongoing project P7 since its beginning until a certain point in time *AP*. In the *AP* point, project phases I and II are already completed. Are as well illustrated in Figure 44 the Critical Success Factors (CSF?) with the respective measurable value (PSP) for phase III.

The results in the *AP* point (which comprises the time between the beginning of the phase III, until the *AP* point) of the ongoing project (OP) show that only two metrics are aligned with the critical success factor values. They are *A* and *B* regarding the Project Managers of the Role Attended Degree metric. In this case, the positive evolution of project managers of both teams A and B, regarding the project meetings participation degree in phase III of a project, are considered critical success factors. In the ongoing project, the same evolution (positive) is observed. This means that regarding the Project Managers project meetings participation degree, the ongoing project is heading towards a successful outcome. In other words, the behavior of PMs in this phase – regarding the project meetings attendee degree –, is aligned with the behavior pattern observed in projects that were successfully delivered. The same is not observed with the Experts.

A negative evolution of Experts regarding the project meetings attendee degree is considered a critical success factor. In the ongoing project, until point *AP* there is a positive evolution regarding the expert's participation. This trend is not aligned with what the critical success factor shows. It means that regarding the expert's project meetings participation degree, the ongoing project is heading towards an unsuccessful outcome.

Applying the same analysis procedure for all the other metrics, it can be concluded that only two points of the Role Attended Degree metric are aligned with a successful project outcome likelihood. On the other side, eight points regarding all the seven POL metrics are not aligned with a successful project outcome likelihood. The results regarding the analysis of the evolution of phase III of the ongoing project, can be plotted in a circular bar as illustrated in Figure 45.

According to the results of the application of the POL Model in phase III in the ongoing project illustrated in Figure 44, it can be concluded that there is a 90% likelihood of leading project P7 to a project failure outcome ( $1/4 + 1/4 + 1/3 + 1/3 + 1/3 + 1 + 1 + 1$ ), and only 10 % likelihood to a successful outcome ( $1/4 + 1/4$ ).

This is true of course, if the project evolution within phase III in the ongoing project – regarding the dynamic interaction of project people – continues the same trend that has been observed since its beginning until the *AP* point. In other words, if from now on (from the *AP* point on) nothing is done to invert the observed trend regarding the dynamic interaction between the different project people in project P7, there is a 90% likelihood that P7 will not be successfully delivered. Simultaneously, there is only 10% likelihood that P7 will be successfully delivered.

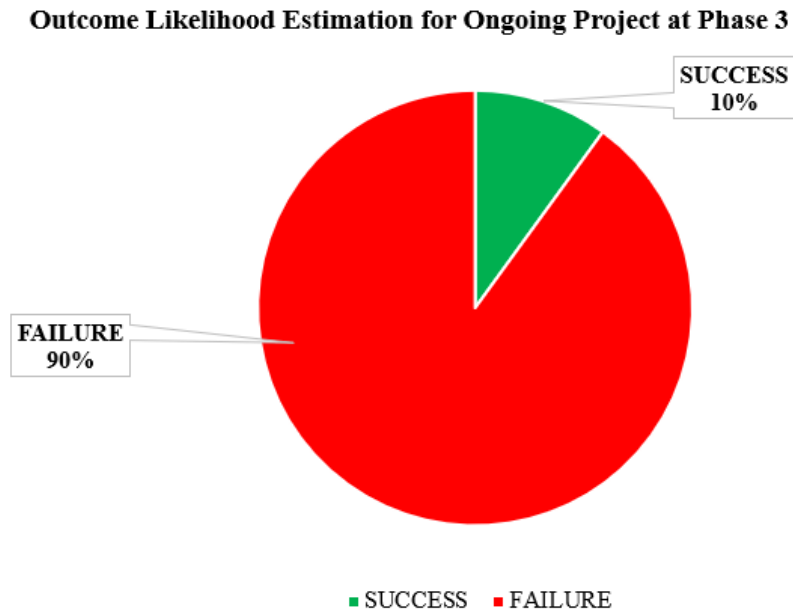


Figure 45 - Outcome Likelihood for Ongoing project in phase III

### 6.2.5 Interpretation of Results & Conclusions

The results obtained by the application of the POL Model show that, for example, considering the Role Attended Degree metric, the project managers – regarding project meetings participation degree – are behaving accordingly to the critical success factor. This means that regarding the

metric - project meetings participation degree, the project managers should keep doing until the end of phase III of the ongoing project what they have been doing since the beginning of phase III until the *AP* point of the ongoing project.

Another example, for the Meetings Cohesion Degree metric for Team A within phase III of a project lifecycle, having a constant team set is a critical success factor. In the ongoing project in phase III, the results of the application of the POL Model show that there has been a non-constant positive team set evolution since it's begin until the *AP* point. This means that tendentially, new project people have been participating in the project meetings in the period between begin of the phase III until the *AP* of phase III. In this case the result obtained from the application of the POL Model for the ongoing project is no longer aligned with the critical success factor identified in part 1. It means then, that some actions should be taken by the project teams A, and B in order to adjust the evolution of the ongoing project P7 in phase III in the direction of the critical success factors values. In Table 42 are illustrated the results of the 5 dimensions of the application of part 1 the proposed model in this work.

Table 39 - Results regarding the 5 dimensions of Part 1 of the proposed model for the case study

PROJECT KNOWLEDGE BASE - CSFs				RESULTS				
DIMENSIONS		POL Metric Name	SNA Metric					
1	Communication & Insight	1-Role attendee Degree	In-degree	CSF				
		2-Mail cohesion degree	Density / Total Degree	CSF	CSF	CSF	NO	NO
		3-Feedback degree	In-degree / Out-degree /Reciprocity	INCONCLUSIVE				
2	Internal & Cross Boundaries- Collaboration	4-Information Seeking / Providing degree	In-degree	CSF				
			Out-degree	NO				
3	Know-how Sharing & Power	5-Action Key Players	In-degree	INCONCLUSIVE				
4	Clustering (variability effect – PSNVar)	6-Meetings Cohesion degree	Variability	CSF				
				NO				
5	Teamwork Efficiency	7-Transferring Speed	In-degree	CSF				
			Transfer av. speed	INCONCLUSIVE				

As it can be seen in Table 42 the results of the application of the proposed model identified critical success factors in four dimensions (dimensions 1, 2,4, and 5). It has also identified the existence of no-critical success factors in three dimensions (dimensions 1, 2, and 4). The application of the model also identified three dimensions where the results were inconclusive. This occurred in dimension 1 in the feedback degree metric, in dimension 3 in the action key players metric, and in dimension 5 in the transferring speed metric. By analyzing the detailed results illustrated in Table 42 it is possible to understand to a certain extent the installed organizational culture in the

organizational analyzed and take more data-informed and objective decisions regarding the aspects that need to be improved.

Finally, recalling the hypothesis **H<sub>0</sub>** (yes, the dynamic interaction of project people across the different phases of a project lifecycle impact project outcome) and **H<sub>1</sub>** (no, the dynamic interaction of project people across the different phases of a project lifecycle do not impact project outcome) described in Chapter 1, it can be concluded that for phase III the results of the application of the proposed model allow not to reject **H<sub>0</sub>**. In other words, this means that the dynamic interactions of project people that occurred across phase III impacted project outcome. In Table 43 are illustrated the results of the 5 dimensions of the application of part 2 the proposed model in this work.

Table 40 - Results regarding the 5 dimensions of Part 2 of the proposed model for the case study

ONGOING PROJECT EVOLUTION				RESULTS				
DIMENSIONS		POL Metric Name	SNA Metric					
1	Communication & Insight	1-Role attendee Degree	In-degree	✓	✓	X	X	X
		2-Mail cohesion degree	Density / Total Degree	X	X	X		
		3-Feedback degree	In-degree / Out-degree /Reciprocity					
2	Internal & Cross Boundaries- Collaboration	4-Information Seeking / Providing degree	In-degree			X		
			Out-degree					
3	Know-how Sharing & Power	5-Action Key Players	In-degree					
4	Clustering (variability effect – PSNVar)	6-Meetings Cohesion degree	Variability			X		
5	Teamwork Efficiency	7-Transferring Speed	In-degree			X		
			Transfer av. speed					

The results illustrated in Table 43 show that only 2/3 of the metric role attendee degree are aligned with the critical success factors identified in part 1 of the proposed model. This means that in the ongoing project only 2 aspects of the metric role attendee degree are aligned with the critical success factors identified in part 1. The results illustrated in Table 43 show that only 2 out of 10 factors are aligned with the critical success factors. In this case it is suggested that those that are responsible for the management of the project should act in order to align as fast as possible the project team dynamic interactions towards the critical success factors. This should be done in the dimensions where the results are not aligned with the identified critical success factors. They are dimensions 1 (role attendee degree and mail cohesion degree), 2 (information providing degree), 4 (meeting cohesion degree), and 5 (transferring speed).

# Chapter 7

## 7 Final Considerations

*“One worthwhile task carried to a successful conclusion is worth half-a-hundred half-finished tasks.”*

Malcolm S. Forbes

### 7.1 Introduction

Throughout this work has been described an heuristic two-part model developed based on three scientific fields ((1) project management (which contributes with the definitions and structure of a project lifecycle), (2) risk management (which contributes with the standard risk management process framework), and (3) social network analysis (which provides the tools & techniques to identify and quantify the collaborative interactions between entities throughout a project lifecycle), to uncover and measure the extent to which the dynamic interactions of project people influence a project’s outcome (success or failure), as they work through networks of collaboration across all the phases of a project lifecycle. The proposed model in this work named as the POL Model analysis five key project collaboration types ((1) Communication and Insight, (2) Internal and Cross Boundaries-Collaboration, (3) Know-how sharing and Power, (4) Clustering (variability effect—PSNVar), and (5) Teamwork efficiency) that usually emerge and evolve in each project phase of a generic project lifecycle, searching for unique repeatable behavioral patterns (RBPs) in project data-related collected in (1) project meetings, (2) project emails, and (3) through the application of a SNA-based questionnaires.

In this final chapter a resume regarding the benefits and limitations of the application of the proposed model in this work will be presented in terms of scientific & academic and managerial implications. Finally, are described the limitations and proposed future works and developments to minimize the limitations of the proposed model in this work.

### 7. 2 Conclusions

As it has been demonstrated across chapter 6 the proposed model in this work has high reliability degree regarding the reproducibility of results. This is demonstrated by the consistent results

obtained for all seven SNA centrality metrics applied to the 12 different projects as illustrated in Figure 43 in the previous sub-chapter Identify Critical Project Success Factors.

This is possible due to the exact definition of the possible output ranges for each SNA centrality metric defined in Table 38. This in turn is consequence from the only possible pre-defined output types generated by the application of the first and second major measurements as defined in Table 38.

If the necessary data regarding project meetings, project emails, and project surveys, is available to feed the proposed model in this work as illustrated in Figure 29, the proposed model in this work will always output the results according to what is established in Table 38.

On the other hand, if any data regarding the project meetings, project emails, and project surveys is missing, then the proposed model in this work will not be able to calculate the respective SNA centrality metric. However, if any parameters concerning the criteria for PSP and PFP are changed the results may vary significantly. This could turn a critical success factor into non-critical success factors and vice-versa. If this happens, means that either the process of identification of CSFs has been widen (this would mean that a CSF would start to be counted at a value greater than a 25%), or shrank (this would mean that a CSF would start to be counted at a value lower than a 25%). This parameter has to do with the accuracy of the proposed model in this work. For *diff* values lower than 25, the accuracy increases and thus the identification of CSFs becomes more refined. For *diff* values higher than 25%, the identification of CSFs becomes is less refined.

Regarding the validity of the presented model in this work the outputted values are fully aligned with other applications of SNA centrality metrics as the reports of reviewed literature indicate (Krackhardt & Hanson, 1993; Wasserman & Faust, 1994; Cross et al., 2002; Freeman, 2004; Cross & Parker, 2004; Borgatti et al., 2009; Scott, 2017; Borgatti et al., 2018; Nunes & Abreu, 2020(a); Nunes & Abreu, 2020(b)).

Throughout chapter 6 has been illustrated how the proposed model in this works and how can be applied in organizations to identify collaborative project critical success factors. Recalling the research question presented in this work - *to which extent do the dynamic interaction of project people, that participate in projects activities across the different phases of a project lifecycle influences a project outcome (success or failure)?* – it is clear now to understand how the proposed model in this work approaches the problem and which are the tools, techniques and principles are applied to solve it.

As it can be observed across all the chapter 6 the proposed model in this work analyzed data from 12 projects (6 of them successfully delivered, and other 6 unsuccessfully delivered) from seven different customers (C1, C2, C3, C4, C5, C6, and C7) as illustrated in Figure 41. All analyzed projects

have been delivered under a waterfall stage-gate methodology. Each of the 12 projects were divided into four different project phases (phase I- initiating, phase II- planning, phase III- executing, and finally phase IV – closing) according to the PMBOK from the Project Management Institute (PMI, 2017). For an illustration purpose of the application and interpretation of results of the proposed model in this work (the POL model), phase III from all delivered successful and unsuccessful projects has been chosen to be detailed analyzed as illustrated in Figures 43 and 44.

The results of the application of the SNA centrality metrics in phase III in all 12 analyzed projects are illustrated in Figure 43 (Metrics results for delivered projects by Organization A in phase III) of chapter 6.

When analyzing the way that the results are outputted by the proposed model in this work regarding the classification of what are and what are not collaborative project critical success factors, it can be argued that the proposed model in this work provides an answer to the research question proposed in this work in a very unambiguous and efficient way. This happens as the model clearly classifies which of the five key project collaboration types ((1) Communication and Insight, (2) Internal and Cross Boundaries-Collaboration, (3) Know-how sharing and Power, (4) Clustering (variability effect—PSNVar), and (5) Teamwork efficiency) are unique in successfully delivered projects and in unsuccessfully delivered projects. This can be observed in the last row (*CSF?*) in Figure 43. As a conclusion, it can clearly be argued that the proposed model in this work successfully has achieved the first part of his objective which corresponds to the part 1 of the proposed model in this work (The POL model).

Furthermore, the proposed model in this work not only identifies which factors are those critical for collaborative project success outcome, but also identifies in a quantitatively way, potential critical failure factors that might have been responsible for unsuccessful collaborative project outcome. This also enables organizations to work out factors that they might not have been aware of, which may ultimately play a decisive role in project outcome.

Regarding the performance of the second part of the proposed model in this work (Part 2), it is also clearly observed the successful application of the POL model in providing guidance and direction to an ongoing project. Here, the proposed model in this work uses the critical success factors identified in the previous part (Part 1) for phase III and compared them with the results of the analysis done in phase III of the ongoing project illustrated in Figure 44. The results of the comparison process are later illustrated in Figure 45 (Outcome Likelihood for Ongoing project in phase III).

When analyzing the results of Figure 45 it can be clearly argued that the proposed model in this work efficiently performed his job in identifying the total percentage of factors that lead to a successful and to an unsuccessful ongoing project outcome. This fact classifies the proposed model in this work as an effective method of holistically quantifying how much is pointing towards the

successful outcome, and how much is pointing towards the unsuccessful outcome regarding the dynamic interaction between project people across the different phases of a collaborative project.

Finally, it can be concluded that the proposed model in this work successfully addresses the two objectives as defined in parts 1 and 2, and clearly answers the research question illustrated in this work.

### **7.2.1 Scientific and Academic implications**

The proposed model in this work (the POL model) aims to provide organizations an efficient support regarding the management of collaborative projects, such as the open innovation for example, where the lack of such models is pointed out as the major obstacle (Santos et al., 2019) for organizations to engage in collaborative network project models more often. In order to do so, the proposed model in this work specifically aims the identification of project critical success factors across the different phases of a project lifecycle.

The research conducted towards the development and application of the proposed model in this work (the POL model), counts as the major contribution to the scientific dimension and community, namely in the project management field, but not only. The development of the proposed model in this work based on three scientific pillars ((1) project management – providing the definitions and structure of a typical project lifecycle, (2) risk management – providing the standard risk management process framework, and (3) the social network analysis – providing the tools & techniques to identify and quantify the dynamic collaborative interactions between entities across the different phases of a project lifecycle), enables the creation and development of expertise and unique knowledge regarding three supportive pillars and has contributed to the development of know-how & know-what in the engineering and industrial management scientific areas.

Simultaneously, the development of the proposed model in this work provides an effective answer to organization's needs regarding the management of dynamic collaborative interactions. This is namely a very important point because to several research shows that due to a lack of proper models to manage collaboration in organizations, they do not engage with the expected frequency in such collaborative initiatives and thus not profit from the benefits that collaborative initiatives may bring to organizations (Workday, 2018; Arena, 2018; Santos et al., 2019; Nunes & Abreu, 2020). This point will enable organizations that do already actively participate in collaborative initiatives to increase their performance and profitability, and especially for those organizations that still are reluctant to start an active participation in such collaborative initiatives.

The application of the proposed model in this work in organizations is an efficient decision-making tool which contributes to increase their performance and innovation initiatives. This in turn, results

in creating and delivering more value to themselves, their customers, their ecosystem, and the global society in general.

The proposed model in this work addresses two important collaborative projects risks as proposed by (Abreu et al., 2018) and (Hillson, 2014). They are: (1) **Project collaborative risks** (comprised by a subset of risks such as critical enterprises risk, assigning tasks to partners risk, and behavioral risk) and (2) **Project ambiguity risks** (also known as “epistemic uncertainty”, where uncertainties essentially arise from lack of knowledge or understanding), respectively.

According to several research (Hillson, 2014; Abreu et al., 2018; Nunes & Abreu, 2020) both risk types (collaborative and ambiguity risks) can effectively be managed by applying project lessons learned and simulations. This is exactly what the proposed model in this work offers organizations, however in a novel approach. The novel approach is characterized by the scope of analysis in projects. The proposed model in this work provides valuable and unique insight regarding the management of those two risk types by, first identifying in a quantitatively way invisible dynamic behavioral interactions that cannot be fully understood by traditional statistical tools and techniques, which will later enable to monitor and simulate the evolution of a system, which in this case is the project social network.

Furthermore, the proposed model in this work also addresses one of the most important subjects that organizations currently face —the organizational transformation through digitalization— defended by several authors as the critical move to organizations achieve competitive advantages or even survive (Arena, 2018; Workday, 2018; Müller, 2020; Nunes & Abreu, 2021). They also argue that organizations need to change the way they think and execute work by introducing agility mindset in organizational processes, procedures, fueled with empowerment and commitment.

In the field of the project risk management the proposed model in this work contributes to a holistic, deeper, and more accurate way of understanding how collaboration really emerges and evolves across the different phases of a project lifecycle, and how such evolution may or may not be originating behaviors that to a certain extent represent collaborative risks to project activities and ultimately project outcome. This in turn, may trigger the development of new theoretical approaches regarding on how to manage project’s collaborative risks.

In the field of SNA in organizations the proposed model in this work contributes to the development of new insights and discoveries regarding the importance and implications of the different informal centrality roles (identified by the application of SNA centrality metrics) within a project social network. Nevertheless, continuous development of new SNA centrality metrics is critical to enable a deeper insight regarding the dynamic interactions between organizations that participate in collaborative project networks.

Finally, in the collaborative networks field the proposed model in this work contributes to identify how other factors, such as problem-solving, information sharing, decision-making, beside trust, reciprocity and interlocking of directorates, can play a central role for an efficient and effective collaborative project network.

### **7.2.2 Managerial implications**

Essentially, the key findings across this work concern the demonstration of the applicability of the proposed model in this work (POL model) in identifying (in a quantitatively way) dynamic interactive behavioral patterns associated to unsuccessful and successfully delivered projects that are run under a collaborative network model approach such as the open innovation model for example. The model essentially uncovers and measures five collaborative project dimensions ((1) Communication & Insight, (2) Internal & Cross Boundaries-Collaboration, (3) Know-how sharing & Power, (4) Clustering (variability effect – PSNVar), and (5) Teamwork efficiency), that usually exist within a collaborative project social network across the different phases a project lifecycle. The data used for the characterization of the five collaborative project dimensions is collected in project email, project meetings, and project questionnaires.

The proposed model in this work provides organizations with a valuable and unique historic picture regarding how collaboration between the different organizations or project people within an organization that did participate in collaborative network projects, occurred across the different phases of a project lifecycle. In other words, the POL model provides organizations with a dynamic lesson-learned, self-updating knowledge base, which enables to learn from past experiences regarding which dynamic behavioral interactions are associated with successful or failure project outcomes.

From a macro perspective, the continuous application of the proposed model in this work in organizational collaborative projects will help organizations to identify and quantify different collaborative working cultures that emerge as they work in collaborative network models. This enables to identify which collaborative working culture is more effective regarding a particular organization's performance and innovation initiatives.

There are still other advantages that the proposed model offers from a macro perspective when compared with other HR people analytics models, where the data to model and analyze organization performance is usually collected through pulse survey or 360° questionnaire approaches. In this dimension, two of the data collecting methods of the proposed model in this work (project emails, and project meetings) are almost completely bias-free and eliminates organizational down-time as organization members do not need to answer performance and quality pulse surveys regarding how collaboration occurred when they worked in projects. Moreover, the identification of project critical success factors is a mathematical process with quantitative outcomes.

From a management perspective, where managers need to take decisions most of the time based on quantitative approaches expecting to improve the quality of results (performance and innovation), the proposed model in this work, by outputting quantitative results regarding the interactive dynamic behavior of the different entities that participate in collaborative network projects, enables managers to quantitatively understand the effect of such dynamic behavior in organizational outcomes. It enables also and to make decisions in a more data-driven way, rather than traditional approaches essentially based on gut feelings and key influencers' biased opinions.

Still, from a managerial perspective the proposed model in this work provides organizations with another benefit related to working in collaborative networks. By quantitatively analyzing the influence that the blur of formal and informal networks of collaboration in successfully and unsuccessfully delivered projects, it provides managers with a unique insight into the real importance of informal networks of collaboration, enabling them to take appropriate action to support, maintain, or even enhance collaborative network dynamics that are associated with successful outcomes.

The proposed model in this work provides organizations a much clearer insight regarding how organizations can benefit from the integration of relational data (data that quantitatively mirrors the dynamic network relationships between entities in collaborative projects) into their organizational strategic management processes or frameworks. The application of the proposed model in organizations will enable them to do more with less, thus contributing to the achievement of sustainable competitive advantages. This means that, as the proposed model in this work enables organizations to better plan and manage organizational collaborative networks (by understanding and identifying the critical factors that drive successful project outcomes), organizations reduce or eliminate risks associated with collaborative projects (collaborative risks), which in turn optimizes resource usage, orienting organizations towards a leaner approach, which ultimately will contribute positively to economic, social, and environmental sustainability.

Regarding the application of the proposed model in organizations in the actual conjecture, strongly marked by the pandemics effect that impacts everyone in every part of the world, brings an additional challenge concerning the efficient and effective application and application of the proposed model in this work. The very first negative aspect to be mentioned, that affects both, the application, and the application of the proposed model in an equal manner, is the strong reduction of projects that can be undertaken due local or governmental constraints.

According to experience most problems are to be observed in the implementation phase rather than in the application phase. Regarding the implementation phase, which in this case comprises all the activities to implement the structure and architecture of the proposed model in this work, there has been huge constraints observed, rather than those "normal ones" which essentially relate to lockdown initiatives promoted by the different world governments in an attempt to control the spread

of the pandemics. In this case, the only major constraint observed relates to the availability of qualified personal that provide support to the application of the proposed model in this work in a typical business intelligence architecture of an organization. Once most tasks regarding the application of the proposed model in this work into a typical business intelligence architecture are IT relate ones - essentially creating dedicated project email accounts, creating project databases to email exchanged project-related information and project survey results, and the installation of the POL model software in a dedicated server -, these do not properly affect the performance of the proposed model in this work. Furthermore, the proposed model in this work is suitable to be integrated into an organizational business intelligence architecture turning into a supervise machine learning system that automatically identifies and refines the identification process of project critical success factors (Nunes et al., 2021).

On the other hand, regarding the application of the proposed model in this work in organizations – which comprises the essentially the process of (1) data collecting, (2) results analysis and discussion, and finally (3) implementation of corrective or supportive project measures -, the actual conjuncture may bring some obstacles to the efficiency and efficacy of the proposed model in this work, essentially regarding the data collecting process and the implementation of corrective or supportive project measures in ongoing or upcoming projects.

The data collecting process adopted by the proposed model in this work is divided in three major different methods. They are: (1) **project meetings data**, (2) **project emails information-related**, and (3) **project surveys**. Regarding the project meetings data there is not much to be related that poses an obstacle to the application of the proposed model. Once the only required data regarding the project meetings is the role attendee degree - which refers to the number of times that key project people participated in each project meeting of a given project lifecycle phase -, no information relative to personal preferences is needed. Due to the pandemics, most of the personal project meetings – the so-called F2F meetings (face to face meetings) - has now been undertaken virtually supported by the most varied web applications. In this dimension, the pandemics poses no problem to the efficient application of the proposed model in this work.

Regarding the exchanged project emails information-related, by nature, the pandemics also brings no problems to the efficient application of the proposed mode in this work. On the contrary, it can be seen as an opportunity. This is so because it contributes to an increase of exchanged project emails information-related, which is to be seen as a very positive aspect because according to several literature, email exchanged information (project relational data) has a lower level of bias when compared with information that is collected through questionnaires or surveys (Krackhardt & Hanson, 1993; Wasserman & Faust, 1994; Cross et al., 2002; Cross & Parker, 2004; Freeman, 2004; Borgatti et al., 2009; Scott, 2017; Nunes & Abreu, 2020; Nunes & Abreu, 2020(a))

Finally, regarding the last data collecting method - project surveys -, the pandemics has in fact brought a negative impact. This happens essentially due to two major reasons. The first reason concerns to the decrease of projects that are being undertaken. This fact leads to less chances of the application of the project surveys on site. The second reason concerns to the consequences of the pandemics, namely in the preventive and protection measures that governments have imposed in order to control the spread of the pandemics. Essentially all implemented measures, aim the reduction of personal contact in all dimensions. This fact strongly constrains the free movement of project people towards the seeking of support and advice in other co-workers, in a F2F (face to face at the project site) environment. This fact limits the emergence and development of personal F2F dynamic relationships between project people in a physical environment. Because of this, the results obtained by the application of project surveys to project people, are to be more subject to bias than before the pandemics. This essentially happens because project people spend much less time in nurturing a F2F relationship, which is to be considered by several reviewed literature (Krackhardt & Hanson, 1993; Wasserman & Faust, 1994; Cross et al., 2002; Cross & Parker, 2004; Freeman, 2004; Borgatti et al., 2009; Scott, 2017; Nunes & Abreu, 2020; Nunes & Abreu, 2020(a)) a key element to generate dynamic preferential connections, from which unique and meaningful insight could be collected, and later correlated with outcomes. In other words, having less F2F contact, turns preferences and opinions about co-workers more subjective than objective, which ultimately, may lead to false interpretation of the reality.

Regarding the implementation of corrective or supportive project measures, the pandemics hasn't brought meaningful negative aspects apart from those already mentioned above.

Finally, as a direct consequence of less F2F interactions, an increase in phone exchanged project related has been observed. This also represents an extra obstacle to efficient application of the proposed model in this work, in the sense that the information that flows across project phone calls is not captured by the actual version of the proposed model in this work. This may represent the loss of unique project information that is simply lost.

### **7.3 Limitations and Future Developments**

The implementation and application of the proposed model may represent a challenge to organizations. This may occur because organizations need to have access to the right technology, and the employment of an adequate working culture as they work through collaborative networks to deliver projects. Essentially, this refers to the process of generating the necessary data to the proposed model in this work. More concretely, in a high-level perspective, it concerns the implementation of a working culture that leads to record in efficient platforms all the required information by the proposed model in this work as illustrated in Table 29.

In this dimension, further research should be undertaken to develop low-cost systems that can be efficiently implemented in organizations, where data can be properly collected in a way that the impact to the working culture is minimal while simultaneously assuring that the collected data mirrors as much as possible how really collaboration occurs. This should take place as if it would have been collected and processed by an efficient business intelligent architecture.

The integration of the POL model in this work into an efficient organizational business intelligence architecture enables a fully automatization of the analysis process, that helps organizations to smarter and faster address digital transformation issues. This in turn, enables organizations to efficiently pursuit the actual and upcoming sustainability challenges in a holistic and consistent way, focusing efforts and resources in the achievement of short and long-term goals.

Furthermore, the integration of the POL model in this work into an organizational business intelligence architecture, would classify the proposed model in this work as an intelligent predictive model that identifies project critical success factors across the different phases of a project lifecycle.

Regarding the adoption of an adequate working culture organizations should clearly explain their employees the medium and long-term benefits that can arise by the application of the proposed model in this work. However, they should first develop and implement initiatives to train employees toward such adequate working culture. In this dimension, and being aware that not all organizations have the necessary resources to implement leadership initiatives that trigger in their employees the “need” to cope with the model requirements regarding the necessary data that the model needs in a timely manner, further research should be undertaken toward the development of low-cost adequate training initiatives that could be available to most organizations in order to enable the efficient application of the proposed model in this work. This would not only benefit the organizations that would pursuit this path, but also their entire ecosystem (employees, partner, customer, and so on), and ultimately the large society in general.

The proposed model in this work only collects data from project meetings, project surveys, and project emails as illustrated in Table 29. However, much project related information flows through other communication and collaboration channels, such as phone calls, instant messaging, corridor meetings, and so on. In this dimension – namely regarding the information that flows across phone calls -, the pandemics has just worsened the things for the application of the proposed model in this work. As personal contact is being restricted, more information flows through phone calls as already mentioned in this work. Once the proposed model in this work is not allowed - due legal GDPR (General Data Protection Regulation) aspects -, access, collect, store, and analyze phone calls project related information, many valuable information that could be used to better understand the extent to which dynamic interaction of project people that participate in projects activities across the different phases of a project lifecycle is simply lost. In this dimension, further research should be

undertaken to develop new data collection methods to be able to filter personal from professional phone interactions, so that such potential valuable project related information is not simply lost.

Regarding the information collected in project surveys there is also a suggestion to be mentioned. As there is no obligation to project people answer project surveys, many valuable information is simply not captured. Regarding this dimension, further research should be undertaken in finding ways to motivate project people to provide bias-free information in project surveys regarding project related matters. For this matter, research should take into consideration side effects that such motivation initiatives would introduce within a given project social network in the work environment, such as retaliation, fear, reluctance, and psychological safety.

Regarding the SNA centrality metrics that the proposed model incorporates there are also suggestions for further research. In the proposed model only SNA centrality metrics have been applied and developed to analyze data collected in project meetings, project emails, and project surveys. This happens essentially because according to reviewed literature (Cross & Parker, 2004; Freeman, 2004; Borgatti et al., 2009; Scott, 2017; Nunes & Abreu, 2020; Nunes & Abreu, 2020(a)), it is suggested that only SNA centrality metrics output unique, meaningful, and actionable results that can be immediately used to decision-making process. However, further research should be undertaken to consider the application of other SNA metrics, rather than centrality, such as dispersion for example.

Finally, and still regarding the SNA centrality metrics, it is suggested the introduction of other SNA centrality metrics apart from those used in the actual version of the proposed model in this work (the POL model) which essentially comprise, in-degree, out-degree, total-degree, average-degree, density, and reciprocity. Other SNA metrics, such as betweenness, and closeness, should be also in the future applied for two major reasons. The first reason concerns the suggestion of specialized reviewed literature (Cross & Parker, 2004; Freeman, 2004; Borgatti et al., 2009; Scott, 2017; Nunes & Abreu, 2020; Nunes & Abreu, 2020(a)) that argues that both, betweenness (which essentially characterizes how often a given project person acts as a bridge between all the other project people within the project social network where they are contained) and closeness (which essentially characterizes how close a given project person is from all the other project people within the project social network where they are contained) may output unique insights regarding the dynamic interaction of project people that usually are not captured by the application of other SNA centrality metrics. The second reason regards the connectedness property that both SNA centrality metrics (closeness and betweenness) have regarding the classification of a given global social network. This would enable a holistic analysis at one-shot time instead of analyzing the contribution of individual connections to the whole network. Here, time spent with the individual analysis could be spent, and new perspectives regarding the analyses of project social networks could be generated.



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# Appendix – 1: Raw data for the calculation of the SNA metric – Role Attendee Degree (A)

**Description:** Raw data for the calculation of the SNA metric – Role Attendee Degree (POL Model) from the service provider side (organization A). Data collected between 2018-2019 (full years), respects the attendance degree to project meetings in phase III. P(i) = project 1, 2, 3, 4, 5; blue= successfully delivered projects; red= unsuccessfully delivered projects; RAD= Role Attendee Degree; PM= project manager role; SME= subject matter expert role; pm(i) = project meeting number 1,2,3, ..., i.

## Service Provider side (Team A)

P1		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13	pm14	pm15	pm16	pm17	pm18	pm19	pm20	pm21
RAD	PM	1	1	0	1	1	0	0	0	1	1	1	0	0	1	1	0	1	1	1	1	1
	SME	1	0	0	1	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0

P2		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13
RAD	PM	1	1	1	1	1	1	1	1	1	1	1	1	1
	SME	1	1	0	1	1	1	1	0	0	1	1	0	0

P3		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13	pm14	pm15	pm16	pm17	pm18
RAD	PM	1	1	0	1	1	0	0	0	1	1	1	0	0	1	1	0	1	1
	SME	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

P4		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11
RAD	PM	0	1	0	0	1	1	1	1	1	1	1
	SME	1	0	1	0	1	0	0	1	1	1	0

P5		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13	pm14	pm15	pm16	pm17	pm18	pm19
RAD	PM	1	0	0	0	1	0	1	1	1	0	1	0	0	0	1	1	1	1	1
	SME	1	1	1	1	1	1	1	0	0	1	1	0	0	0	0	0	1	0	0

P6		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13	pm14	pm15	pm16	pm17
RAD	PM	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
	SME	1	0	0	0	1	1	1	0	0	1	1	0	1	0	0	0	0

P1		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13	pm14	pm15	pm16	pm17
RAD	PM	1	1	0	1	1	0	0	0	1	0	0	0	0	1	0	1	0
	SME	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

P2		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13	pm14	pm15	pm16	pm17	pm18
RAD	PM	1	1	0	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1
	SME	1	1	0	1	0	1	0	1	1	1	1	0	1	0	0	1	1	1

P3		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13	pm14	pm15	pm16	pm17	pm18	pm19	pm20	pm21	pm22
RAD	PM	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	SME	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0

P4		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8
RAD	PM	1	1	0	0	1	0	0	0
	SME	1	0	1	0	1	0	1	0

P5		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11
RAD	PM	1	1	1	1	1	1	1	1	1	1	1
	SME	1	1	0	0	0	1	0	0	0	0	0

P6		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13
RAD	PM	1	1	1	1	1	0	0	0	0	1	0	0	0
	SME	0	0	1	1	0	0	1	0	0	0	0	0	1



# Appendix – 2: Raw data for the calculation of the SNA metric – Role Attendee Degree (B)

**Description:** Raw data for the calculation of the SNA metric – Role Attendee Degree (POL Model) from the customer side (organizations B). Data collected between 2018-2019 (full years), respects the attendance degree to project meetings in phase III. P(i) = project 1, 2, 3, 4, 5; blue= successfully delivered projects; red= unsuccessfully delivered projects; RAD= Role Attendee Degree; PM= project manager role; SME= subject matter expert role; pm(i) = project meeting number 1,2,3, ..., i.

### Customer side (Team B)

P1		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13	pm14	pm15	pm16	pm17	pm18	pm19	pm20	pm21
RAD	PM	1	1	0	1	1	0	0	0	1	1	1	0	0	1	1	0	1	1	1	1	1
	SME	1	1	1	0	1	1	0	0	0	1	1	0	0	0	0	0	1	1	1	1	1

P2		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13
RAD	PM	0	1	0	1	1	0	0	0	1	0	1	0	0
	SME	1	0	0	1	1	1	0	0	0	0	1	0	0

P3		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13	pm14	pm15	pm16	pm17	pm18
RAD	PM	0	1	0	1	1	0	0	0	1	1	1	0	0	1	1	1	1	1
	SME	1	0	1	1	0	0	1	0	0	1	1	0	0	0	1	0	1	1

P4		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11
RAD	PM	0	0	0	1	1	0	0	0	1	1	1
	SME	1	0	0	1	1	1	1	0	0	1	0

P5		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13	pm14	pm15	pm16	pm17	pm18	pm19
RAD	PM	0	1	0	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1
	SME	1	0	0	1	0	1	1	0	0	1	1	0	1	1	1	1	1	0	1

P6		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13	pm14	pm15	pm16	pm17
RAD	PM	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1
	SME	1	1	0	1	1	1	1	0	0	1	1	1	0	0	0	0	1

P1		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13	pm14	pm15	pm16	pm17
RAD	PM	0	0	0	1	1	0	0	1	1	1	1	1	0	0	0	0	0
	SME	0	1	0	1	1	1	1	0	1	0	1	0	1	0	1	0	1

P2		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13	pm14	pm15	pm16	pm17	pm18
RAD	PM	0	0	1	0	1	0	0	0	1	1	1	0	0	1	1	1	1	1
	SME	0	0	1	0	1	1	0	0	0	0	1	1	1	1	1	0	0	1

P3		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13	pm14	pm15	pm16	pm17	pm18	pm19	pm20	pm21	pm22
RAD	PM	0	1	0	0	0	0	0	0	1	1	1	0	0	0	1	1	0	1	0	1	1	
	SME	1	1	0	0	1	1	1	0	1	1	1	0	0	0	1	1	1	1	1	0	0	

P4		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8
RAD	PM	1	1	0	0	0	0	0	0
	SME	1	0	1	1	1	1	0	1

P5		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11
RAD	PM	1	1	0	1	1	0	0	0	0	0	0
	SME	1	0	0	0	0	0	0	1	1	0	0

P6		pm1	pm2	pm3	pm4	pm5	pm6	pm7	pm8	pm9	pm10	pm11	pm12	pm13
RAD	PM	0	1	1	1	1	0	0	0	0	0	0	0	0
	SME	0	1	0	1	0	0	1	0	1	1	1	1	1



## Appendix – 3: Raw data for the calculation of the SNA metric – Mail Cohesion Degree

**Description:** Raw data for the calculation of the SNA metric – Mail Cohesion Degree (POL Model) from the service provider side (organization A) project managers and subject matter experts, and the customer side (Organizations B) project managers and subject matter experts. Data collected between 2018-2019 (full years), respects the number of email communication channels (directed channels) existing within the project social network (MCD (1)) density), and the total number of project related emails exchanged (MCD (2)) density) by project managers and subject matter experts for phase III. MCD = Mail Cohesion Degree; Element. Total= number of official designated elements from both teams (A and B) to deliver a respective project; Links= number of direct emails channels existing within the project social network; P(i) = project 1, 2, 3, 4, 5; blue= successfully delivered projects; red= unsuccessfully delivered projects; PM= project manager role; SME= subject matter expert role. Elements from = total number of project people of each team (A and B). There is one project manager in each side of the blocks (1 x in the service provider side, and 1 x in the customer side). The number of SME varies between 1-3.

Organization A side (Team A) + Customer B side (Team B)

	P1		P2		P3		P4		P5		P6	
MCD (1) density	Elemen. Total	9	Elemen. Total	20	Elemen. Total	16	Elemen. Total	6	Elemen. Total	14	Elemen. Total	16
	Links:	36	Links:	334	Links:	240	Links:	30	Links:	157	Links:	228
MCD (2) Total-degree	PM	33	PM	65	PM	88	PM	92	PM	88	PM	98
	SME	85	SME	66	SME	78	SME	26	SME	36	SME	88

Elements from	Team A:	5	8	7	3	6	4
Elements from	Team B:	4	12	9	3	8	12

	P1		P2		P3		P4		P5		P6	
MCD (1) density	Elemen. Total	18	Elemen. Total	23	Elemen. Total	7	Elemen. Total	10	Elemen. Total	17	Elemen. Total	8
	Links:	101	Links:	51	Links:	34	Links:	90	Links:	33	Links:	20
MCD (2) Total-degree	PM	100	PM	88	PM	65	PM	75	PM	77	PM	85
	SME	35	SME	16	SME	23	SME	22	SME	84	SME	16

Elements from	Team A:	7	12	3	6	11	2
Elements from	Team B:	11	11	4	4	6	6



## Appendix – 4: Raw data for the calculation of the SNA metric – Feedback Degree

**Description:** Raw data for the calculation of the SNA metric – Feedback Degree (POL Model) from the service provider side (organization A) project elements (which include managers and subject matter experts), and the customer side (Organizations B) project elements (which include managers and subject matter experts). Data collected between 2018-2019 (full years), respects the number of feedbacked emails regarding any project matter related for phase III of all displayed 12 projects. FD = Feedback Degree. P. Team= project team A, B; Sent= number of projects related (any) matters from team A and from Team B. P(i) = project 1, 2, 3, 4, 5; blue= successfully delivered projects; red= unsuccessfully delivered projects. Feedbacked data does not necessarily implies answering a particular question or providing specific help.

		Sent project related emails and <i>feedbacked</i> (function of subject on heading of email)											
		P1		P2		P3		P4		P5		P6	
FD	P. Team	Team A	Team B	Team A	Team B	Team A	Team B	Team A	Team B	Team A	Team B	Team A	Team B
		Sent	22	39	75	12	78	43	39	25	22	17	57

		Sent project related emails and <i>feedbacked</i> (function of subject on heading of email)											
		P1		P2		P3		P4		P5		P6	
FD	P. Team	Team A	Team B	Team A	Team B	Team A	Team B	Team A	Team B	Team A	Team B	Team A	Team B
		Sent	11	92	18	20	67	10	80	8	114	8	86



## Appendix – 5: Raw data for the calculation of the SNA metric – Information Seeking / Providing degree

**Description:** Raw data for the calculation of the SNA metric – Information Seeking / Providing degree (POL Model) between the service provider side (organization A) project elements (which include managers and subject matter experts), and the customer side (Organizations B) project elements (which include managers and subject matter experts). Data collected between 2018-2019 (full years), respects the number of emails sent asking for specific project matters related (any type), and emails sent providing specific project related matters in phase III. Do not necessarily implies feedback to a particular specific matter. ISP= information seeking and providing; Team A (s) = emails sent from team A to team B searching for specific project related information (includes project calculations, management tools, leadership behaviors, project strategies and so on); Team A (p)= emails sent from team A to team B providing specific project related information (includes project calculations, management tools, leadership behaviors, project strategies and so on); Team B (s) = emails sent from team B to team A searching for specific project related information (includes project calculations, management tools, leadership behaviors, project strategies and so on); Team B (p)= emails sent from team B to team A providing specific project related information (includes project calculations, management tools, leadership behaviors, project strategies and so on); ISP = information seeking and providing; P(i) = project 1, 2, 3, 4, 5; blue= successfully delivered projects; red= unsuccessfully delivered projects. Feedbacked data does not necessarily implies answering a particular question or providing specific help.

Information Seeking / Providing regarding project related emails exchanged													
		P1		P2		P3		P4		P5		P6	
ISP	Team A (s)	30	Team A (s)	6	Team A (s)	11	Team A (s)	23	Team A (s)	76	Team A (s)	4	
	Team B (s)	26	Team B (s)	16	Team B (s)	7	Team B (s)	33	Team B (s)	12	Team B (s)	8	
	Team A (p)	36	Team A (p)	43	Team A (p)	43	Team A (p)	58	Team A (p)	46	Team A (p)	36	
	Team B (p)	53	Team B (p)	56	Team B (p)	57	Team B (p)	29	Team B (p)	13	Team B (p)	32	

Information Seeking / Providing regarding project related emails exchanged													
		P1		P2		P3		P4		P5		P6	
ISP	Team A (s)	16	Team A (s)	43	Team A (s)	32	Team A (s)	12	Team A (s)	23	Team A (s)	12	
	Team B (s)	10	Team B (s)	34	Team B (s)	24	Team B (s)	52	Team B (s)	43	Team B (s)	75	
	Team A (p)	12	Team A (p)	9	Team A (p)	15	Team A (p)	28	Team A (p)	32	Team A (p)	13	
	Team B (p)	19	Team B (p)	6	Team B (p)	10	Team B (p)	16	Team B (p)	25	Team B (p)	5	



## Appendix – 6: Raw data for the calculation of the SNA metric – Action Key Players

**Description:** Raw data for the calculation of the SNA metric – Action Key Players (POL Model) from the service provider side (organization A) project elements (which include managers and subject matter experts), and the customer side (Organizations B) project elements (which include managers and subject matter experts). Data collected between 2018-2019 (full years), respects the number of nominations given in project questionnaires from elements for Team C to elements of teams A and B in phase III. AKP Q1= Action key players question 1 addressed to team C elements in phase III. Elements = teams A and B elements; Team C elements = all elements of team C that participated in phase III; to Team A = nominations from team C elements to team A elements; to Team B = nominations from team C elements to team B elements; AKP Q2 = Action key players question 2 addressed to team C elements in phase III. Question 1= to which elements from team A or team B do you go to when you have uncertainties regarding any activity related to mechanical installations, such as welding problems and equipment, support physical equipment (platforms, ladders, etc.), application according to P&IDs, Layouts, and 3D drawing models? Question 2= to which elements from team A or team B do you go to when you need approval for any activity related to mechanical installations? (it includes, when, how, and why start, stop, or finish a particular task or activity); P(i) = project 1, 2, 3, 4, 5; blue= successfully delivered projects; red= unsuccessfully delivered projects. Feedbacked data does not necessarily implies answering a particular question or providing specific help.

		P1		P2		P3		P4		P5		P6	
AKP Q1	Elements	9	Elements	20	Elements	16	Elements	6	Elements	14	Elements	16	
	Team C Elements	15	Team C Elements	9	Team C Elements	12	Team C Elements	26	Team C Elements	17	Elements	8	
	to Team A	12	to Team A	8	to Team A	11	to Team A	22	to Team A	8	to Team A	8	
	to Team B	6	to Team B	7	to Team B	2	to Team B	8	to Team B	14	to Team B	0	

		P1		P2		P3		P4		P5		P6	
AKP Q2	Elements	9	Elements	20	Elements	16	Elements	6	Elements	14	Elements	16	
	Team C Elements	15	Team C Elements	9	Team C Elements	12	Team C Elements	26	Team C Elements	17	Elements	8	
	to Team A	8	to Team A	3	to Team A	12	to Team A	3	to Team A	8	to Team A	5	
	to Team B	12	to Team B	8	to Team B	2	to Team B	9	to Team B	4	to Team B	1	

		P1		P2		P3		P4		P5		P6	
AKP Q1	Elements	18	Elements	23	Elements	7	Elements	10	Elements	17	Elements	8	
	Team C Elements	15	Team C Elements	46	Team C Elements	23	Team C Elements	18	Team C Elements	22	Elements	11	
	to Team A	12	to Team A	6	to Team A	7	to Team A	18	to Team A	21	to Team A	8	
	to Team B	3	to Team B	13	to Team B	13	to Team B	3	to Team B	8	to Team B	2	

		P1		P2		P3		P4		P5		P6	
AKP Q2	Elements	18	Elements	23	Elements	7	Elements	10	Elements	17	Elements	8	
	Team C Elements	15	Team C Elements	46	Team C Elements	23	Team C Elements	18	Team C Elements	22	Elements	11	
	to Team A	7	to Team A	14	to Team A	16	to Team A	12	to Team A	15	to Team A	8	
	to Team B	14	to Team B	11	to Team B	8	to Team B	6	to Team B	20	to Team B	11	