SOLUTION READINESS ASSESSMENT

Guiding Corporate Decision Making

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Master's thesis

Strategic Leadership of Technology Based Business

Visamäki, autumn 2016

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VISAMÄKI
Strategic Leadership of Technology Based Business

ABSTRACT

Author Niko Alexander Forsström **Year** 2016

Title of Master's thesis Solution Readiness Assessment Guiding Corporate Decision Making

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This thesis describes a development project that aims to provide means for a solution readiness assessment for a multinational company. The case company has strong position in its field of business and it constantly seeks for new business opportunities and competitive advantage in the very competitive environment. The main purpose of the thesis is to develop a model that would in a simple way provide an overlook for solution maturity or solution readiness level to be used in communication and as a basis for decision making. The developed model works a bit like a camera device by providing a snapshot to readiness level for a steering group to see and properly decide based on the fact-based information provided. Theoretical frame of the study consists of theories related to technology management supported by strategic management and organizational theories to provide look into business environment as a whole, the restrictions and assumptions set by environment. The research is conducted following the principles of actions research which suits well this kind of development project. During the research it became clear that the model works in case company's environment and is able to ease individuals everyday tasks by providing an outlook of the status and by providing a method for simulation of activities in respect to overall solution readiness in the long run when also development of activities and a holistic view into the development projects will be achieved. The key finding is that by visualizing the maturity in a familiar way grants possibility to easily understand what is happening in the development project and on the other hand contributes to a positive learning experience. On the decision making part the thesis findings show a hint of progress provided by the model created. The tool will remain in use at the case company and is available for others as well. If the defined Critical Solution Elements do not fit other companies the those may be altered to fit all needs as the principle stays the same. Further development ideas relate to system readiness level.

Keywords Strategy, Technology Management, Technology Readiness, Technology maturity, TRL, TRA, Decision making

Pages 98 p. + appendices 4 p.

TIIVISTELMÄ

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VISAMÄKI
Teknologiaosaamisen johtaminen

Tekijä	Niko Alexander Forsström	**Vuosi** 2016
Työn nimi	Ratkaisun kypsyyden arviointi päätöksenteon tukena yrityksessä	

TIIVISTELMÄ

Tämä opinnäytetyö kuvaa kehityshanketta joka pyrkii kehittämään ratkaisun kypsyyden arviointityökalua monikansallisen yrityksen tarpeisiin. Yritys on menestynyt toimialallaan ja pyrkii jatkuvasti kehittämään liiketoimintaansa, sekä hakee kilpailuetua kilpaillulla toimialallaan. Työn päätarkoituksena on kehittää malli, joka tarjoaa yksinkertaisella tavalla yleisnäkymän ratkaisun kypsyyteen käytettäväksi sekä kommunikoinnin, että päätöksenteon apuvälineenä. Kehitetty työkalu toimii ikään kuin kamera tarjoamalla näkymän ratkaisun kypsyyteen, jolloin kuva toimii ohjausryhmän apuna ratkaisuun liittyvän päätöksenteon yhteydessä. Tämän työn teoreettinen osuus koostuu pääasiassa teknologiajohtamisen teorioista, joita tukevat sekä strategisen johtamisen, että organisaatioteoriat toimintaympäristön rajoitteiden esiintuomiseksi. Tutkimus on toimintatutkimus mikä sopii erinomaisesti tällaisen kehityshankkeen menestyksekkään läpiviemisen avuksi. Tutkimuksen aikana tuli esiin, että kehitetty malli palvelee yrityksen tarpeita mainiosti ja helpottaa yksilön tarpeita päivittäisessä työssä. Tarjoamalla tilannenäkymän ja keinon simuloida toimintoja ja niiden vaikutusta kokonaiskypsyyteen kyetään pitkällä aikajänteellä paitsi kehittämään toimintaa myös tuomaa holistista ajattelumallia ratkaisun kehityshankkeisiin. Työn avainlöydöksenä voidaan pitää visualisoinnin voimaa. Tarjoamalla visualisoidun näkymän kypsyyteen teknologiankehityksestä tutulla tavalla mahdollistetaan helpolla tavalla tilannenäkymän muodostaminen ja toisaalta myös oppimiskokemus. Päätöksentekoon liittyen työn tuloksista voidaan päätellä, että pientä muutosta positiiviseen suuntaan on aistittavissa työkalua käytettäessä. Työkalun järjestelmällinen käyttö aloitetaan kohdeyrityksessä, mutta se on myös muiden vapaasti käytettävissä. Mikäli tapausyrityksen tarpeisiin määritetyt kriittiset ratkaisuelementit eivät sovellu muiden yritysten tarpeisiin voidaan niitä muuttaa vastaamaan kulloisiakin tarpeita. Muutoksista riippumatta työkalun perusperiaate pysyy samana. Jatkokehitystarpeina nähdään systeemitason kehitys.

Avainsanat strategia, teknologiajohtaminen, teknologian kypsyys, TRL, TRA, päätöksenteko

Sivut 98 s. + liitteet 4 s.

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TERMS AND ABBREVIATIONS

CSE	Critical Solution Elements
CTE	Critical Technology Elements
CVN	Collaborative Value Network
DoD	Department of Defence
DOE	Department of Energy
EC	European Commission
EMD	Engineering and Manufacturing Development
ESA	European Space Agency
FOM	Figure of Merit
IoT	Internet of Things
IRL	Integration Readiness Level
MRL	Manufacturing Readiness Level
NASA	National Aeronautics and Space Administration
OSI	Open Systems Interconnect
R&D	Research and Development
ROI	Return of Investment
SBU	Strategic Business Units
SE	Systems Engineering
SRA	Solution Readiness Assessment
SRL	System Readiness Level
TNV	Technology need value
TRA	Technology Readiness Assessment
TRL	Technology readiness levels
TRRA	Technology Readiness And Risk Assessment
UX	User Experience
V&V	Verification and Validation
WBS	Work Breakdown Structure

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PREFACE

I have to admit that I was really lucky to get such a challenging thesis subject from the case company. It has taken me through dark times and frustration but has eventually given me an opportunity to learn new things and to form an enhanced strategic viewpoint to my everyday job. The professional guidance provided by my senior colleagues has proven out to be a critical success factor for the research. My gratitude goes for my professor who helped me through the darkest hours of writing and thanks of surviving this challenging task goes to my wife and family.

As the model under development reached a good flow right from the beginning of the project and the correct decision making took place in the very early phase the initial feel of success lead to an excellent and unforeseen collaborative spirit. This really became participative actions research where the end result reflects the need for such a standardized tool that both enables a standardized communication and eventually fact-based decision making. The study really engaged the thesis' steering group closely to the core development and a huge amount of tacit knowledge is included in the resulting assessment tool. There were numerous discussions along the way on one kind of details and many struggle with other kind of details, such as guiding questions when quantifying values for the readiness during solution readiness assessment. In the end solutions to all the challenges were found which helped to end up with a great, value adding Solution Readiness Assessment tool that will become an integral part of case company's Technology functions solution creation process. It could even alter the organizational culture to some extent, increase holistic approach for development and reduce the risk of releasing immature solutions to market in the long run..

I want to thank the whole guiding group and in particular, I give a special thanks for Mr. Harri Hakala whose comments and guidance were maybe the most important during the early days of the model and guaranteed the professional outcome and the overall success.

1 INTRODUCTION

Since the dawn of the mankind the competition has been around guiding our behaviour and decision of actions. In the stone age competition with each other on who will survive, who is the best archer or hunter-gatherer, to simplify who will survive. Later mankind forming into different tribes and communities that began to compete and in the worst case ended up to a war, where organizational and strategic skills gained importance. Who was able to lead forces in the most efficient way survived in competition. Technological advantage played an important role. In order to being competitive e.g. in war the technology was critical success factor. Majority of the innovativeness in the history of mankind has been put into killing each other in various ways. The mankind has not changed that much during the years, the survival and competition apply for contemporary enterprises as well. Enterprises compete each other on technological advancement. Belonging to the biggest and technologically most successful enterprises in constantly accelerating socio-economic environment sets new challenges for survival and successful inventions. Increased computing power and Internet of Things (IoT) form standards for success in competition, now and in the future. In its field of business the case company has to face and overcome constant strategic, technological and organizational challenges in order to maintain its competitiveness and innovativeness in a global market. During the last ten years the case company has grown rapidly and some of the processes may not necessarily be up-to-date to meet modern market and customer expectations. The elevated level of requirement emerging from e.g. increased market and customer needs makes development projects more complex while on the other hand cost competitiveness seeks for simplification of solutions in which e.g. reliability creates a foundation, an image, of good quality. Quality should be all around. The importance of quality should not be neglected, it should be embedded in the DNA of corporate culture, on each action that the enterprise needs to take in order to being competitive and beating the competition. The strategic focus has been set in the company strategy in form of the key-focus-areas that have been set to quality and safety. In addition to these accelerating time-to-market requirement together with the speed of both technological and strategical change in the case company's socio-economic operating environment set more and more need for a systematic and holistic management of technology, development process, development projects and solution development involved. Systemic thinking has been around and some enterprises have grabbed it. The importance of competitive advantage is easy to lose on individual level when struggling with everyday challenges. The schedule is overruling everything that was recognized critical in the beginning of the development. Releasing immature solutions to the market may end up in a disaster, providing completely wrong solution for wrong market segment in the wrong time or not meeting customer need, not being able to guarantee proper quality standards. The worst case, unsafe solutions on the market. Many more may also contribute to enterprises loss of market share. The biggest enterprises may fall if there is no systematic way to assess the maturity of solutions under development. In this study a model for assessing solution readiness is created and the renewed and new type of holistic communication tested against decision making in the case company.

1.1 Background

Megatrends guide and frame actions available to be taken by enterprises in the modern world the customers also set requirements for a successful innovation. Increased environmental awareness sets whole new set of requirements. In the best case the megatrends are taken into account when corporate strategy and strategical targets are set. On the other hand the customer requirement is as important as understanding the enterprises socio-economic environment. There could be an invention that has never been seen on the surface of earth but it will never become a successful innovation if customer acceptance and market understanding is not in place.

The company has a long history in business and it stands among the few most globally successful Finnish companies while being one the greatest in selected field of business in global perspective. Regardless of the success in history the accelerating speed of change in company's operational environment, the competition, increasing customer demand and the global megatrends are driving the business closer to the end-user with contemporary user needs and requirements for digital services and solutions. First time right mentality has become more and more important task for the new product and service development while maintaining development project budget, schedule and quality has met their own challenges. In the area of case company's business various standards, local rules, safety, and quality set boundaries for activities. It is understandable that the case company seeks for a solution for solution readiness assessment in order to gain competitive advantage with solutions that take into account a wide variety of critical elements crucial for the success. In optimum case when applied from the beginning it could lead into less rework during development projects, improved budget discipline, better use of resources and knowledge and improved time-to-market. Developing competitive products and services that meet and exceed the customer demand is the key factor not only for the case company but for every enterprise. Assessing the readiness could in the first place reduce rework, save time and increase time-to-market while providing means for assessing in a simple manner right from the beginning a solution not only from technological point of view but as a complete solution that includes sustainability and operations right from the beginning. The cost of poor quality has been recognized as an increasing item of expenditure and releasing premature technologies due to other constraints.

The modern day hype word services sets traditional business to business company into a whole new situation where dealing directly with an end user is more challenging and creates much uncertainty and unknown challenges for new product and service development. Is the Research and Development (R&D) organization in case company able to perform organizational learning or not? Accelerating change of business environment has created a gap between the decision makers and project managers making effective communication sometimes difficult and creating too much uncertainty on actual solution maturity. What 5 years ago was fast development speed is nowadays expected level of performance. There are too many details to maintain speed and too much uncertainty to effectively make decisions when concentration span of decision makers demand at-a-glance understanding of the status regardless if it is technological item or operations related item.

The background for this study is the organizational change in the case company. The company has done a major reorganization by combining it's R&D function to the IT function in order to better respond to the challenge set by a global digitalization megatrend and the challenges and requirements that come along with it. In its traditional business the case company has survived and succeeded with Finnish ”sisu” and innovative solutions that come in many fields of technology to delight the customer, was it a constructor, facility manager or an end user of the solution. The background for innovativeness cumulates from the organization's history and has been fed with many success stories during the last decades and beyond.

In the near future the Internet of Things (IoT) together with the birth and rise of smart buildings, smart cities and even smart environments accelerate the operational environment change to unforeseen speed. Megacities like Tokyo today will become more of a standard as a city due to urbanization. The urbanization is not only a megatrend. It is more and more becoming demographic change accelerated by digitalization megatrend. New city dwellers' quality of life might become more challenging. Digitalization has been recognized being an answer to increased demand for quality of life in the future cities. Environmental thinking and sustainability will become more and more common. All this lightning speed increase of demand and the speed of development already has established a concrete need for systematic approach for technology management in the case company and probably others like. As time-to-market becomes more and more inevitable for success in competition. Knowledge-based organization developing solutions first time right becomes an asset in order to achieving competitive advantage over the rivalling enterprises. In order to have this in place requires understanding the R&D project's status and decision making based on clarity to readiness of a solution.

1.2 Purpose of the research and research goals

The case company's undergoing organizational transformation places this research is in the core of case company's transformation program from traditional metal industry corporation into a digital one as part of the ongoing global IoT hype. The main purpose of the research is to (1) define a working model to be used by the case company's R&D function in order to meet the increased customer demand on both quality and safety (2) Ease the decision making in governance and to (3) generate a proposal of the tool to be utilized in order to obtaining a more systematic approach to case company's solution creation. This is possible by providing a simple and holistic well visualized view to a solution creation project's critical success elements' status.

Assessing solution readiness enables a simple way to either re-organize development projects if there is to be seen schedule slip or to prioritize development of elements that have high uncertainty. For high-tech technology enterprises the development of technology plays an important role when developing competitive solutions on the market. Immature technology leads in increased cost and schedule delays that add to time-to-market and in the worst case there will be wrong solution in the wrong market at the wrong time. Taking a holistic view to solution creation right from the beginning could reduce uncertainty and rework tremendously and in addition improve company's position on the market. Dawson (2007) wraps this up in one sentence: 25% - 50% of technology development projects fail to reach set business goals. Reasons for this are generally the risks involved in technology development.

1.3 Research questions

RQ1: What would the solution readiness assessment look like in the case company?
RQ2: How to fit that into the case company's existing solution creation process?
RQ3: Would solution readiness ease communication and improve decision making?

1.4 Scope of the research

The scope of the research is set to defining the baseline in the case company, defining the current level of technology maturity management and to finally creating a working model concept for assessing solution readiness level in the case company based on existing maturity models applicable. The study concentrates to concept development and implementation phases. The Innovation Management and Front-end of Innovation range has been purposely left out of the research scope although maturity assessment and technology lifecycle will affect these as well right from the beginning. The assessment tool created as an outcome of this thesis will be implemented globally to all technology units of case company.

1.5 Structure of the research

The structure of the research has been illustrated in the Figure 1that concludes the contents.

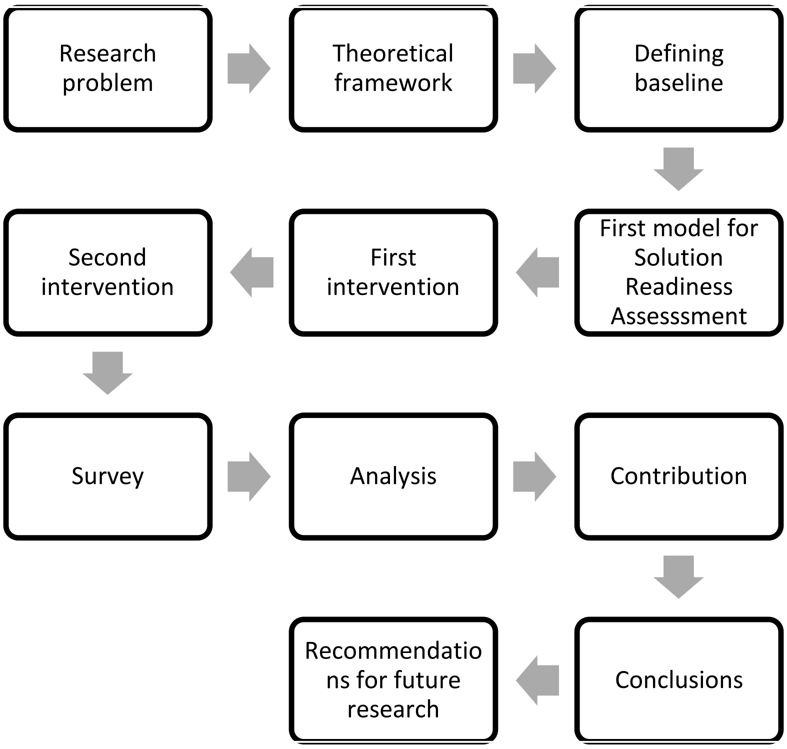


Figure 1 Structure of the research

1.6 Research methodology

This is a development project. The research follows the principles of the traditional scientific research. It can be seen eventually as action research which lies on epistemological foundation leaning slightly more on the subjective perspective. The paradigm is interpretative hermeneutic. The study is mainly critically realistic and the research approach is qualitative while the methodology used in the first phase of the research is a themed interview, to be specific a focus group. The methodology used to interpret the results in the second part of this research (action research) is a mainly quantitative survey with predefined statements, partly qualitative as the survey has 3 free field questions in order to get reliability and validity for research by triangulation.

To complete analysis the participative observation is used throughout the research as the researcher has nearly nine years of working experience in the technology organization of the case company. It should be noticed that the researcher's daily role as an employee of the case organization might affect the research's results not being as objective as possible in the optimum case. Naturally in case of loss of objectiveness this won't be intentional.

A qualitative action research fits this research's first target to form a baseline that the final model will be built onto. The second part continues on principles of action research with two stage intervention. Definition of action research by Stringer (1996, xv.)

"Tradition that links processes of inquiry to the lives of people as they come to grips with the problems and stresses that beset them in their day-to-day lives"

2 CORPORATE STRATEGY

Defining the corporate strategy is as important as developing technology. Solutions or managing an organization and individuals by sharing a clear direction and defining vision and mission. Porter's five forces analysis and overall understanding of the socio-economic environment create a foundation for each successful corporate strategy creation. There are tools and techniques to predicting upcoming changes in enterprises socio-economic environment such as PESTEL-analysis or Delphi. By utilizing such tools the enterprises top management is able to predict the customer need in constantly changing operating environment and to understand their position in competition. By setting strategical goals enterprises are able to form a justification for their existence in competition and to define how competitive companies might be in the future. A typical lifespan of a corporate strategy is three to five years. The very basis for competitive advantage and how to achieve the pole position in competition are defined in corporate strategy. Strategy alone does not guarantee success, eventually it guides technology development that is enabler for reaching strategic targets. One could ask who develops the technology to reach enterprises strategic targets? It is an organization, personnel and eventually an individual who possesses knowledge to produce technological advantage in competition that leads to fulfill the enterprises strategic targets. As an example a successful Finnish company strategy is described in more detail.

"The direction and shape of the global elevator and escalator industry are driven by four megatrends: urbanization, demographic change, the increasing importance of safety, and concern for the environment"(KONE Corporation 2016.)

An example of corporate strategy by a successful Finnish high-tech company shown in Figure 2.

Figure 2 An example of corporate strategy map by Finnish high-tech company

2.1 Urbanization

“Urbanization is the most important megatrend within the global elevator and escalator industry, and is expected to drive demand for years to come. For the first time in history, and equal number of people live in urban and rural areas. The concentration of people in urban areas increases the importance of moving them efficiently from one point to another, and calls for sustainable innovations” (KONE Corporation 2016).

2.2 Demographic change

“The global demographic structure is changing. At the same time, economic growth translates into higher standards of living for a larger part of the world's population. The number of people classified as middle-income earners is expected to grow 2.7 billion by 2030. Middle-income earners expect more spacious and better-equipped apartments, which drives higher demand for elevators. The world's population is also aging at an unprecedented rate. The growing number of older people raises the importance of accessibility in buildings and urban infrastructure” (KONE Corporation 2016).

2.3 Safety

“Urban infrastructure in certain markets is aging. In Europe alone, many buildings have old elevators which need to be upgraded. The proper functioning of the equipment used daily by millions of people is becoming increasingly important for authorities and consumers around the world. This makes safety one of the key drives for our industry” (KONE Corporation 2016).

2.4 Environment

“The demand for energy efficient solutions for moving people in and between buildings is driven by voluntary sustainability ratings and national green building ratings. These are becoming more common and are of increasing importance to our customers. Sustainable urban building refers to building practices that improve energy efficiency, use sustainable materials and reduce a building's negative impacts on human health and the environment” (KONE Corporation 2016).

2.5 Summary

Megatrends are long-term, global macro-level trends that impact businesses and the society. They set boundaries to enterprises in their socio-economic environment as they shape the market now and in future. In the best case enterprises are use their core competencies to gain competitive advantage and simultaneously provide value to customers e.g. by improving customers lives with cross-industry-partnerships in guidance of megatrends like digitalization and smart-environments like smart buildings and smart cities keeping the sustainability requirements in mind.

3 THEORETICAL BACKGROUND

The purpose of the solution creation process in the case company is to improve competitiveness in socio-economic environment and the variety of different criteria for solution maturity reflect strongly to strategy, technology and organization, including internal and external environment variables it's values and corporate strategy and eventually the employees of the company. Theoretical frame of this study is based on theories shown in Figure 3 and described below. The principles of strategic management [Porter 1985, Nag et al. 2006, Kamensky 2014], competitive advantage, competencies, and knowledge management [Nonaka 2008] are presented briefly. Strategy alone will not suffice when aiming for competitive advantage and improved decision making by utilizing a solution readiness assessment. In order to deepen the theoretical background for the thesis. Systemic thinking [Senge 1992] and core competence contribution to knowledge management are studied. Technology as an enabler of competitive advantage is also looked at more deeply starting from the definition of technology and the principles of technology management [Phaal, Pharrukh, Probert 2001 and 2004, Cetindamar 2009, Sahlman 2010] as an integral part of an enterprise. The acceptance, development of new technologies and finally the principles of technology lifecycle, maturity [Nolte 2008], assessing technology readiness [Mankins 1995, 1998, 2009a, 2009b] and raising up problems with NASA TRL model found e.g. by Sauser et al. (2007) and Mankins (2009a, 2009b.) TRRA, an improved TRL model and existing System Readiness Assessment models are reviewed briefly to deepen understanding. Management of organization, organization culture [Schein 2004], managing risk and uncertainty, barriers of communication and corporate decision making are looked at to raise understanding over these important factors in making decisions in a certain environment or culture.

- Strategic management
- Technology Management
- Organizational management

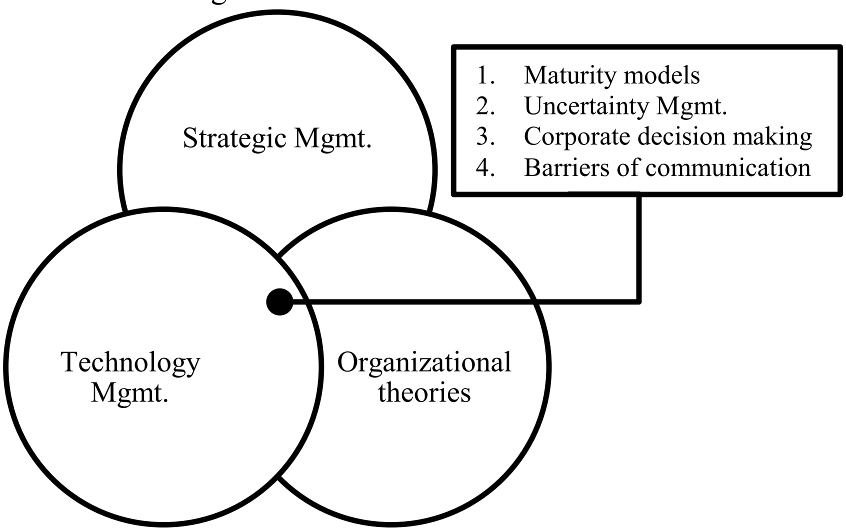


Figure 3 Theoretical frame of this study

Strategy ("war leadership skill") (Kamensky 2014, 16). On a concept level the strategy can be utilized everywhere due to its nature: the formulation and implementation of major strategic goals and initiatives that have been set by a company's top management on behalf of owners. These goals are based on available resources and an assessment of the internal and external environments in competition in which the organization competes in (Nag, Hambrick, Chen 2006, 16—17). The vast majority of the strategic management's business models have been generated during the last 50 years albeit strategy is among the oldest organizational leadership disciplines utilized during the history of mankind (Kamensky 2014, 13). Strategic management discipline has normally been seen as enabler of succeeding in competitive socio-economic environment. Therefore most of the models introduced during last decades share this viewpoint (Kamensky 2014, 16). Strategic Management as a discipline resembles a multifaceted form that is able to provide a versatile framework for business, organization, personnel or individual development (Kamensky 2014, 13.)

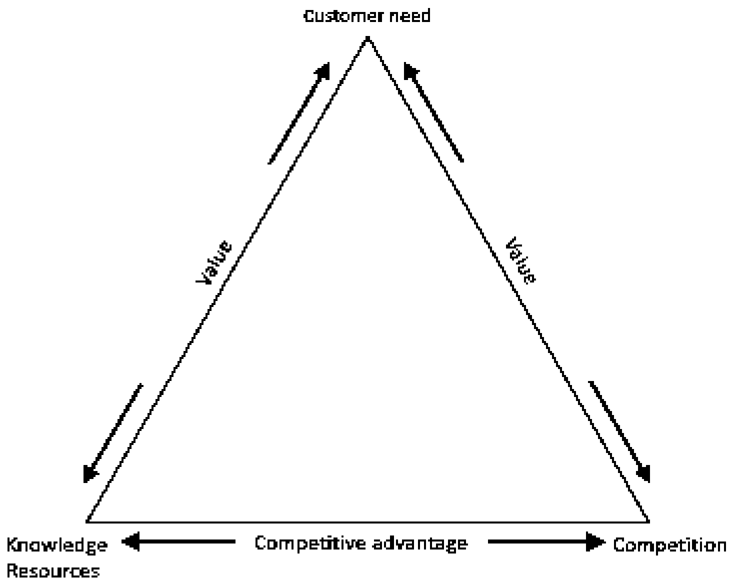


Figure 4 Strategic triangle (Kamensky 2014, 24)

Stated by Kamensky (2014, 24) the legitimacy for every firm's existence is based on their ability to fulfil customer or organization needs. Being able to do so requires correct use of resources and knowledge available in the enterprises resource/knowledge pool. These factors form the basics of firm's business, strategic triangle shown in Figure 4. Companies able to answer the challenge set by the triangle succeed in competition due to their excellent value-cost factor (Kamensky 2014, 25.)

"In the short run, a company's competitiveness derives from the price/performance attributes of current products." Prahalad and Hamel (1990, 82.)

3.1.1 Porter's five forces analysis

Five forces analysis originally presented by Michael Porter form the very basis for enterprises competitiveness in the market. To be competitive these forces should be understood thoroughly in order being able to predict and create competitive strategy and direction for business. When thinking on prices the company can charge the buyer power and threat of substitution have their say on it. The suppliers determine raw material cost that then affects the prices. Rivals and new entrant affect the enterprises business environment too e.g. on pricing. The characteristics of industry structure are mainly determined by these forces. Industry structure itself is stable but it evolves with the industry. The changes in the forces can positively or negatively affect the company's business. Many successful strategies have fundamentally shifted the rules of competition. These forces suppliers, substitutes, potential entrants, buyers and rivalry are illustrated in Figure 5 (Porter 1985, 5, 6.)

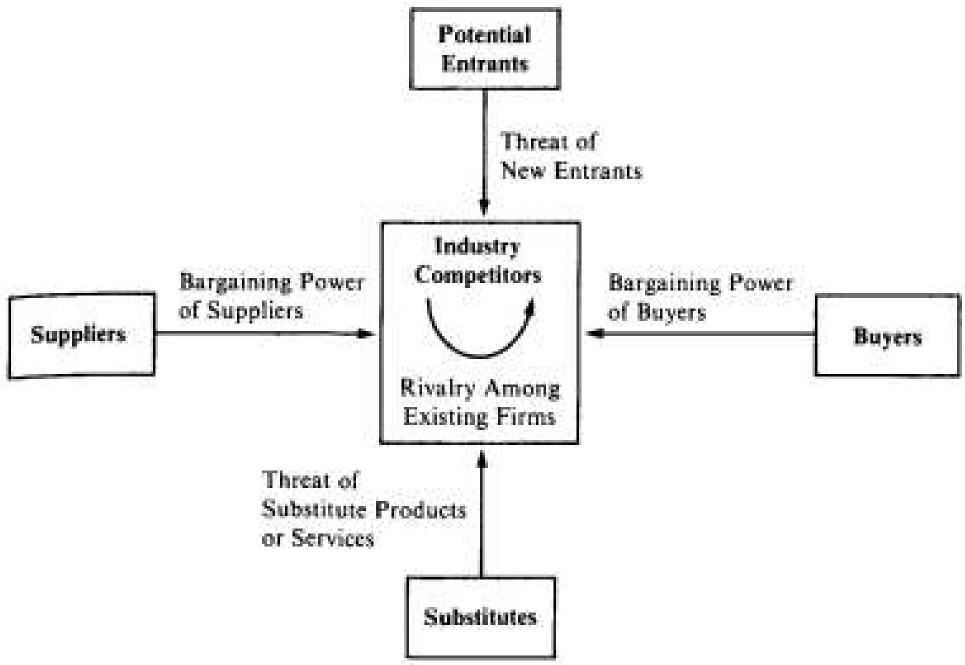


Figure 5 Graphical presentation of Porter's five forces analysis (Porter 1985, 5)

<u>Bargaining power of suppliers</u>

"Determines the extent to which value created for buyers will be appropriated by suppliers rather than by firms in industry" (Porter 1985, 6.)

<u>Threat of substitutes</u>

The threat of substitutes defines the limit to which extent buyers are willing to pay for the value (Porter 1985, 6.)

Threat of new entrants

The likelihood that new enterprises will enter the industry and either aggressively compete in cost or raise costs by providing more added value to customers (Buyers) (Porter 1985, 6.)

Bargaining power of buyers

“Satisfying buyer need is at the core of the business.” Company can differentiate itself from the competition by satisfying customer needs in order to justify charging more than the production cost of their products (Porter 1985, 8.) This is one way to value creation described in strategic triangle in Figure 4.

Rivalry

Defines the limits that rival enterprises are willing to go in added value competition (Porter 1985, 6.)

3.1.2 Porter’s three generic strategies

Company’s relative position in industry generates the foundation of its competitive strategy. Position determines whether the company is above or below the industry average and is therefore important factor. Being able to position itself correctly in its socio-economic environment may guarantee good return of investment (ROI) for an enterprise (Porter 1985, 11.)

> A strategy delineates a territory in which a company seeks to be unique
>
> Michael Porter
> (Boone LE, Kurtz DL 2015.)

“Technological change is one of the principal drivers for competition” (Porter 1985, 164.)

And

”The competitive advantage is at the heart of any strategy, and achieving competitive advantage requires a firm to make a choice”
(Porter 1985, 12.)

The choice required is the choice about the type of competitive advantage the firm seeks for. Trying to reach everything leads into a mediocre strategy that provides no competitive advantage at all. Figure 6 represents two basic types of strategies that a firm can possess: (1) differentiation and (2) cost advantage. These create competitive advantage for a firm that result from ability to cope with five forces better than rivals. These two basic types combined with scope of activities that a firm seeks lead to three generic strategies for better than average performance in competition. The focus is combination of two strategies, differentiation and cost leadership (Porter 1985, 11, 12.)

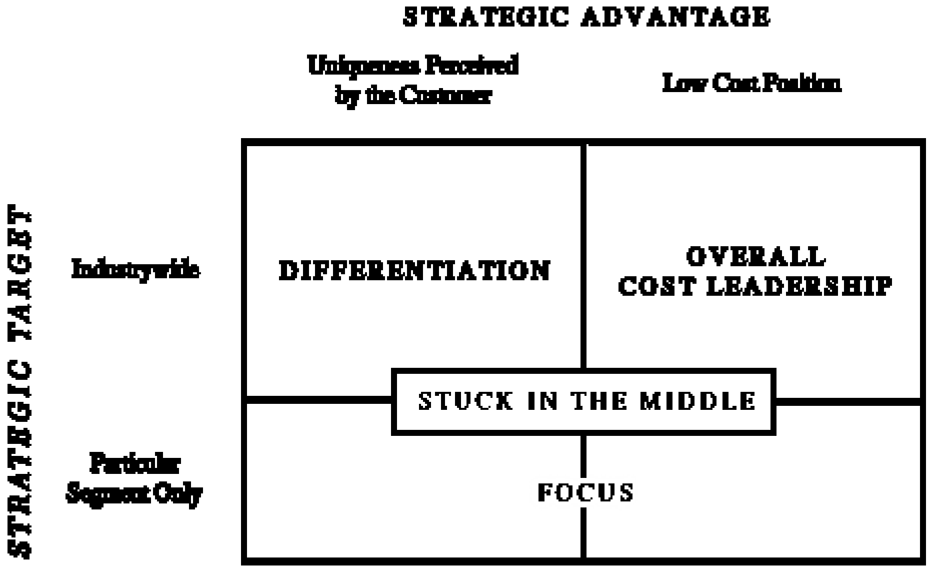


Figure 6 Michael Porter's three generic strategies (Wikipedia 2016a.)

Types of the generic strategies are different way to achieving strategic targets. Cost leadership and differentiation seek for competitive advantage in a broader range of industry's segments while focus aims for cost leadership or differentiation on a selected segment only (Porter 1985, 11.)

Overall cost leadership

Upper right corner in Figure 6 is a selection by company seeking to become a low-cost provider in the industry. Company operates in many segments of the industry in a broad scope. Most important of all, a low-cost producer task is to find out all sources of cost-cut opportunities to succeed, raw materials and other factors included. Achieving low cost leads to high returns and company operates on above average performance in the industry. Should the company fail on this strategy e.g. not being cost leader would force to lower prices and loss of profitability, the outcome may be disastrous (Porter 1985, 13.)

Differentiation

Depending on industry there can be several differentiation possibilities in an industry. Upper left corner of Figure 6, company seeks to differentiate itself in competition to the favor of buyer (customer), to be unique in some area of industry. When one or several features appreciated by buyers are selected and needs are met the company is able to charge premium prices from its customers. Sources for differentiation strategy are multiple e.g. products, delivery system efficiency etc. Like in cost leadership strategy should the company succeed it becomes above average performer and cost of uniqueness is covered by the premium price that can be charged for its products (Porter 1985, 14.)

Focus

Third generic strategy is focus which differs from others because of its narrow scope. In this strategy a specific market segment or a couple are selected and focus is put to provide value in these. Use of this strategy provides competitive advantage on selected segments as overall competitive advantage cannot be reached. Focus can be both cost or differentiation strategy on selected segments (Porter 1985, 15—17.)

Stuck in the middle

This is a company engaging on all the generic strategies and failing to achieve competitive advantage. Being stuck in the middle is rare occasion as the profitable business cannot be easily accomplished due to failing in generic strategies unlike the other companies succeeding in theirs (Porter 1985, 16—17.)

Generic strategies do not mean that a company should select only one. In the best case cost-leadership and differentiation can be combined inside an enterprise seamlessly (Porter 1985, 17.) Yamin, Gunasekaran and Mavondo (1999) studied the relationship between generic strategies, competitive advantage and organizational performance. Yamin et al. (1999, 508-509) refer to Miller (1992) who lists risks of generic strategies and state that blindly following a single generic strategy involves risks and specializing in a single strategy most certainly leaves gaps or form weaknesses into following elements of business (1) product offering, (2) creates ignorance of important customer needs, (3) leaves too much room for rivals to live at and act against, (4) causes inflexibility in the long run and (5) narrows the vision of the organization in the long run.

Yamin et al. (1999) back up Miller (1992) by also referring to Wright et al. (1990) who studied random companies using multiple strategies vs. ones relying on single strategy and continue referring to Wright et al. (1990) by stating:

"They concluded that companies that adopt multiple strategies such as low-cost and differentiation outperform businesses that compete mainly with either one or the other."

Risks of generic strategies

Each generic strategy is vulnerable to certain types of attacks. Figure 7 shows analysis of ways to attack competitors employing generic strategies (Porter 1985, 21.)

TABLE 1–1 Risks of the Generic Strategies

RISKS OF COST LEADERSHIP	RISKS OF DIFFERENTIATION	RISKS OF FOCUS
Cost leadership is not sustained • competitors imitate • technology changes • other bases for cost leadership erode	Differentiation is not sustained • competitors imitate • bases for differentiation become less important to buyers	The focus strategy is imitated The target segment becomes structurally unattractive • structure erodes • demand disappears
Proximity in differentiation is lost	Cost proximity is lost	Broadly-targeted competitors overwhelm the segment • the segment's differences from other segments narrow • the advantages of a broad line increase
Cost focusers achieve even lower cost in segments	Differentiation focusers achieve even greater differentiation in segments	New focusers sub-segment the industry

Figure 7 Risks of generic strategies (Porter 1985, 21)

3.1.3 Value chain and value networks

Generic strategy's goal is to create value for customers that exceed the value of creating it. Each enterprise forms of unique set of different activities like (1) R&D, (2) production, (3) marketing, (4) delivery and support. The way firm performs it's activities and its value chain are reflecting from firms history, strategy, approach to implementing firms strategy and the underlying economic activities. Porter (1985) refers McKinsey and Company model and business system concept by Gluck (1980) Bauron (1981) and Bower (1973.) Competitive advantage accumulate from differences among competitor value chains. Business unit level is correct level for constructing firms value chain activities as industry wide level is way too large (Porter 1985, 36-38.)

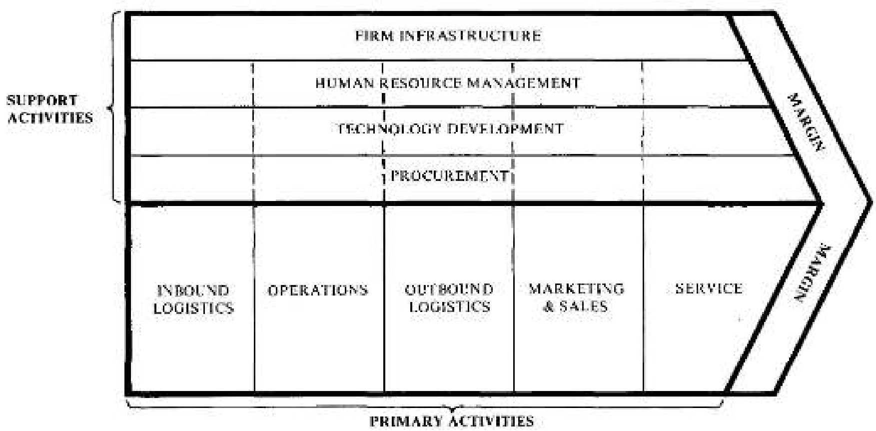


Figure 8 Generic value chain (Porter 1985, 37)

Figure 8 represents how value activities and margin form a total value of value chain (Porter 1985, 38.) The value chain transfers goods in a chain. Links between traditional value chain to knowledge management and enterprises transformation from traditional goods-based to knowledge-based are presented.

"The manufacturing and transportation of physical goods from suppliers, via a factory to a buyer gave us the concept of the Value Chain. If we see the organization as creating value from transfers and conversions of knowledge together with its customers the Value Chain collapses and the relationship should better be seen as a Value Network" (Allee 2000 in Sveiby 2001.)

This resembles business model of the future as added value via IoT and service-based offering becomes more popular. It also creates a solid link between the importance of knowledge management and core competence being in the center of any enterprise that desires to be fast and agile in competition. Value networks enable use of external knowledge as enterprise utilize networks knowledge base in its operations and innovation e.g. it's customers.

"Value networks are set up by several companies to fulfil a certain purpose, which mostly is focused on improving the way to satisfy customers"
(Lehto, Hermes, Rajaniemi, Myllykoski, n.d..)

Figure 9 Collaborative Value Network (CVN) Concept (Arc Advisory Group 2016)

Figure 9 describes value network of next decade as seen by Arc Advisory Group (2016) In the figure the value network becomes seamlessly intertwined between design, make and deliver parties of value network. Transforming from traditional metal company to a service provider and moving from b-2-b into b-2-c requires increased external collaboration and information sharing. Customers and partners need this in order to being satisfied and effective. In contemporary business value creation takes place in Design-Make-Deliver network as the socio-economic environment business drivers are built on uncertainty management, security, scarce resources, sustainability, global competition, changing workforce, increasing regulations, emerging smart grid and easy IT solutions (Arc Advisory Group 2011.) Innovation has become an absolute value as ever growing speed of change in socio-economic environment requires it as an automation. The answer to this requirement for constant innovation in order to maintain competitive advantage lies within knowledge management as by Nonaka (2008), Prahalad and Hamel (1990) and the Japanese companies have proven. Aalto university (2013) took this to next level by forecasting the development of value networks into dynamic value networks already in 2020s Figure 10.

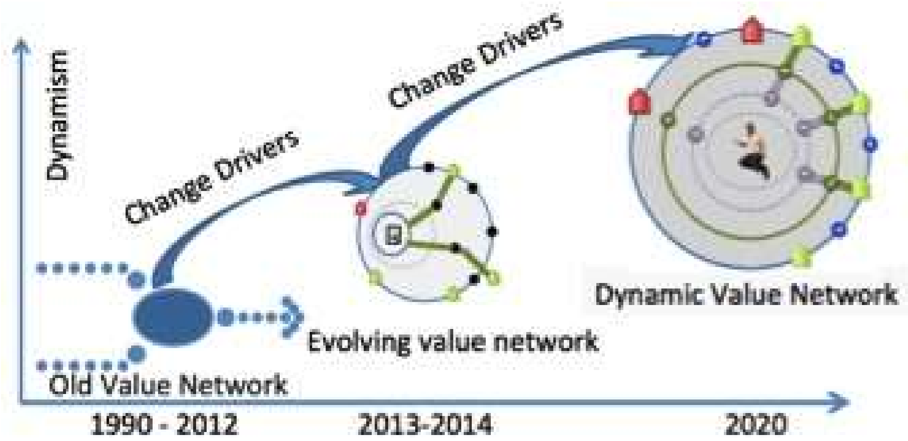


Figure 10 Evolution of networking (Aalto University 2013)

This trend for ecosystem thinking in value networks is forcefully driven by increasingly networked global economy that forces enterprises to think beyond contemporary value networks (Aalto University 2013.) Partnerships and knowledge sharing, crowd innovation, co-creating innovation and crowd sourcing are signs of this kind of value networks toward clients and consumers as the enterprises reach for their thoughts on possible value adding innovations.

3.1.4 Tacit Knowledge and knowledge management

Knowledge is a vast subject and it is wise to ground it to certain limits first, before diving deeper to knowledge management and tacit knowledge. There are two main types of knowledge: Explicit knowledge that easily turns into e.g. specification being therefore formal and systematic and implicit, tacit knowledge, that fluctuates from humans personal knowledge being very hard to formalize and communicate to others (Nonaka 2008, 165.)

<u>Knowledge</u>

"Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms" (Davenport and Prusak 2000, 5.)

An integral part of the organizational culture, its artifacts, values and assumptions that lie under the surface waiting to be challenged.

Knowledge management

"Knowledge Management is the explicit and systematic management of vital knowledge - and its associated processes of creation, organization, diffusion, use and exploitation - in pursuit of business objectives" (Skyrme 2011.)

Business objectives emerging from the strategical targets, vision, mission and technological development guidelines defined by top management to reach these targets. The importance of knowledge to competitive advantage is presented well by Nonaka, the knowledge is maybe the most important factor in shifting socio-economic environment where technologies may become obsolete overnight. Successful companies are those able to create new technologies fast based on their knowledgebase therefore being able to become a company that's business is built on top of continuous innovation (Nonaka 2008, 162.) In western countries where the favored management style sets knowledge into position that it must be quantifiable the knowledge is not necessarily appreciated as much as it should. Especially when set to perspective with competitive advantage (Nonaka 2008, 163.) Nonaka's findings become supported by Prahalad and Hamel (1990, 82) who underline the previous statement in their study stating that Japanese firms understand, nurture and exploit their core competencies better than western firms. Often though in a very one dimensional way: Only useful knowledge is formal and systematic and often the key metrics for measuring the value of knowledge are quantifiable: improved efficiency, lower costs, improved return of investment (ROI) (Nonaka 2008, 163.) The western style of knowledge management is not the only way to manage it. In comparison: Successful Japanese companies such as Honda and Canon the knowledge management has been thought differently which has led to their ability to: respond fast to customers, creating new markets and rapidly develop new products and dominate emerging technologies (Nonaka 2008, 163; Prahalad and Hamel (1990, 82.)

Competence can be utilized in two ways when creating value: externally or internally. When knowledge is transferred internally as an outcome tangible goods and intangible structures are created, such goods and structures are e.g. processes and new designs for products. When the attention projects outwards, in addition to delivery of goods and money also intangible structures become created. These include e.g. customer relationships, brand awareness, reputation and new experiences for the customers (Sveiby 2001.) Multiple reasons for the success of above mentioned Japanese knowledge creation raises up the most critical success factor: the approach to place knowledge creation in the very center of enterprises human relations strategy. In the best case knowledge creation is an automation allowing individual knowledge of manager or worker to turn into knowledge valuable to the whole company. Here lies the secret of knowledge-creating company (Nonaka 2008, 163—165.)

3.1.5 Core competence

Knowledge-based strategy builds upon the competence of people (Sveiby 2001.) Core competence is knowledge that diminishes if not used, at the best they make up a solid foundation for new business development as already briefly mentioned in 3.3.1. Core competencies are a collective learning in organization, coordination of diverse production skills and integration of multiple technology streams in other words creating a solid foundation for systemic thinking in an organization and enabling knowledge-based business. In the best case core competence allows enterprises to diversify from competition in their selected field allowing collaboration across artificial boundaries created by organizations and people, in a nut shell it is communication, involvement, partnership and working across organizational boundaries (Prahalad and Hamel 1990, 82, 83.)

Figure 11 represents Leonard-Barton's (1992, 113, 114) knowledge-view to core capability as a source for competitive advantage. The four dimensions of Leonard-Barton's model are (1) employee knowledge and skills and (2) knowledge embedded in technical systems (e.g. processes, tacit knowledge) both of which are guided by (3) managerial systems. Values and norms are the fourth dimension that associates with process of knowledge creation and control. Values and norms are critical in managing new product development and core capabilities.

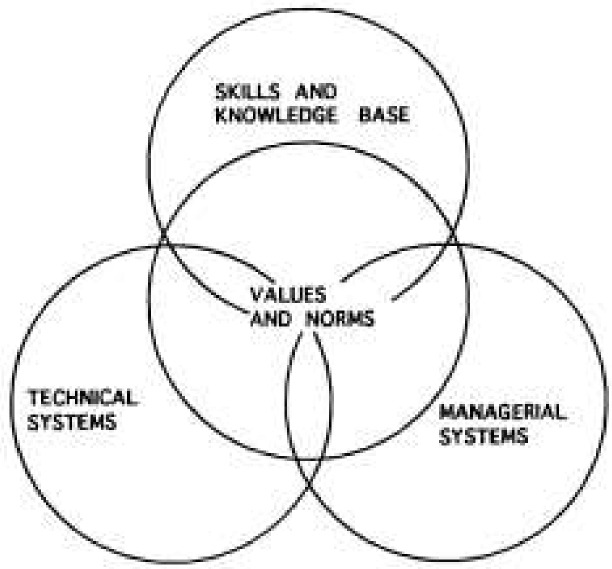


Figure 11 The four dimensions of core capability (Leonard-Barton D 1992, 114)

Core competencies enable for core products that are an embodiment of one or more core competence. As an enterprise introduces its core products into a larger market it can lower risk in new product development, lower cost and reduce time in R&D (Prahalad and Hamel 1990, 86-87.)

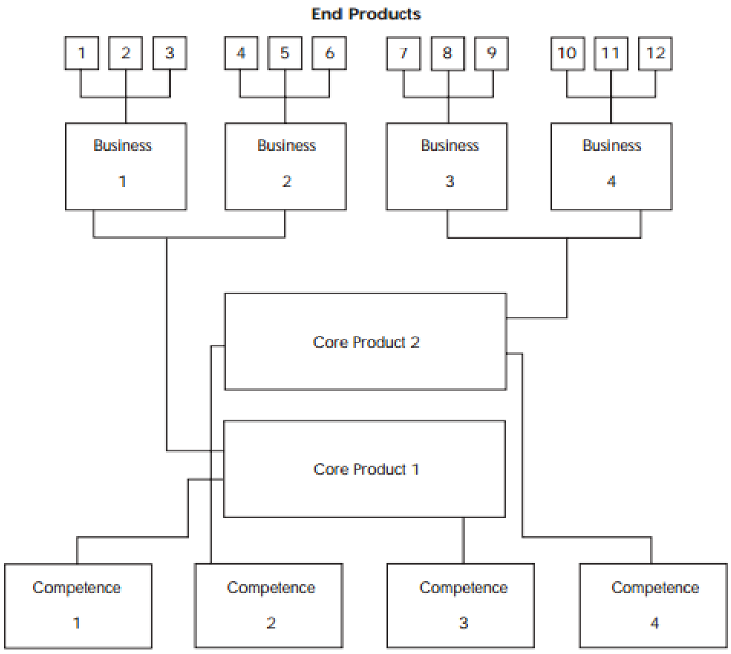


Figure 12 Roots of competitiveness (Prahalad 1990, 83)

Figure 12 shows core competencies resulting in core products. Competencies are roots and the trunk. Major limbs are core products and the Strategic Business Units (SBUs) are smaller branches. The leaves are end products (Prahalad and Hamel 1990, 82.)

3.1.6 Sustainability

The corporate responsibility and corporate sustainability have increased popularity in contemporary business (Benn, Dunphy, Griffiths 2014, 3.) The customers demand "green" products and make their choices based on the energy consumption of products produced by sustainable enterprises around the world. Enterprises that have already transformed into sustaining corporations are strong in both business and competitive advantage through sustainable business economy has proven to be successful. Unfortunately this is not the case with all the companies. It is not uncommon in neoclassical economies that business and economics define our ecological and community issues In the most significant decisions the ecological issues are ignored for them being invisible for decision makers. There exists no cultural categories for these among the decision makers or that the issues become irrelevant or have marginal or no importance at all in decisions (Benn et al. 2014, 10.) Phases in organizations transformation process on becoming a true sustainable corporations. Six distinguishing phases are (1) rejection, (2) non-responsiveness, (3) compliance, (4) efficiency,(5) strategic proactivity and the (6) sustaining corporation. These are not necessarily meant to be followed as phases step-by-step the steps form an understanding over where the corporation resides in a given time. It is also notable in the figure that the movement can be back and forth depending on the course of action taken by the corporation (Benn et al. 2014, 15.)

Technology development based on principles of eco-design is more and more of an importance for successful business in contemporary socio-economic environment enterprises are competing at. The objective of eco-design is total bio-integration with the environment, a symbiosis where human made objects and structures such as buildings, infrastructure, parts, components processes etc. are integrated seamlessly into the ecosystem (natural environment) in a harmonious way in the full chain. Full chain reaches out from source to operations and further to reusing, recycling and reintegration of technologies that reach end-of-life (Yeong 2008, 25.) It is important to understand the environmental impact of developed solution in strategic and sustainable context. The reduction of waste, both material and energy in manufacturing process has gained more focus and become of importance lately. Also understanding the carbon footprint size and amount of residues produced during the useful lifetime of manmade artefacts and structures, selection of sustainable materials and end of life treatment of materials contribute to creation of a sustainable corporation (Yeong 2008, 309.)

3.2 Technology management

Technology "science of craft" from Greek techne, "art, skill, cunning of hand" and -logia (Liddell, Scott 1980.) is the collection of techniques, skills, methods and processes used in the production of goods or services or in the accomplishment of objectives, such as scientific investigation. Technology can be anything between the knowledge of techniques, processes, etc. and it being embedded in machines, computers, devices and factories, which can be operated by individuals without detailed knowledge of the workings of such things. The mankind has pursued to develop natural resources into various tools and devices that would make life and everyday tasks easier. Among the earliest technological corner stones can be listed e.g. the discovery of fire. The stone working in order to create stone tools such as a spearhead to make hunting more effective and therefore increasing the amount of food readily available have been one of the greatest technological developments in the early ages together with the invention of the wheel. When talking about technology it often comes to mind that it must be a concrete item or gadget, such as a DVD-player. Technology can also be a piece of software, a process or a computer, even a new practice could be counted as one since it’s an application of science that allows mankind to do things in a new way. In a very core technology is based on knowledge. The difference between a product and technology is often difficult (Nolte 2008, 8.)

”When you put technology into a product, you productize or commercialize the technology. Productizing a technology makes it useful” (Nolte 2008, 8.)

As a definition for technology management Phaal, Farrukh, Probert (2004, 7) adopt a proposal by European Institute of Technology Management (EITM):

"Technology management addresses the effective identification, selection, acquisition, development, exploitation and protection of technologies (product, process and infrastructural) needed to maintain a market position and business performance in accordance with the company's objectives."

As such technology management is not an independent function inside an enterprise albeit it strongly correlates with company’s business strategy and processes. Technological challenges influence the business and vice versa. The core-processes of technology process are not only technology dependant but also business processes e.g. Strategy, Innovation and Operations (Phaal, Farrukh, Probert 2001, 7—8.) On the other hand Kropsu (2009) defines that the main purpose of technology management in an enterprise is to understand the value of a certain technology, its business impact and to guarantee competitive advantage. Technology management means continuous development and exploitation of technology at the core of the technology-oriented enterprise. Technology itself is the critical success factor in order to guarantee enterprises’ competitive advantage (Phaal et al. 2004, n.d..)

3.2.1 Technology management framework models

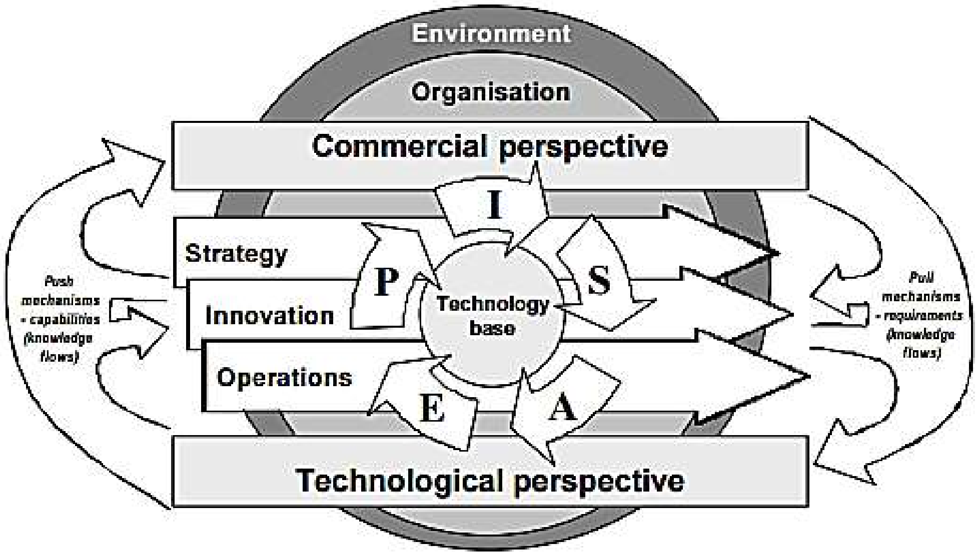


Figure 13 Technology Management Framework (Phaal et al. 2001, 7.)

Figure 13 represents Phaal’s technology management framework that aims to illustrate technology push and market pull in technology management and enterprises socio-economic environment. Based on Phaals theory in between these two main factors must remain balance. Enterprise’s internal functions and processes such as communication, processes, personnel rotation and training support the operations, technological and commercial perspective. The arrows crossing the organization in its operational environment describe Strategy, Innovation and Operations which are macro level processes that nest in them many other core processes of an enterprise (Cetindamar, Phaal, Probert 2009, 240-241.) In the core of the framework is the technology base that has its own core activities constantly running: **I**dentification, **S**election, **A**cquisition, **E**xploitation and **P**rotection.

These five core-activities of technology management have been defined by Gregory (1995.) Rush et al. (2007) added **L**earning as the sixth since learning is critical part of technological competence, so called lessons learned philosophy applies to it as part of organizational learning (Cetindamar et al. 2009, 242.) As seen in the Figure 13 that the managerial disciplines such as strategic management, organizational management and technology management form the very core of the strategic technology management framework. Enterprises should consider establishing and integrating the strategic technology management framework as a separate managerial discipline (Sahlman 2010, 66.) Strategic technology management model Figure 14 describes technology management in enterprises business context. The complexity of both disciplines: strategic business management and technology management linked together leads into managerial challenges in enterprises albeit in the accelerating socio-economic environment it is essential for technology-oriented enterprises, due to the critical role of technology, to develop and sustain their technological capabilities (Sahlman, 2010, 15—16.)

Figure 14 Utilization of framework model in enterprise context (Sahlman and Haapasalo 2010, 60)

Purpose of strategic management in business is to strengthen company's market position and business figures. Strategic technology management on the other hand is targeting on technological properties which differ from strategic targets such as customer requirements and product features that are targeted for adding value to customers. With this clarification of difference between strategic and technological targets the need for a transformation to favor of business targets to strategic targets for technology gets highlighted - strategic technology management. An application of the framework requires analysis of (1) technology gaps reflected to the (2) company's strategic business targets. For target setting the framework shows viewpoints on objectives related to product offering, value chain, technology assets, productivity, internal policies and industry relations. The framework in an enterprise context is shown in Figure 14 (Sahlman 2010, 59.)

"According to the logic of the framework model, the objectives are implemented through operational activities which in turn influence the technology infrastructure of the company and create internal and external impacts. Consequently, the resulting technology infrastructure and impacts influence on formulation and execution of the company strategy" (Sahlman 2010, 59.)

Consider to develop necessary structures and objectives in order to being able to proactively manage the impacts of technology for competitiveness and to develop enterprises' sustainable growth in its socio-economic environment (Sahlman 2010, 66.)

3.2.2 Technology acceptance

Customer enables of future business, customer pays for the products developed, customer uses the products and technology developed. Customer acceptance is key to success. Technology must meet the customer requirements. One way would be to include customer in development team (Nolte 2008, 16.) There are challenges in adoption of technologies. It is essential to consider a corporate or organizational culture when customer's readiness to accept new technology is estimated. It is well known that organizations that possess very conservative culture favor in sticking with known and familiar technologies. In the other end an innovative mindset marks an organization that more readily adapts to new technology. Same applies for how the enterprise will introduce a new product. Some prefer small controlled target groups while other go all-in. The enterprise culture can either enhance or inhibit organizational ability to adopt new technology (Nolte 2008, 18—19.) In addition to organizational culture the perceived usefulness and perceived ease of use of technology (a software, components or a process) have been determined as fundamental parameters contributing to attitude toward actual system use. The acceptance model described in Figure 15 illustrates the process of adoption and acceptance. External variables include following items: system characteristics, training, user involvement in design and the nature of the implementation process (Venkatesh and Davis 1996, 453.) First people use an application to an extent to define whether or not it will help them e.g. to perform their work better. Therefore Perceived Usefulness contributes positively toward attitude to using. The other point of view the acceptance begins by judging the ease of use. The positive experience of ease of use contributes to the attitude toward starting to use an application/process or technology (Davis Bagozzi, Warshaw 1989, 320.)

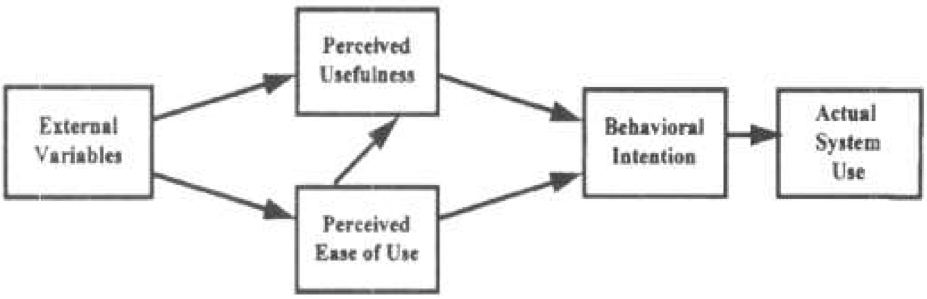


Figure 15 Technology Acceptance Model (Venkatesh and Davis 1996, 453)

3.2.3 Technology maturity and lifecycle

"Knowledge of the state of technology or product maturity provides you with valuable insight." (Nolte 2008, 17.)

Visualization of the maturing, emerging technologies can be provided by a hype cycle that is branded, developed and used by American Information Technology research and advisory firm Gartner. It is divided into 5 stages which are shown in Figure 16 and explained in Table 1. Linden (2003, 5) describe hype cycle being means to decision when to begin adopting new technology. It consists of 3 main functions: (1) Expectation that most technologies will inevitably progress through the pattern of overenthusiasm and disillusionment, (2) provides a snapshot of the relative maturity of technologies within a certain segment of the world, such as a technology area, horizontal or vertical business market, or a certain demographic audience, and it has a (3) simple and clear message: Enterprises should not invest in a technology just because it is being hyped, nor should they ignore a technology just because it is not living up to early over expectations.

Figure 16 The hype cycle (Linden A, Fenn J 2003, 5) Gartner Research (2003)

No.	Phase	Description
1	Technology Trigger	A potential technology breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist and commercial viability is unproven.
2	Peak of Inflated expectations	Early publicity produces a number of success stories—often accompanied by scores of failures. Some companies take action; most don't.
3	Trough of Disillusionment	Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investments continue only if the surviving providers improve their products to the satisfaction of early adopters.
4	Slope of Enlightenment	More instances of how the technology can benefit the enterprise start to crystallize and become more widely understood. Second- and third-generation products appear from technology providers. More enterprises fund pilots; conservative companies remain cautious.
5	Plateau of Productivity	Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined. The technology's broad market applicability and relevance are clearly paying off.

Table 1 Five key phases of technology's lifecycle (Wikipedia 2016b.)

Measuring technology maturity has gained more importance lately as the increased customer demand and requirement derived from both safety and quality has increased the level for success tremendously Safety being already a megatrend and creating new kind of security challenges for the society (Kiiski 2016, 8.) The speed of change in enterprise's socio-economic environment has accelerated as the digitalization and data management mainly due to improved ability to better analyse data has integrated to our daily lives (Kiiski 2016, 11) The business has been transferred more global including various local requirements. A handful of tools actually measure the maturity of technology and yet, it's not standardized.

"There's no standard, generally accepted measure of technology maturity that goes beyond the technology readiness levels (TRLs) originally developed by NASA." (Nolte 2008, 1)

Measuring system readiness by utilizing System Readiness Level (SRL) that is an extension to TRL. It is multiplication of Integration Readiness Level – (IRL) of systems and TRL of system (Sauser, Ramirez-Marquez, Verma, Gove and Chinkatnam 2016, 181.) Trying to illustrate technology lifecycle and stages of maturity has a nick name by Nolte (2008), a "whale chart." It extends the familiar S-curve in to a longer form until the technology reaches stage named *death*. The whale chart in Figure 17 aims to describe different stages that technology meets during its life cycle. X-axis describes time and y-axis shows utility, usefulness of technology (Nolte 2008, 24.) While the technology becomes more and more useful it eventually becomes older and its usefulness declines by time as it starts to become obsolete. In the end technology dies (Nolte 2008 20.)

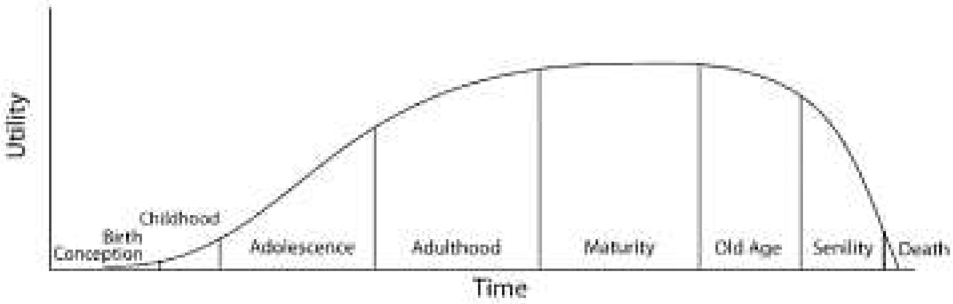


Figure 17 Technology Lifecycle (Nolte 2008, 26)

In the *conception* phase there is an idea, no guarantee there's use for it and no guarantee if it works. It may take a long time to pass through this phase since this phase since it consists mainly of preparation and gathering scientific or technical knowledge. Working out basics of the problem. The *birth* stands for realizing that there is something for the idea that theoretically works in some use. The R&D effort starts at the *childhood* phase where the verification of technological theory takes place. Once the technology works in laboratory environment in different variations. At the end of the childhood phase technology may possess some bugs but the concept has been proven to be feasible and functional in its intended use. *Adolescence* marks that the technology functions but the user convenience is not yet there. The commercial environment e.g. the reliability and consistency improvement efforts step in together with manufacturing process development At the end of the phase marketing will step in to make technology into a great product (Nolte 2008, 20-22.)

”The adulthood is competitive phase where market share, price, and brand recognition are more important than the capability of the product, since every supplier can provide roughly the same capability.” (Nolte 2008, 22)

When reaching *maturity* phase the market becomes saturated as the competition becomes cut-throat. The *old age* has been reached when the market starts to decline as the only customer base is formed by the ones that need to replace their old broken devices. S*enility* phase marks that support and spares become more difficult to be found and most of the suppliers quit providing products based on the technology and begin to seek for more profitable ventures. Finally the *death* means end of any support as the interest of even third party suppliers dries out (Nolte 2008, 22-23.) It is rare that technology or a product can avoid becoming obsolete but a few expectations that have managed to make themselves an integral part of society exist. Such technologies or products are e.g. a light bulb, fire or a wheel (Nolte 2008, 10.) There are also other models to describe technology maturity like e.g. DoDs 5-stage model that concentrates on the first four stages into development of technology, only the last stage is reserved for system development (Nolte 2008, 24-26.)

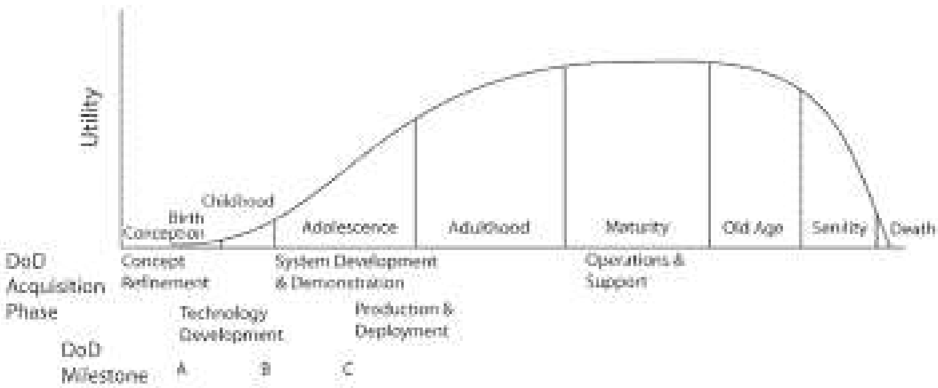


Figure 18 Technology Lifecycle with DoD acquisition cycle (Nolte 2008, 27)

Figure 18 describes Technology Lifecycle with DoD acquisition cycle embedded to it. Milestones A, B and C pay an important role in the picture because it tries to unite these two models into one. Milestone A decision starts the effort to lower technology risk and seeks to determine correct use of technology and/or technologies in a system. Further on the Milestones B consists of two main efforts system integration and system demonstration. Finally Milestone C involves mature system development, integration and demonstration to support milestone decision (Nolte 2008, 26, 27.) Linden (2003, 6) name Nolte’s whale chart with name adoption curve. All together it has the same purpose with S-Curve and Hype cycle. To describe technology maturity. Figure 19.

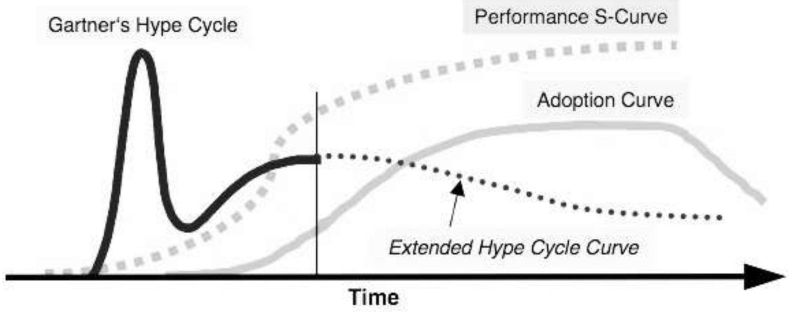


Figure 19 Technology lifecycle models (Linn A 2003, 6) Gartner research (2003)

"Systems that depend upon the application of new technologies inevitably face three major challenges during development: performance, schedule and budget." (Mankins 2009a, 1208)

A premature technological introduction will lead to schedule and budget overruns. Time-to-market requirement and accelerating change of speed in enterprises' socio-economic environment can lead to a disaster if the technology transfer is not done in a systematic way to better understand and mitigate the risks involved in development and introduction of new technologies (Stig et al. 2011, n.d..) Bilbro (Nolte 2008, xvi.) writes that a NASA comptroller Werner Cruel analyzed projects in 1980s. His analysis showed that projects that were investing less than 5% of total project cost in the early phase created cost growth and schedule slip. The problem was found to be immature technology not meeting the set requirements. There are similar thoughts and findings (Mankins 2009a; Dawson 2007.)

"The literature suggests that technology insertion projects, and technology projects as a whole, are prone to failure. It appears that only around 25 to 50 per cent of projects successfully integrate new technology with the business goals of the organization."
(Dawson 2007, 1.)

Technology readiness assessment suggested in literature can support the decision making also in industrial companies (Stig et al. 2011, n.d..) According to Dawson (2007, 1.) present day Risk management and project management tools do not succeed to provide support during technology insertion process.

"Existing tools allow users to, inadvertently, take a narrow view and ignore key organizational, contextual and systemic factors. A toolkit designed to alert the practitioner to a broader range of issues, including the technical, human, systemic and organizational, would be a valuable development in helping achieve successful technology insertion programs."
(Dawson 2007, 1)

Dawson (2007) cites Smith (2005) who points out that 'readiness' and 'maturity'—though frequently used interchangeably—are not the same thing. Knowledge of technology maturity level will help to control risks involved in new technology development. A manufacturing risk that may cause low yield, higher defect rate, reworks or even hand work in production may in the worst case cause loss of market share (Nolte 2008, 4.)

3.2.4 Technology maturity characteristics and dimensions

There are three main characteristics of a technology neutrality, context dependency and dimensionality as these relate to product and technology maturity (Nolte 2008, 11.) Richard Turner in (Nolte 2008, 11) highlights that the idea of technology or product maturity is value-neutral concept and it is only to be used to measure where a technology is positioned in a certain time. Maturity cannot be judged being good nor can it be judged being bad. It is neither better nor worse. The circumstances defining maturity level form the term context dependency that defines whether more mature is good or bad. Reduction of risk or uncertainty involved in new product development cries out for mature, well known technology and to be ready to get out of lab requires a minimum level of maturity (Nolte 2008, 11.) Was the technology measured only from one viewpoint would give a flat and incomplete view. Dimensionality that means using different viewpoints to a certain technology. By utilizing different ways of looking for measuring the readiness of technology one achieves triangulation and a possibility to look at the technology being assessed as a complete (Nolte 2008, 12, 15.) As such viewpoint the following apply with a reminder by Nolte (2008, 12) also reminds that latter three are often looked over maturity of technology, programmatic maturity (documentation, customer focus, budget), developer maturity and customer maturity. Six main maturity dimensions are (1) current state of technology development, (2) amount of development work remaining, (3) difficulty of remaining work, (4) predicted supportability of final products (reliability, availability, maintainability), (5) interoperability with existing systems or products and (6) manufacturing and productivity (Nolte 2008, 12, 14.)

3.2.5 Technology development

Technology development is vital for enterprises survival. Companies long-term growth is dependent on the introduction of new products, technologies, processes – knowledge. Developing technologies and/or solution requires an investment of various scale. Uncertainty is present in this kind of new technology development projects as their core development purpose is to reduce uncertainty and increase performance level of the technology developed (Cooper 2007, 67-68.) Figure 20 describes relation between technology risk and technology performance & maturity. As time passes the investment is transformed into value of performance & maturity and simultaneously reduced uncertainty of the technology developed (Mankins 2009a, 1209.)

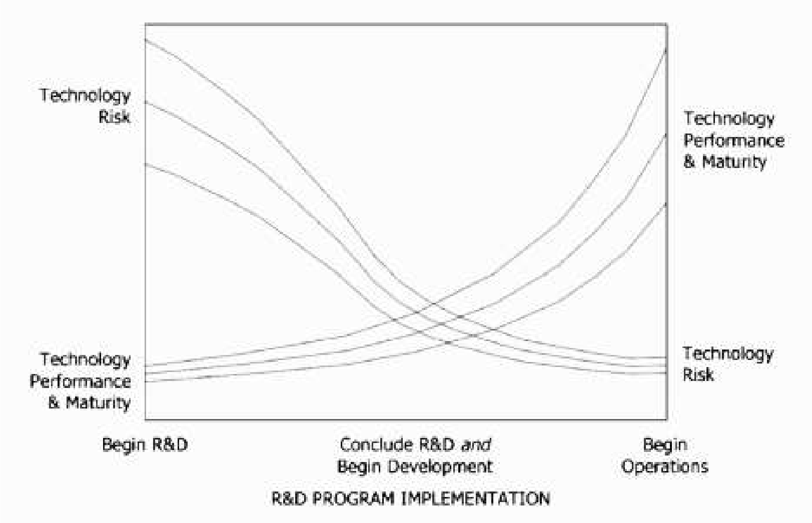


Figure 20 Alternate view to technology development (Mankins 2009a. 1210)

Reasons for introducing a new technology are numerous in organizations (1) cost reduction, (2) productivity optimization, (3) quality improvement actions, (4) reduction of dependency on skilled labor, it always seems a good idea (5) to be up to date, (6) competition by competitors introducing new technology, (7) new technology is found interesting and (8) need to change the relations between various groups in the organization (Dawson 2007, 8.)

One of the systems engineering approaches to development is “Vee” model that’s key principle is to manage risk in a systematic way (Louis G. Neudorff P.E. Jeffrey E. Randall P.E. Robert Reiss P.E. Robert Gordon P.E. 2006, 3—12.) Developed technology is built on requirements that can be obtained in a real system context by applying Systems Engineering (SE) process that is basically a set of activities that define requirements for a system, transform defined requirements into a system through development and eventually deploy the system in an operational environment. Systems Engineering process builds quality into complex systems by utilizing requirements driven development process approach (Louis et al. 2006, 3.10.) It takes into account systems lifecycle and key steps in the system development from concept to development, integration, testing and system implementation. Typically the process is seen in a diagram that resembles a letter “V”, also known as a “Vee” model (Figure 21.) The Vee represents a progressive product development process (Khan and McLucas 2008, 2.) There has been used multiple versions of the “Vee” model in Systems Engineering but regardless of variation the main message is the same:

“'Vee Models present similar activities though with different terminology and the use of various levels of decomposition and integration.”

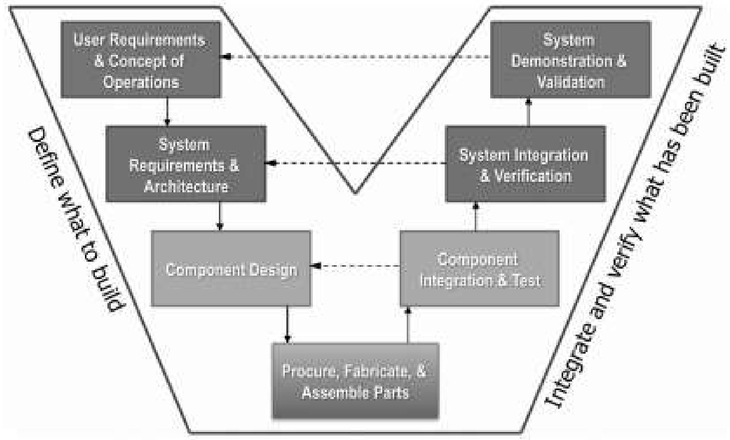


Figure 21 Typical systems engineering V-model (Sauser et al. 2010, 18)

In Figure 21 the left side shows the definition phase, the activities relevant when planning the development of a system such as concept, requirements or expectations (Khan and McLucas 2008, 3—4.) In general a "Vee" model is requirement mapping, building specification, verifying that system is built according to its specification and validation of user satisfaction (Khan and McLucas 208, 4.) The ultimate goal is to increase performance and reduction of uncertainty. Four key activities of Systems Engineering that have an impact to project's success: identify and evaluate alternatives, manage uncertainty and risk in our systems, design quality into our systems, handle program management issues that arise. Identifying and evaluating alternatives requires the feasibility of each alternative to be measured from three different points of view (1) technical feasibility, (2) cost feasibility and (3) schedule feasibility (Louis et al. (2006, 3—10, 3—11.)

"Technical feasibility addresses whether we can build, maintain, and operate system alternative, given the technology and people available to us."
(Louis et al. 2006, 3—11)

"Cost feasibility looks at whether we can build, maintain, and operate a system alternative with the funds available for it."
(Louis et al. 2006, 3—11)

"Schedule feasibility considers whether we can build a system alternative within the time frame allotted for its development. Usually we have to make trade-offs, deciding which alternative offers the better value."
(Louis et al. 2006, 3—11)

Design quality into our systems can be accomplished by addressing factors negatively affecting quality. The International Organization for Standardization (ISO) defines quality as:

"The totality of features of a system that bear on its ability to satisfy stated or implied needs."

Complexity, inflexibility, lack of standardized components, reliability and availability can contribute negatively to the quality of a system. Finally handling program management issues that arise requires a good project plan that is both complete, comprehensive, and communicated.

3.2.6 Technology Readiness Levels - TRL

Technology Readiness Level, a metric to support assessment of technology maturity and to compare maturity between different technologies (Sauser et al. 2006, 1.) TRL was originally developed for space and military technologies by National Aeronautics and Space Administration (NASA) and later utilized and further developed by Department Defence (DoD), (Dawson 2007, 14) by industry, and also internationally during the last 15 years (Mankins 2009a, 2011.) The model was first used for evaluation purposes to assessing maturity of technology prior to transition (Dawson 2007, 14.) Typical for such development programs are single series and long development span. NASA began to research and develop the model after the Apollo flights and is one of the main contributors on the topic in the early phase. The beginnings of TRLs date back to 1980s albeit the history seems a bit blurred, some dates come already from the 1960s as Nolte (2008, 46) and Mankins (2009b, 1221) refer to Sadin (1989.) Nevertheless levels have undergone several iterations to present day. Iterations have not only been conducted by NASA. In 1990s the use of model expanded to 9-stage model shown in Figure 22 and explained in more detail in Table 2 from the original 7 stages and has been utilized and further developed by others as well (Nolte 2008, xv-xvi; NASA 2015.) Several sources lists other known models that have been developed by e.g. European Space Agency (ESA), Department of Defence (DoD), European Commission (EC) and Department of Energy (DOE), they differ in detailed level from each other.

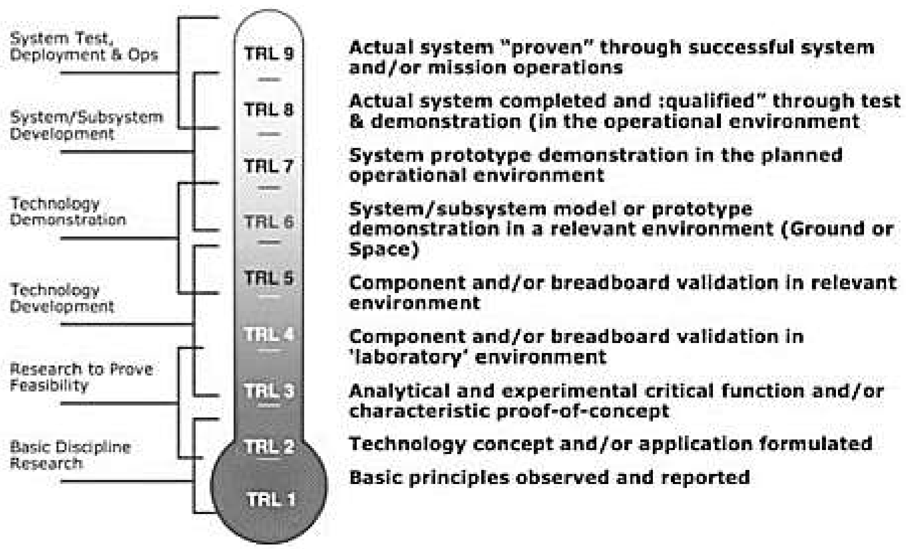


Figure 22 Technology Readiness Scale (TRLs)(Mankins 2009a, 1211)

The basic principle of TRLs is that the technology, while being developed, undergoes certain maturity stages starting from recognizing the basic principles of technology and ending into a large scale industrial production.

Typically it estimates Critical Technology Elements (CTE) of the system/subsystem/component under development (DOE 2011, 7) At the lower levels the nature of the technology is not thoroughly known and it contains many uncertainties and conceal many risks and uncertainties. Therefore the focus is typically put into increasing the knowledge and understanding by analysis, testing and validation (DOE 2011, 6, 8) In the original model the technology maturity is quantified by a figure between 1 and 7 which was later expanded to 9 where a larger number describes the technology being more mature for technology transfer (Nolte 2008, xvi.)

TRLs are mainly utilized in organizations in order to aid management in decision making related to the development and transitioning of technology. The advantages or TRLs: (1) provides a common understanding of technology status, (2) risk management, (3) useful to making decisions concerning technology funding and (4) useful to support decisions concerning transition of technology (Dawson 2007, 14.) The models have reached popularity among the business enterprises as the cost pressure has grown. One of the main advantages of the existing models is that those can be adopted to all kinds of technologies. The definitions of the levels are explicit that guarantees possibility to evaluate easily with one grade even such technologies that have nothing in common. The models work mainly as a supportive tool for decision making, risk management and maturity assessment (Dawson 2007.) Other process models may also be used. For the general model to be most it must include the following primary steps: ”basic” research in new technologies and concepts (targeting identified goals, but not necessary specific systems), focused technology development addressing specific technologies for one or more potential identified applications, technology development and demonstration for each specific application before the beginning of full system development of that application, system development (through first unit fabrication) and system ”launch” and operations (Mankins 1995.) In addition TRLs can form a part of technology’s exit criteria (Nolte 2008, 57)

Concerning the questions what are TRLs good for? There are several positives on using the TRLs in Research & Development. TRLs provide a snapshot of maturity in a given moment, indicate current level of technology on the scale, can serve as a communication means, TRLs can help both sides to understand exactly what is required to by providing a common reference point and can help eliminate and mitigate misunderstandings and ambiguities in transition process (Nolte 2008, 57.)

TRL	Definition	Description
1	Basic principles observed and reported	Transition from scientific research to applied research. Essential characteristics and behaviors of systems and architectures. Descriptive tools are mathematical formulations or algorithms.
2	Technology concept and/or application formulated	Applied research. Theory and scientific principles are focused on specific application area to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.
3	Analytical and experimental critical function and/or characteristic proof-of-concept	Proof of concept validation. Active Research and Development (R&D) is initiated with analytical and laboratory studies. Demonstration of technical feasibility using breadboard or brass board implementations that are exercised with representative data.
4	Component/subsystem validation in laboratory environment	Standalone prototyping implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.
5	System / subsystem/component validation in relevant environment	Thorough testing of prototyping in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.
6	System / subsystem model or prototyping demonstration in a relevant end-to-end environment (ground or space)	Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.
7	System prototyping demonstration in an operational environment (ground or space)	System prototyping demonstration in operational environment. System is at or near scale of the operational system, with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.
8	Actual system completed and "mission qualified" through test and demonstration in an operational environment (ground or space)	End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. Verification and Validation (V&V) completed.
9	Actual system "mission proven" through successful mission operations (ground or space)	Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place.

Table 2 Definition of Technology Readiness Levels (NASA n.d.)

3.2.7 Technology Readiness Levels' limitations

The scale has been criticized as being subjective, inaccurate and poorly defined to be able to support the decision making effectively (Stig et al. 2011) cite (Cornford 2004.) In addition criticism of decision making and inaccuracy Sauser et al. (2006, 5) judge TRL scale only evaluating the maturity of an individual technology and not a set of technologies or a system. Complete system integration remains unclear as they finally contend that most complex systems will fail at the integration points. Readiness does not necessarily fit with appropriateness or technology maturity, a mature product may possess a greater or lesser degree of readiness for use in a particular system context than one of lower maturity and numerous factors must be considered, including the relevance of the products' operational environment to the system at hand, as well as the product-system architectural mismatch (Dawson 2007, 14.)

Technology readiness between several subsystems is an ongoing challenge from system point of view due to the fact that different technologies mature in different times (Mankins 2009b, 1223.) Regardless of criticism NASA and DoD have used TRL metric as primary maturity assessment tool. As the system complexity has increased maturity assessment technique has not been able to match with the customer demand in both hardware and software development. DoD has developed their own metrics to better support defence acquisition but still have not been able to correct the lack of objectivity problem that leads to overreliance on tacit knowledge (Azizian, Sarkani, Mazzuchi 2009, 4) As the TRLs are placed in the beginning of the whale chart they do not measure maturity in technology's whole lifecycle neither do TRLs indicate the required effort between TRLs (Nolte 2008, 59.)

3.2.8 Technology Readiness Assessment – TRA

Technology Readiness Assessment (further TRA) is a systematic tool created to quantify abstract technology development stages. It helps to assess technology readiness while it is under development. In addition to this it helps in comparing two rival technologies being developed simultaneously with a simple grade. Such technologies do not need to be similar. By the utilization of the assessment the projects risks related to the development work can be mitigated. On the other hand it may also be useful when obtaining technologies outside the own enterprise (Mankins 1995.) Department of Defense (further DoD) defines Technology Readiness Assessment in their guidance (ASD(R&E) 2011) in a following sentence:

"A TRA focuses on the programs "critical" technologies (i.e., those that may pose major technological risk during development, particularly during the Engineering and Manufacturing Development (EMD) phase of acquisition.)"

It shouldn't be forgotten that TRA is only a tool in technology management framework other tools are e.g. technology watch, technology road mapping, technology make-buy, and technology risk management (Fernandez 2010.)

<u>Qualitative methods for defining technology maturity</u>

"The TRL metric has served as the primary maturity assessment tool since first incepted by NASA and later adopted by the DoD. With the drastic increase in system complexity in the recent years, this traditional maturity assessment technique has become incapable of meeting customer demands in both hardware and software intensive programs. Although the TRLs have been tailored by the DoD to better support defense acquisition, it lacks objectivity which result in overreliance on tacit knowledge." (Azizian et al. 2009, 4)

Quantitative methods for defining technology maturity

"As a result of their mathematically integrative nature, quantitative techniques can be intimidating and discouraging to use when assessing technology maturity. They are also prone to mathematical miscalculation that can lead to wrong maturity assessment, cost overrun, and schedule delay. On the other hand, quantitative techniques integrate multiple system metrics, which result in tangible outputs to accurately support decision-making." (Azizian et al. 2009, 6)

Computerized method for defining technology maturity

"They are more objective than the qualitative metrics because the result is calculated based on answers to a series of questions, which in essence incorporate information about design and development risks. Further, they make the process of calculating maturity of a product more repeatable and allow for more consistent comparison of different technologies based on its standard set of questions." (Azizian et al. 2009, 7)

3.2.9 Technology risk management and technological uncertainty

Managing uncertainty and risk is about avoidance of mistakes and problems that we meet during development projects. Dealing with uncertainty and risk is a necessity. Again Systems Engineering is focusing on three aspects of risk management: identification, analysis, and mitigation. The risk and uncertainty are reason for new product development. The effort is put on both lowering the uncertainty and improving the performance. The types of risk that technology meets during its lifetime can be related to development risk, manufacturing risk, marketing risk or simply the risk of technology becoming obsolete in the later phases of lifecycle. The development risk is on its highest at TRL 1 to TRL 6. In TRL6 to TRL 9 range the risk is related to production risk (Nolte 2008, 99—100.) In (Nolte, 2008, xvii) De Meyer et al. (2002) lists four different types of uncertainty that form fundament of uncertainty-based-management in hi-tech-projects. Variation (the accumulation of small influences that cannot be controlled but can be accounted for), foreseen uncertainty (that which lies within the experimental base), unforeseen uncertainty (that which lies outside the experimental base) and finally chaos (when unforeseen uncertainty dominates.)

"The complexity, innovativeness and certain, although limited, uniqueness of projects, all presume a degree of uncertainty associated with them. Being bounded by budget, scope, time and quality, projects strive for the ultimate goal of performing to satisfy the customer needs. In order to avoid unforeseen situation." (Perminova 2011, 30.)

*"The goal is to create value for the customer: to provide a solution package that is aimed at fulfilling the customer's specific preferences and wishes, which potentially includes a wide range of financing, consulting, and, operation and maintenance services." (*Perminova 2011, 20)

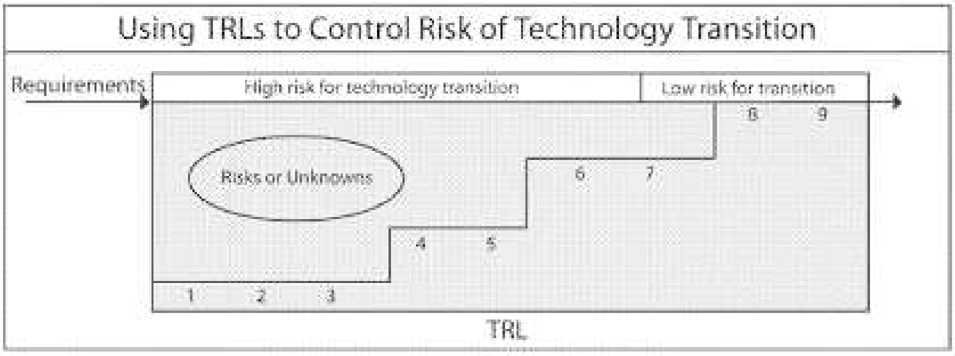


Figure 23 TRL as a measure of program risk (Nolte 2008, 58)

3.2.10 Technology Readiness and Risk Assessment - TRRA

Figure 24 describes an ideal approach to technology readiness and risk assessment (TRRA) defined by Mankins (2009a, 1208, 1209.) TRL provides a metric to systematically assess technology readiness but it is not perfect in doing so. Because of many recognized flaws in the original TRL model Mankins (2009a) proposed to integrate TRL scale (Figure 22), research and Development Degree of Difficulty (R&D^3) (3.2.11) and technology Need Value (3.2.11) into one model in order to assess three factors in a risk matrix (Stig et al. 2011).

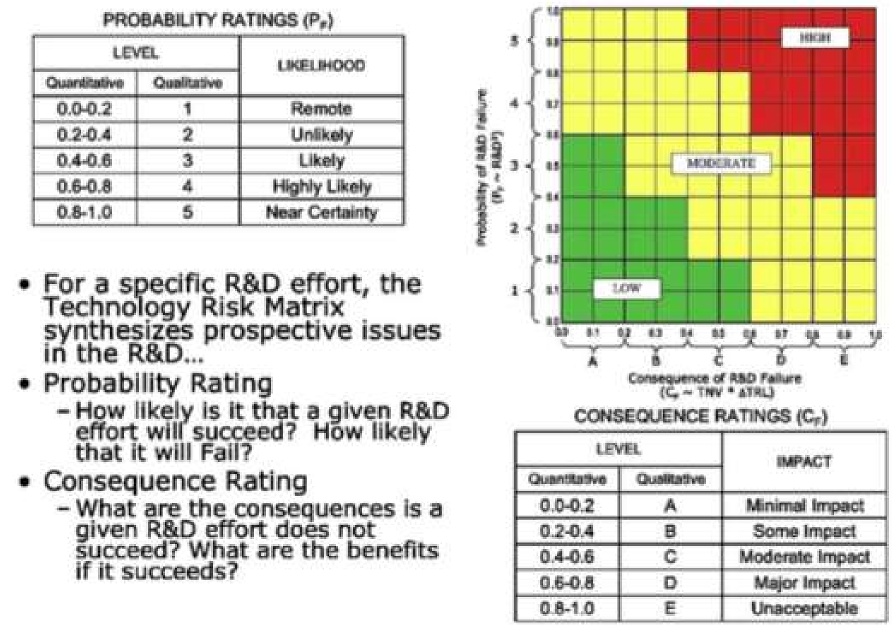


Figure 24 Generic technology program risk matrix (Mankins 2009a, 1213)

Risk matrix has built in capability to illustrate uncertainty and consequences related to it. Before Mankins' research these had not been put together (Mankins 2009a, 1208.) It should include following characteristics:

– Clarity
"The process would involve clear decision criteria for determining both risks and technology readiness; and these criteria should be analytically grounded in a way that allows independent evaluation and verification of results." (Mankins 2009a, 1209.)

– Transparency
"The process for technology risk and readiness assessment should be formal. (but not overwhelmingly bureaucratic), and consensus based. It should easy for participants, managers and independent observers to understand both the process, the interim steps in the assessment, and its results." (Mankins 2009a, 1209.)

– "Crispness"
"Decisions during the TRRA assessment should be made by and/or with the ownership of senior management. They must be crisp, timely, and keyed to annual R&D and system program budget planning requirements." (Mankins 2009a, 1209.)

– Useful in program advocacy
"The processes used for making TRRA decisions should also produce the basis for advocacy of the result (hit the ground running....)" (Mankins 2009a, 1209.)

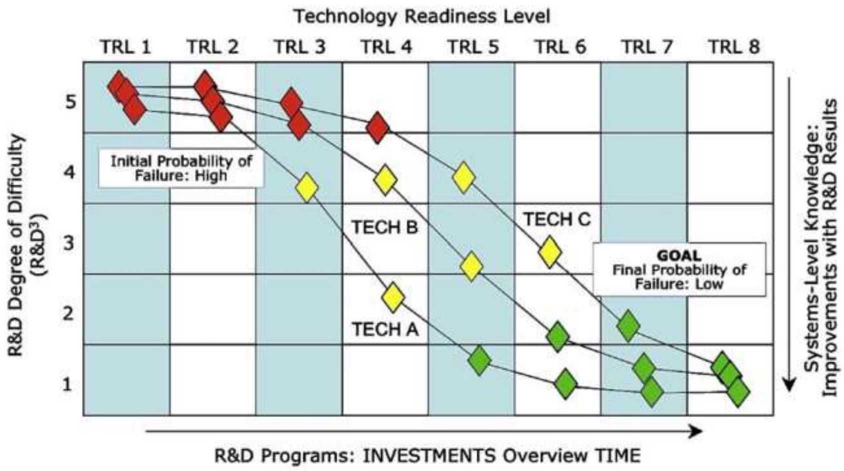


Figure 25 Generic scenario for technology development (Mankins 2009a, 1210)

"Unfortunately, most approaches to assessing technology readiness or risks do not possess this important combination of characteristics." (Mankins 2009a, 1209)

Figure 25 provides an illustration to technology development scenario where three technologies (TECH A, TECH B and TECH C) are being developed. It should be noted that it is not uncommon that technologies are likely to mature in different ways. One technology might progress in uncertainty reduction and the other matures in performance. It is the project manager who must understand all factors affecting the maturity and manage these during the R&D project (Mankins 2009a, 1209.)

"Any TRRA process must focus on key technical performance parameters and progress made to advance those parameters through R&D efforts." (Mankins 2009a, 1209)

"TRRA process must also address the following critical programmatic figures of merit: TRL, (R&D3), and R&D degree of difficulty technology need value (TNV.)"
(Mankins 2009a, 1209)

TRL has proven its ability to effectively communicate the maturity of technology but has failed e.g. in addressing the difficulty in R&D to move forward in TRL scale. For this problem R&D Degree of Difficulty ($R\&D^3$) has been developed. Alone $R\&D^3$ does not provide an answer to this challenge and to complete this Technology Need value (TNV) has been developed to provide means for communication and to provide an understanding over the importance of given technology importance TNV is best understood as weighting factor based on assessed importance of technology developed. These three together provide means of communication, a shared language between developers and senior managers (Mankins 2009a, 1211.)

- *"What is the current level of maturity of the technology, and what is my maturation objective?"*
- *"How hard is it going to be to advance the technology from where it is now (current TRL) to where the program needs the technology to be (future TRL) in order to make well informed decisions?"*
- *"How important is each specific technology in the portfolio to the overall goals of the R&D program?"*

In order to combining these into a simple and easy to understand illustration of technology maturity and uncertainty risk matrix was used. In Figure 24 the risk matrix reflects probability of failure $R\&D^3$ on the y-axis and consequence on the x-axis (failure or success) (Mankins 2009a, 1211, 1212.)

$$\Delta - TRL \ \times TNV$$

Equation 1 x-axis Consequence of R&D failure (Mankins 2009a, 1212.)

In Equation 1 $\Delta - TRL$ remaining work for maturation of technology. In order to define remaining work target TRL and current TRL are needed as inputs. Target TRL in the beginning of system development. As mentioned earlier TNV is weighting factor to highlight the importance of technology effort for success (Mankins 2009a, 1212.)

"This approach allows a single matrix to summarize diverse technology risk areas for ready comparison." (Mankins 2009a, 1212.)

As a project in the beginning of its development span is assessed it usually becomes plotted in the top right corner, the red area – uncertainty is high. As it becomes more mature the plot will move toward the bottom left corner. For TRRA to work efficiently it has critical data and organizational requirements: There must be a clear linkage to a pre-defined, overall WBS for the

R&D program (consistent with the functionality of the eventual system application), consistent identification of the technologies to be pursued (including, the name of the technology, a succinct description of its characteristics, etc.), meaningful statements of the measures of performance to be achieved during the R&D effort (e.g., improvements in mass, power, processing speed, etc.), selected technology assessment data, including TRL's R&D3, TNVs, etc., careful statement of any links to past assessments; including current Figure of Merit (FOM) values, projected future values and explicit statements of justifications for each of these assessments (Mankins 2009, 13—15.)

3.2.11 Technology Need Value – TNV

Figure 26 describe Technology Need Value (TNV) which is used as a weighting factor in Mankins (2009a) TRRA. Like R&D^3 it consists of five values ranging from 1-5 where 1 stands for non-critical and 5 for critically important.

Technology Need Value	Weighting Factor	Description
TNV-1	40%	The technology effort is **not critical at this time** to the success of the program— the advances to be achieved are useful for some cost improvements; However, the information to be provided is not needed for management decisions until the far- term
TNV-2	60%	The technology effort is **useful** to the success of the program—the advances to be achieved would meaningfully improve cost and/or performance; However, the information to be provided is not needed for management decisions until the mid- to far- term
TNV-3	80%	The technology effort is **important** to the success of the program—the advances to be achieved are important for performance and/or cost objectives AND the information to be provided is needed for management decisions in the near- to mid- term
TNV-4	100%	The technology effort is **very important** to the success of the program; the advances to be achieved are enabling for cost goals and/or important for performance objectives AND the information to be provided would be highly valuable for near-term management decisions
TNV-5	120%	The technology effort is **critically important** to the success of the program at present—the performance advances to be achieved are enabling AND the information to be provided is essential for near-term management decisions

Figure 26 Technology need values TNVs (Mankins 2009a)

3.2.12 R&D Degree of difficulty -R&D^3

R&D Degree of Difficulty (R&D^3) is an additional measure to TRL that provides a way to quantify the required effort to mature a technology from current TRL. Figure 27 shows the 5 levels of difficulty which are later defined in detail, higher the number bigger the effort to mature technology further (Mankins 1998, 1.)

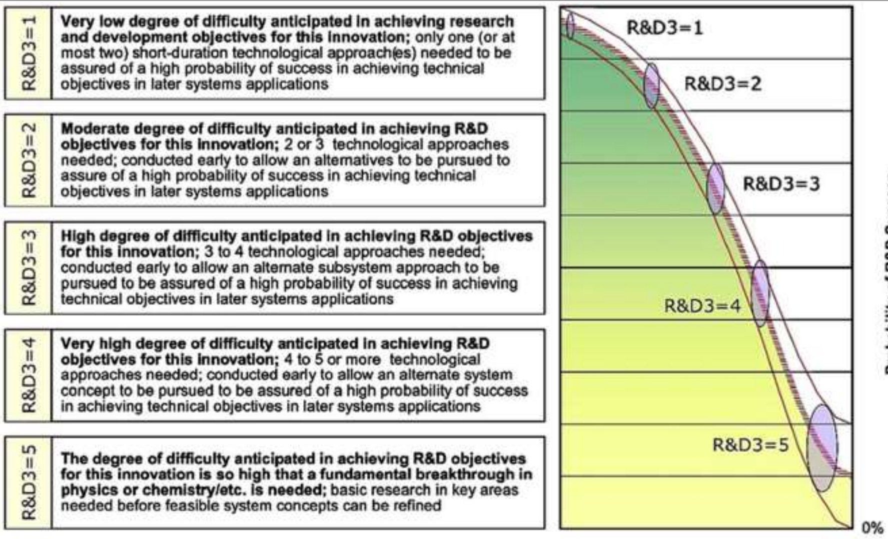


Figure 27 R&D degree of difficulty scale R&D^3 (Mankins 2009a)

– R&D^3 – Level I

"A very low degree of difficulty is anticipated in achieving research and development objectives for this technology (including both the system concept, as well as performance, reliability and cost goals.) Only a single, short-duration technological approach needed to be assured of a high probability of success in achieving technical objectives in later systems applications." (Mankins 1998, 3.)

– R&D3 – Level II

"A moderate degree of difficulty should be anticipated in achieving R&D objectives for this technology. A single technological approach will probably be sufficient; however, this R&D should be conducted early to allow an alternate approach to be pursued if needed in order to be assured of a high probability of success in achieving technical objectives in later systems applications." (Mankins 1998, 3.)

– R&D3 – Level III

"A high degree of difficulty could be anticipated in achieving R&D objectives for this technology. At least two technological approaches will probably be needed and these efforts should be conducted early enough to allow an alternate subsystem approach to be pursued to be assured of a high probability of success in achieving technical objectives in later systems applications." (Mankins 1998, 3.)

– R&D3 – Level IV

"A very high degree of difficulty should be anticipated in achieving R&D objectives for this technology. Multiple technological approaches need to be pursued. These activities should be conducted early enough to allow an alternate system concept to be pursued in order to allow managers to be assured of a high probability of success in achieving technical objectives in later systems applications." (Mankins 1998, 3.)

– R&D3 – Level V

"The degree of difficulty should be anticipated in achieving R&D objectives for this technology is so high that a fundamental breakthrough in physics/chemistry/etc. is needed. Basic research in key areas needed before feasible system concepts can be refined." (Mankins 1998, 3.)

3.2.13 System Readiness Level - SRL

There has been several studies performed on the System Readiness Level, some of them utilizing appropriate systems engineering principals but still with all its flaws and shortcoming the TRL has been used as a foundation in turning qualitative maturity data into quantified and enabling maturity assessment (Sauser et al. 2006, 4—5.) System Readiness Level (SRL) relies on systems engineering principle and system design. As TRL is a metric proving technology to assessing maturity of a technology and a way for comparing different technologies in a systematic way the System Readiness Level (SRL) is an improved version of TRL developed by Sauser et al. (2016, 181) who also introduced Integration Readiness Level (IRL) to support assessing SRL. SRL is an outcome of multiplication between system TRL and the Integration Readiness Level (IRL) of systems.

“We contend that a true system readiness level should consider technology readiness as well as the achieved maturity and readiness involved with integrating it with the intended and operational system.” (Sauser et al. 2006, 14.)

Technology maturity alone does not tell much about how to integrate two separate technologies into a system, therefore a need for SRL. Referring to Ruben and Kim (1975) who proposed four basic assumptions for all systems.

“*The sum is greater than the parts and there are consequences for not understanding the dynamics of each part”, “There is multilateral causality among subsystems, systems, and the environments they function in”, “One set of initial conditions can give rise to different final states”, “There is concern with the flow of information between subsystems (components)”* (Sauser et al. 2006, 4.)

IRL	Definition
7	The integration of technologies has been verified and validated with sufficient detail to be actionable.
6	The integrating technologies can accept, translate, and structure information for its intended application.
5	There is sufficient control between technologies necessary to establish, manage, and terminate the integration.
4	There is sufficient detail in the quality and assurance of the integration between technologies.
3	There is compatibility (i.e. common language) between technologies to orderly and efficiently integrate and interact.
2	There is some level of specificity to characterize the interaction (i.e. ability to influence) between technologies through their interface.
1	An interface (i.e. physical connection) between technologies has been identified with sufficient detail to allow characterization of the relationship.

Table 3 Integration Readiness Levels – IRL (Sauser et al. 2006, 6)

TRL is about assessing uncertainty and/or risk with developing technologies as IRL assesses risk of integration. IRL scale not only provides means and scale for the assessment of technology on integration readiness, it supports taking a direction for integration improvement with other technologies. Sauser et al. (2006, 5) is a reference to Valerdi and Kohl (2004) who pointed to well-known TRL flaw, TRL not accurately capturing the risk in technology adoption. Also Smith (2005) stating that technologies may have an architectural inequality related to integration. Open Systems Interconnect (OSI) model familiar from computer networking by (Beasley 2004) has been used as a foundation to IRL model (Sauser et al. 2006, 5—6.)

SRL	Name	Definition
5	Operations & Support	Execute a support program that meets operational support performance requirements and sustains the system in the most cost-effective manor over its total life cycle.
4	Production & Development	Achieve operational capability that satisfies mission needs.
3	System Development & Demonstration	Develop a system or increment of capability; reduce integration and manufacturing risk; ensure operational supportability; reduce logistics footprint; implement human systems integration; design for producibility; ensure affordability and protection of critical program information; and demonstrate system integration, interoperability, safety, and utility.
2	Technology Development	Reduce technology risks and determine appropriate set of technologies to integrate into a full system.
1	Concept Refinement	Refine initial concept. Develop system/technology development strategy

Table 4 System Readiness Level – SRL

Multiplication of TRL and IRL is correlated to a five level SRL. The SRL model is not final. It is an opening for thought that requires more development work on integration to systems engineering framework. Adding maturity difficulty Figure 28 would be one way together with contingency theory to provide ways to analyze the extent of fit between system characteristics in order to being able to select suitable approach to systems engineering based on a SRL index (Sauser et al. 2006, 8.)

“The SRL model presented here is to be a first step in a contingency model for systems engineering that is built on the fundamental theory of a system.” (Sauser et al. 2006, 8.)

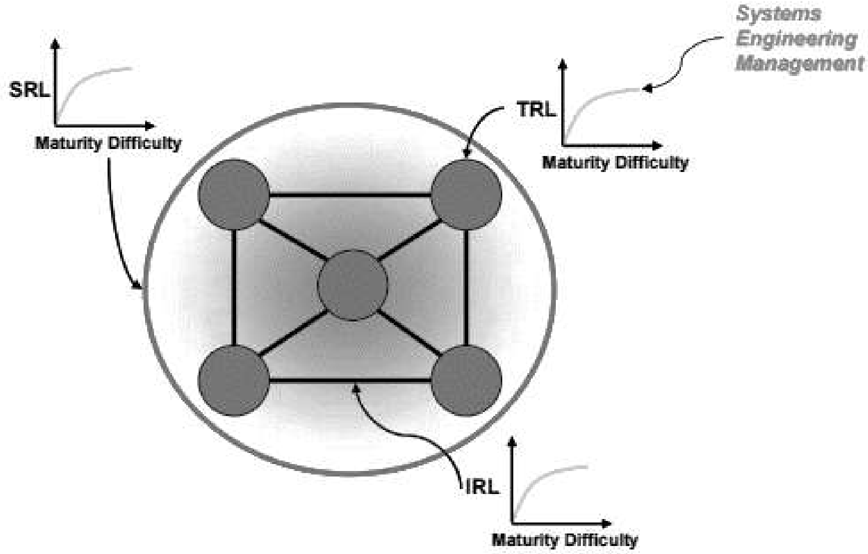


Figure 28 The future of SRL model (Sauser et al. 2006, 9)

3.3 Organizational management

As the society and socio-economic environment that companies operate at has become more complex the chapter concentrates primarily on learning organization and systemic thinking. Secondary point of interest is on the principle of cultural dimension and features of organizational culture. Managerial decision making and factors influencing decisions are reviewed briefly, the chapter ends on barriers of communication and their influence on getting message trough.

3.3.1 Systemic thinking

Due megatrends like globalization and digitalization the world and socio-economic environment of enterprises is developing into more and more complex entity in which intrinsically complex, nonlinear, interconnected, and overdetermined things are multiply caused (Schein 2014, 401-402.) Sveiby (2001) takes on this by highlighting the traditional strategy view in context with pursue for competitive advantage and strategy being associated with activities and decisions that concern the long-term targets in enterprise's socio-economic environment. As already seen in strategic triangle (Kamensky 2014, 25) Prahalad and Hamel's (1990, 82) competitive-based and product-based strategy formulation makes markets and customers the starting point. On the other hand the resource-based approach puts more emphasis on the enterprise's capabilities and/or core competences. Ability to think systemically and understanding joint causal effects together with abandoning a simple, linear, causal logic in favor of complex mental models is becoming more critical to learning as the interdependency between various factors affecting the environment require that (Schein 2004, 401-402.) Boulding (1956, 199) wrote on generic systems theory:

"The more science breaks into sub-groups, and the less communication is possible among the disciplines, however, the greater chance there is that the total growth of knowledge is being slowed down by the loss of relevant communications. The spread of specialized deafness means that someone who ought to know something that someone else knows isn't able to find it out of lack of generalized ears."

The five disciplines of which systemic thinking is one, are the cornerstone for a learning organization. Other factors building on top of the systemic thinking are personal mastery, mental models, building shared visions, and team learning. Systemic thinking or the others alone do nothing, to build on top of the other four as building the shared vision that fosters commitment in the long run, mental models that focus on openness needed when overcoming - learning out from - contemporary ways of seeing the world, team learning that builds groups of peoples' skills to seeing – the big picture - wider than the individual perspective and finally personal mastery that creates personal motivation to continually learn from individual actions and their effects on the world. In the end the systemic thinking makes understandable the word 'learning organization' - seeing how our own actions create the problems we experience (Senge 1992, 6, 12.)

"I see systems thinking as a way of seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static snapshots." (Senge 1992, 68.)

3.3.2 Cultural dimension

Culture is a construct (Hofstede 1994, 89.) Cultural dimensions were originally observed by IBM as they surveyed values of similar people. Cultural dimensions are constructs too, they do not exist in the words literal meaning and should be though as tools for analyzing a situation. These cultural dimensions are power distance, individualism, masculinity, uncertainty avoidance and long-term vs. short-term orientation. Power distance can be seen as degree of inequality. All societies are unequal, some are more and some are less. The individualism sets the degree to which people are willing to act as individuals rather than as a group. The opposite to individualism is collectivism. Masculinity is opposite to femininity. Masculinity set the degree to which tough values like assertiveness, performance, success and competition are followed in a society. On the other hand values like quality of life, maintaining warm personal relationships, service, care for the weak and solidarity are seen as feminine traits. Uncertainty avoidance is the degree to which people prefer structured over un-structured situation. Long-term and short-term orientation defines how much values are oriented toward the future whereas the short-term defines past and present orientation of values (Hofstede 1994, 89-90.)

3.3.3 Organizational culture

Schein (2004, 25, 26) divides organizational culture into three visible layers in which organization can be observed (Figure 29) artifacts, espoused beliefs & values and assumptions. The challenge is to enter the deeper levels of a culture. Leaders first need to develop ways for assessing assumptions per each level of culture. Dealing with the anxiety that is unleashed when those levels are challenged is essential. There is a link between organizational culture and uncertainty management in enterprise *(*Schein 2004, 37.)

"A set of beliefs and values that become embodied in an ideology or organizational philosophy thus can serve as a guide and as a way of dealing with the uncertainty of intrinsically uncontrollable or difficult events" (Schein 2004, 29.)

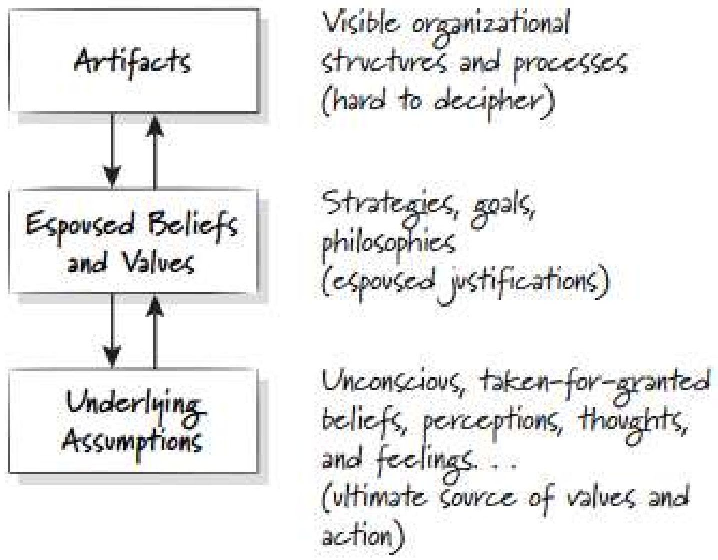


Figure 29 Levels of Culture (Schein 2004, 26)

Artefacts are visible signs that mark the company both internally and externally. Internal factors can be e.g. processes and external are everything that is shown to the outside world e.g. logo, technology and clothing which are mainly hard to copy. Espoused beliefs & values conclude on the transformation mechanism of a belief to a value that first group needs to act on a new point of view or a belief and experience the shared perception on the success of it. Only then if actions continue to be successful the belief may transform into a value (Schein 2004, 65—68.)

"If this transformation process occurs, group members will tend to forget that originally they were not sure and that the proposed course of action was at an earlier time just a proposal to be debated and confronted." (Schein 2004, 68.)

The underlying assumptions concerning assumptions in cultures DNA:

"Culture as a set of basic assumptions defines for us what to pay attention to, what things mean, how to react emotionally to what is going on, and what actions to take in various kinds of situations." (Douglas 1986 by Schein 2004, 32.)

Schein's layers have been used e.g. by Homburg and Pflesser (2000, 450) whose study on market-oriented-organizational culture uses Schein's cultural layers and set the layers in particularly relevant role. Recognizing them allowing analysis of interrelations among these layers and ultimately leading to better understanding of the forces affecting market-oriented behavior. Schein (2004, 3) uses and example where management group needed improve following challenges: Communication, interpersonal relationships and decision making. Visualizing the problem helped to communicate and make decisions: (Schein 2004, 6.)

"The group began to focus on the items on the chart and found that this really did help their communication and decision process." (Schein 2004, 6.)

Leadership element to be discussed with it e.g. organization crisis situation handling:

"Culture is the result of a complex group learning process that is only partially influenced by leader behavior. But if the group's survival is threatened because elements of its culture have become maladapted, it is ultimately the function of leadership at all levels of the organization to recognize and do something about this situation. It is in this sense that leadership and culture are conceptually intertwined." (Schein 2004, 11.)

3.3.4 Managerial decision making

Decision making has been defined by Harrison and March (1984): Decision making includes evaluation and estimation of the values and of available alternatives of actions, decision making includes also choosing the best alternative. Decided action may be good or bad. Errors are costly and suboptimal decision making may affect the society, people, customers, stock value and eventually the fate of the company. As the society has shifted from agricultural production into an industrial one and socio-economic environment has changed into a complex and multifaceted the importance of optimal decision making has increased. As the environment has become global also the decisions are affecting a wider audience than before. The decision making can be biased by multiple factors e.g. time pressure, too much information, simultaneous choice or some other factor (Milkman, Chugh, Bazerman 2008, 1—2.) Source for bad decision making is lack of knowledge, lack of critical information regarding the decision. Lack of information blocks decision makers noticing the available information due to maintaining only a small amount of information in their usable memory. Theory of "system 1" and "system 2" proposed by Stanovich and West (2000) explain the decision usually taking place in this kind of situation. For the reason being busy, the mind is filled with various information which keeps blocking the managers from seeing the reasoning (slower, conscious, effortful, implicit, emotional), "system 2" instead option (fast, automatic, effortless, Implicit, emotional), "system 1" will be used to make decisions (Chugh and Bazerman 2008, 3.)

Strategic managerial decision making process involves taking into account e.g. perceptions of quality and customers reactions. Figure 30 describes strategic decision making context where the manager makes decisions within an organization. Made decisions affect company and many others in socio-economic environment. The reactions of these others contribute to the final outcome of a decision. The contributor's in the model are customers and competitors. In the end manager's decisions depend largely on the knowledge of status and probable reactions of company, customers, competitors and the world (Boulding, Moore, Staelin, Corfman, Dickson, Fitzsimons, Gupta, Lehmann, Mitchell, Urbany and Weitz 1994, 414.) The resemblance with strategic triangle Figure 4 is obvious. In strategic triangle the resources were contributing to competition and customer.

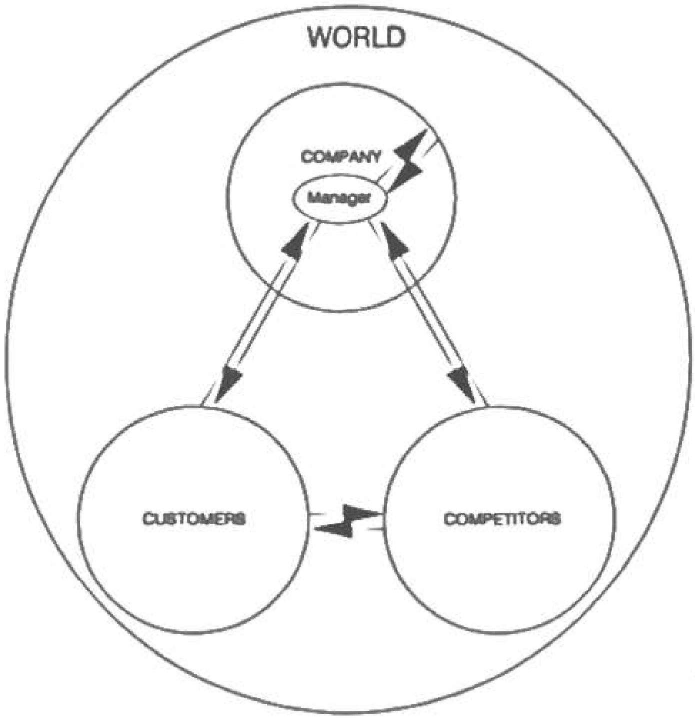


Figure 30 Strategic context for managerial decision making (Boulding et al. 1994, 415)

Figure 31 describes conceptual decision making process of a manager in strategic context. The formulas represent anticipated outcome measures and possible actions that can be taken. Key features of the conceptual model are following: The decision trigger mechanism, manager's overall market model including decision rules, mental models of market and context response, the decision, the actual market response function, the recognition and context and learning occurs from outcomes of the decision process. The context in the model is in key role as it affect all the others as well as manager's mental image of the environment as manager compiles the factors into a set of beliefs (Boulding 1994, 415, 417-418.)

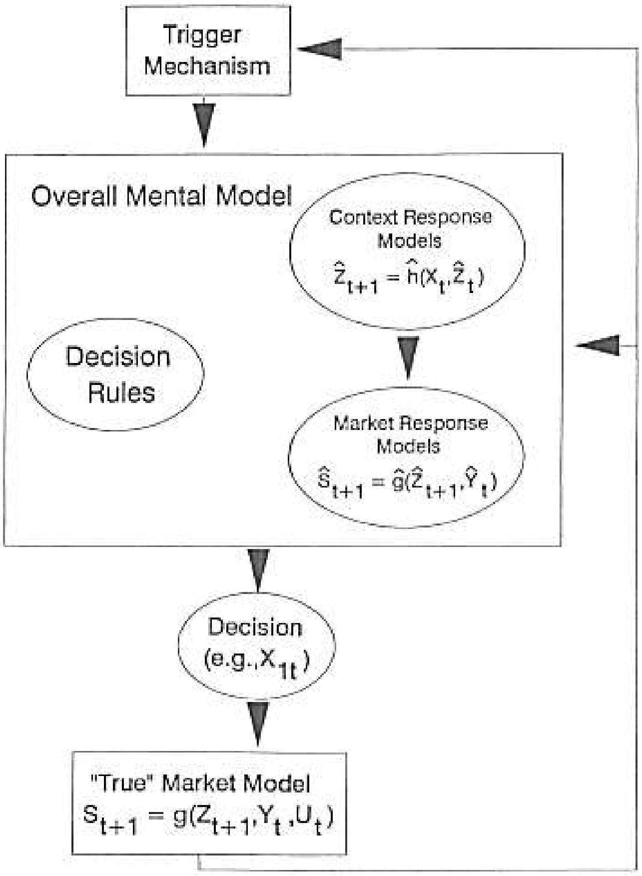


Figure 31 Conceptual model of managerial decision making (Boulding et al. 1994, 416)

E.g. effective data visualization provides a way to effective decision making. Providing a visualized view of measurable, actionable data allows decision makers knowledge and quick analysis of patterns, correlations, business conditions and trends. By visualization a large amount of information can be quickly examined and possible issues recognized. Recently e.g. dashboards in communication have gained popularity due to reasons listed above. These include various pie charts, graphs and status indicators that represent well the traditional data visualization (Blevet 2011, 1.)

3.3.5 Barriers of communication

As a principle communication means sharing meaning. To communicate efficiently one needs to understand barriers that prevent sending and receiving message. Five types of such barriers are: (1) Attitudinal, (2) behavioral, (3) cultural, (4) language and (5) environmental barriers. Attitudinal barriers are common in workplace as people hold different attitudes, values and discrimination. Behavioral barriers like bias, generalizations and stereotyping can cause barriers too, such barriers are costly in organizational context. Communication with people coming from different cultural background requires awareness of values, beliefs and attitudes held by people. If this is not succeeded a cultural barrier exists. One way to overcome these is empathy that enables us to sense feelings and attitudes of others. The language barriers are pretty self-explanatory, this will take place when people aren't sharing the same language. This may also occur when there's a shared language but language used in communication bases on jargon, slang or not possessing similar level of skill. Environmental barriers on the other hand are not caused by people. There are many such environmental factors that may cause message not being received properly or not at all. Environmental barriers could be for example, noise, temperature, comfortability, safety or caused by mobile phones etc (Usha Kani 2016, 74-76.)

3.4 Summary

In this section we've seen that a contemporary socio-economic environment enterprises compete at is complex. It requires a holistic understanding over company's position in the market to understand sources for competitive advantage. All the time more complex technologies require more systematic approach e.g. for technology maturity evaluation in the enterprises. Lifelong responsibility for the product quality and the end user safety during the lifetime of products and/or services is crucial for both economic and technological reasons. Fail early - preferably in development. Organizational learning has been provided as solution to handling of increasing complexity in both products and the environment. Digitalization and demographic change are causing turbulence in environment while also digitalization has been provided as a solution to the challenge of complexity. Realizing both internal and external requirements is essential.

Customer is the king. Ability to provide added value to customer is the key to enterprises' success in competition. The success is achieved - one dimensionally thinking - by developing technologies and pushing novel ideas to the market. What happens when no one is going to buy those novelties? – No business as the company will not succeed in competition. The secret behind competitive advantage in contemporary socio-economic environment is networking, partnerships - value networks, competence and the knowledge. Knowledge can be internal or external as well, alone it can do wonders as Japanese companies have shown during the past decades. It allows companies velocity, agility and productivity. It makes enterprises agile in development and enables them to provide right products in the right markets on time. Market knowledge is important factor in success, technological knowledge guarantees the successful products for a high-tech company, tacit knowledge enables the organization to be a real culture of innovation where the fitter can be an innovator as well as R&D engineer. Knowledge cumulates when nurtured well and creates success. Technology Management is an integral part of an high-tech enterprise that guarantees solid technology base. Solid technology base then guarantees quality products' introduction to market in a fast pace. In combination with tacit knowledge there should be competitive advantage and increased market share for the enterprise.

Technologies do usually have a lifecycle and various steps for maturity. Introducing an immature technology creates a business risk due to great amount of uncertainty involved. The reduction of technological uncertainty is achievable by developing technologies in controlled process that follows systems engineering practices e.g. Vee model and proper requirements mapping, verification and validation processes included. Uncertainty equals risk and it is measurable. Measuring the maturity has been around for a while and yet there's no standardized way to measure technological readiness during development projects. Governmental offices have taken action to improve the situation during last 50 years but still something is lacking. There are several ways to assessing technology readiness or maturity e.g. TRLs, IRLs, MRL etc. but system readiness SRL is much more complex issue. Mankins' Technology Readiness and Risk Assessment TRRA is an interesting option to start development with since there should be possibilities to visualize status in order to achieving proper fact-based decision making in case company. Subjectivity and not enabling a roper systems view are seen as TRLs missing features which may not be corrected in this thesis. Nevertheless TRL will be selected as starting point as it is simple enough for users to agree with and start using a tool based on TRLs. Although an organization and organizational culture are affecting the tool as well as are the actions and the decisions that can be taken in a certain environment/culture.

4 SOLUTION READINESS ASSESSMENT IN CASE COMPANY

4.1 Background information

Effective communication becomes important when decisions critical for project/program progression are required e.g. in a gate readiness decisions. It is often difficult for steering group members to form an understanding of various project's statuses in a limited time and to make correct, fact-based decisions based on the given information that may be very hard to understand for people who are not daily in communication with the solution development project personnel. Usually time granted for a project in a steering meeting is 15-30 minutes which leads into situations where in the worst case decisions are based on imagination instead of facts. There are often challenges to understand where the major development is needed in a project and wat the challenges really are. Depending on the competence these may be correctly communicated or not.

Case company is a multinational corporation that operates globally. In R&D function a gate model is used to grant gates for development projects when seeking e.g. progress. Development is roughly split in two separate functions, there is a separate process for concept development and another one for implementation. Often the border line is not clear and implementation may be responsible for rework due to badly managed concept phase. Variance in the level of readiness in transition phase is typically huge. In total there are 8 gates before the release and 1 extra gate for follow-up purposes. Gates in the process are divided in a following way: 2 for concept development, 1 to be used as a transfer gate between concept development and implementation which then consists of 6+1 gates. The purpose of the gates is to provide a controlled process and to serve as a guarantee for readiness of the deliverables of the project. Gates also function as decision points in pre-determined points in the solution development process. Figure 32 describes the reduction of uncertainty per gate which is built-in the process. “Vee“ model applies fairly well with gate model as gate B1 starts the research with concept idea, D0 transfers from research to development. D1 is reserved for requirements gathering, D2 for specification and D3 marks design ready. D4 stands for process ready and beginning of piloting. D5 means release and D6 control point to validate if target setting has been correct and whether or not targets were met.

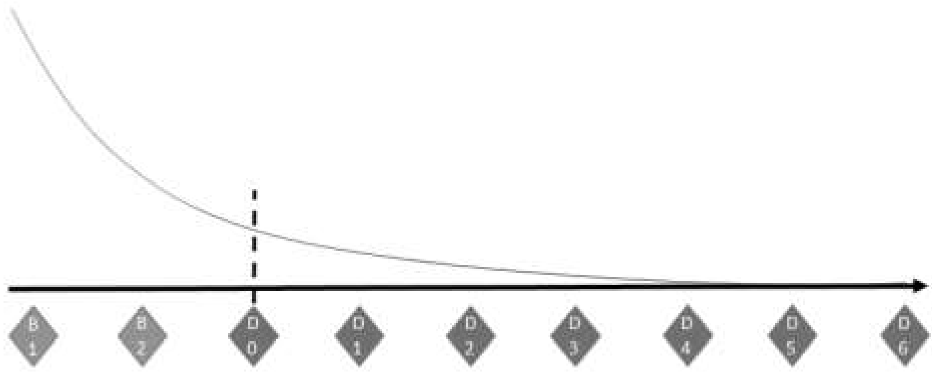


Figure 32 Gate model and uncertainty reduction

4.2 Research goals

The main goal of the study is to create a model of a tool that would serve as an effective communication method between a project and/or program manager and stakeholders to enable solution development related decision making easier in the case company.

In the first part primary target is to understand, to find out, the current status of matters in the case company. An answer to the question what is? On the other hand it is equally important to understand what is the aim, a targeted level, answer to the question what should be? What should be will frame the tool to be developed and will partially frame the answer to *RQ1*. Figure 33 describes the approach.

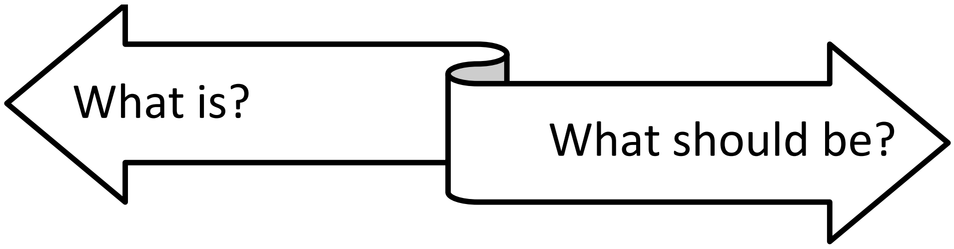


Figure 33 Research goals for the first part

In the second part primary target is first to develop and verify a proposal for a tool that would bring clarity to the solution readiness status in project, improve communication of the status in order to ease the decision making. The second part goal is to answer to *RQ2*. The ultimate goal is to validate the proposed tool and to provide an answer to the *RQ3* and validate preliminary answers to *RQ1* and *RQ2*.

Further the research goals for the study are following:

- To study how the existing maturity models would fit into case company's existing processes
- To find operating model/tool that best fit case company organization and personnel
- To provide means for easier decision making with the tool being developed for case company
- To provide means when evaluating whether the technology implementation could be started
- To provide means for risk evaluation process
- To provide means for comparison between two rival technologies/solutions

4.3 Research planning

Initiation

The research was planned in order to providing an answer to the internal customer need: to provide means for effectively communicating status of the development project/program in a standardized form. In order to provide means for correct, fact based, decision making on given status information in technology based technology function of case company. The research questions were helping to frame the thesis.

- *RQ1: What would the solution readiness assessment look like in the case company?*
- *RQ2: How to fit that into the case company's existing solution creation process?*
- *RQ3: Would solution readiness ease communication and improve decision making?*

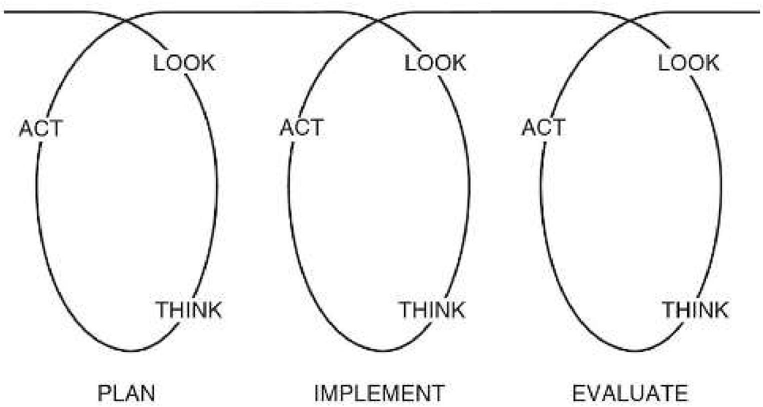


Figure 34 Action research interacting spiral. (Stringer 2013, 9)

Baseline - plan

After successful framing of the research arranging a group discussion in order to form a baseline for research was planned. The purpose of this phase aimed to understanding a) current state of matters and b) collective future direction. The assumption that the reasons for recognized challenges in this area was that possible problems were originated from poor management of technology, organizational history and culture, even company strategy and its relation to individuals role in their everyday job.

The first model proposal - plan

After defining status of matter the first model proposal was created.

Interventions – implement

Two interventions were planned. The first intervention to be done with a very basic prototype version of the solution readiness assessment tool in order to find out if there was room for further development. The results of the first intervention to be gathered by formal questions asked right after the assessment. Based on feedback the need for second intervention to be agreed and the second intervention to be carried out based on the feedback gathered after the first intervention and second intervention results to be validated by a survey.

Contribution and conclusions- evaluate

Based on results gathered and analyzed the further actions and studies to be recognized and recommended.

4.3.1 Selecting interviewees to define the baseline

To start with the research it was required to understand the starting point. For this purpose a focus group which later became steering group for the research was found. The six interviewees for the focus group were selected from the key main areas of technology function of the case company. Such key areas were recognized as following:

- usability
- market & customer function
- reliability laboratory
- concept development
- process development
- technology

4.3.2 Defining baseline - focus group questions

As the nature of the focus group is a flow where the focus group evolves in discussion. The discussion was performed with a two-way approach toward the research problem in order to gain enough confidence toward answering the research questions. On the other hand the researcher was interested in getting the answer to the base question “What is?” and on the other hand to the question “What should be?” These are the primary goals and in addition to these the following guidance questions were prepared and mostly also used during the focus group session because of the lively discussion.

- What kind of experiences we have from the history?
- What similar systems we already have in use?
- What would the suitable readiness level assessment be like at our company?
- What does the technology readiness mean to you?
- What are the requirements for the model?
- What would be the main risks while using this model in this organization?
- What is the role of the organizational culture in the whole picture?

4.3.3 Planning the interventions

The interventions were separated into two. The purpose of first intervention - 'dry-run' was to get limited amount of projects assessed and to find out if the tool was functional in its early development phase, if it included all the necessary view-points and to find out if it would suit case company environment at all. To accomplish the goal feedback after assessment was collected in a short discussion. In between the interventions was created an exit. If first intervention would not look promising the exit could be used and the research closed. The purpose of the second intervention was to validate the tool and report from the assessment with wider audience including more projects and stakeholders.

4.4 A baseline

Straightforward method used was group discussion. Discussion was recorded and analysis done by moving the discussion into a mind map. With the selected method information for history, present and future direction was mapped and baseline was clarified. Based on the baseline data the first model proposal was built. Part of the baseline information is sensitive and has been classified. General findings that form the basis for the proposed model and such information that can be included in the public version of the thesis are included in the chapter 4.4.6.

4.4.1 Analysis of the focus group discussion

The results were recorded and the discussion was analyzed by the use of mind map. As the first step of analysis the mind map was divided into the following relevant subtopics:

Information category	**Point of interest**
What is?	Organizational behavior, Present status, Issues coming from R&D way of working, Problems included
What should be?	Requirements, Vision, New technology process, Existing tools to be utilized in the model to come, Prerequisites
Technological challenge	Generally
What similar system are already used?	Generally
Risks related to current way of working	Understanding market area, Understanding the business risk, Understanding the customer, Business opportunity vs. technology opportunity
Real life cases discussed	Positive experiences, Negative experiences
Further questions/discussion	

Table 5 Group discussion topic divided into suitable categories

4.4.2 Interpretation of the results - Baseline of the research

This chapter is separately delivered to case company and will not be described in thesis text.

4.4.3 Technology management

This chapter is separately delivered to case company and will not be described in thesis text.

4.4.4 Organization

This chapter is separately delivered to case company and will not be described in thesis text.

4.4.5 Decision making

This chapter is separately delivered to case company and will not be described in thesis text.

4.4.6 Summary

The group discussion proved out to be really effective information collection method for research baseline understanding. The researcher was acting as facilitator and did not take part in the discussion. When the discussion was flourishing the most and was about to de-rail facilitator took role and put the discussion back on track. As a whole the discussion brought valuable insight to problems existing in company culture, company way of working and major problems that exists. Also mapping the future during the group discussion proved out to be useful as the outcome of the discussion together with what is? - section framed the solution readiness assessment well and made it easier to start developing the first model for the first intervention. The discussion’s result strengthened the view point of the researcher on most of the issues, enlightened possible problems residing in the company culture and brought new information for the researcher to start working with the model proposal for Solution Readiness Assessment. The discussion group became later steering group for the thesis.

Few most important findings were related to requirements mapping, lack of systems engineering utilization, losing the market momentum due to being slower in development than the rivals or the change in socio-economic environment. Also multiple rework was found to be done which is an outcome of previous. Risk avoidance and fear of failure is strong in the organization culture.

No extra bureaucracy was the first strong statement when moving into the what should be? - section during the discussion. Another was discussion on the existing processes and their fit on the model to be which was essential for framing the development. Competence development opportunity was recognized, as was an opportunity to provide an answer to often happening scope explosion during development. Providing entry and exit criteria for different development phases was also recognized as an opportunity and an interesting point was discussed on the following sentence: “Risk taking is advisable when the facts are formalized on some tool.” Also use of risk chart was discussed as a powerful way of visualization.

4.5 Proposed solution readiness assessment (SRA) model

This part of the thesis combines theory to practice and aims to find an answer the *RQ1* and *RQ2*. The baseline data collected is to be combined with proper theories and the end result will represent the initial answer to *RQ1*. As a solution to *RQ2* the technology lifecycle model available in Figure 18 and case company’s development gate model will be set as basis for the solution and included in the proposed SRA model.

Due to an urge toward trying to correct observed TRL challenges, trying to understand, to control uncertainty, and follow-up of the program progress there has been proliferation from the original TRL model that have led to variety of uses e.g. Manufacturing Readiness Level (MRL), Integration readiness Level (IRL) and System Readiness Level (SRL) (Nolte 2008, 77-79.) The proposal is partially based on recommendations for theoretical frame of readiness levels set by both (1) Mankins (1995) and (2) Nolte (2008.) Features that every Readiness Level tool should include:

(1)

- ”Basic” research in new technologies and concepts (targeting identified goals, but not necessary specific systems)
- Focused technology development addressing specific technologies for one or more potential identified applications
- Technology development and demonstration for each specific application before the beginning of full system development of that application
- System development (through first unit fabrication) and system ”launch” and operations (Mankins 1995.)

(2)

- Readiness levels should be captured in requirements definition
- Readiness levels should include logistics
- Readiness levels should include integration
- Readiness levels should include human/system interface etc (Nolte 2008, 79.)

As the *RQ1* & *RQ2* states the main target for the thesis is to study existing models and to create a proposal that would best suit case company’s targets and ambitions, improve communication, provide means for evaluating solution maturity and in the end ease the decision making. Based on the initial baseline analysis’ “what should be?” that aimed to create the criteria for working model that would fulfill the needs of both project management and stakeholder parties in order to creating added value for communication, clarity to the solution readiness state and the most importantly ease the decision making in the case company.

Recognized difficulties for finding an effective way of communication in order to being able to make decisions effectively and on the right subjects were defined as the most critical items for success of the proposed model. Based on the finding from baseline study. There was challenges to keep immature technology away from the early business pull in case company as well as problems to define the correct market area and market segment for the solutions under development. One of the most important must-have features that rose up was no need for any extra bureaucracy that maturity assessment might easily be causing to already complex solution creation process in case company. On the other hand it would have required too much effort in thesis scope to alter existing solution creation process to meet the requirements of the tool. It was decided easier to alter tool under development to match existing solution creation process of the case company. Price for the decision might reduce the reliability of thesis in some other environment. The Solution Readiness Assessment proposed in this thesis adds to the population of *RLs yet another approach which bases on TRL scale and follows the logic of ideate-verify-validate that already forms built-in logic behind the Solution Development Process in the case company being also the main idea behind the "Vee" model and existing *RL models. The decision for creating a novel model that uses the ingredients of existing models was agreed since TRRA even following similar logic was found too bureaucratic and difficult to use as it is presented in Mankins (20009a.) This agreement also makes it easier to answer the research questions *RQ1* & *RQ2*. The sample output of proposed model is shown in Figure 25.

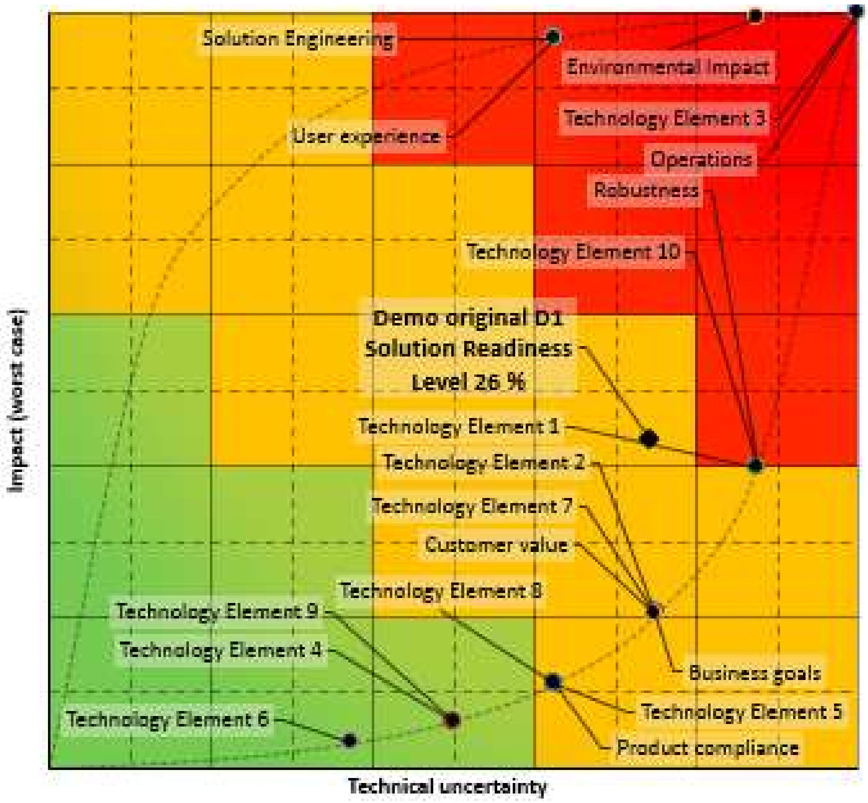


Figure 35 Proposed SRA model including all provided critical solution elements

Keeping simplicity in mind the original Mankins TRL was defined as a starting point since the scale ranging from 1 to 9 is simple enough to form the basis for the assessment model and could be easily adopted by both user groups (project managers and stakeholders.) A key to adoption success lies within Venkatesh and Davis (1996) model shown in Figure 14. A tool requiring too much effort to adopt might have risk the effective implementation and might create friction inside the company due to its complexity and added level of bureaucracy. TRL is selected because it is self-evident, clear and rather well documented to meet the thesis scope and schedule. It is also easier to understand by project managers compared to R&D[3], TNV and similar tools developed to fill the gaps of the original model that is reviewed in the theoretic frame of this thesis. Criticism to the original TRL model, it being too subjective and lacking dimension of severity in some parts of the development. Partly due to this feedback toward the TRL the Mankins' revisited model is taken into use partially. The risk chart is added value to communication due to being familiar in the field of business and widely recognized visualization element to highlight risk. In addition to already mentioned reasons for a novel method and output training effort would have been enormous as the concept of TRL alone is new to the case company on the principle level. On the other hand more depth to traditional TRL assessment is necessary and an additional impact on the y-axis that is defined with mathematical formulas based on the subjectively quantified as objective-as-possible Readiness Level value. Similar approach that Mankins (2009a) chose when revisiting TRL in his TRRA model.

4.5.1 From assessment to visualization

Assessment process leading to visualization is rather straightforward. Assessment is performed in a form of a discussion by use of pre-defined guiding questions that are fixed and follow the case company's solution development process steps. Unlike different TRA models using a specific questionnaire The main purpose of the assessment is to purge the understanding of the project manager or the development team out (Figure 35) and form a well visualized and standardized view into developed solutions' readiness. The process to achieving case shown in Figure 35 is explained in Figure 36.

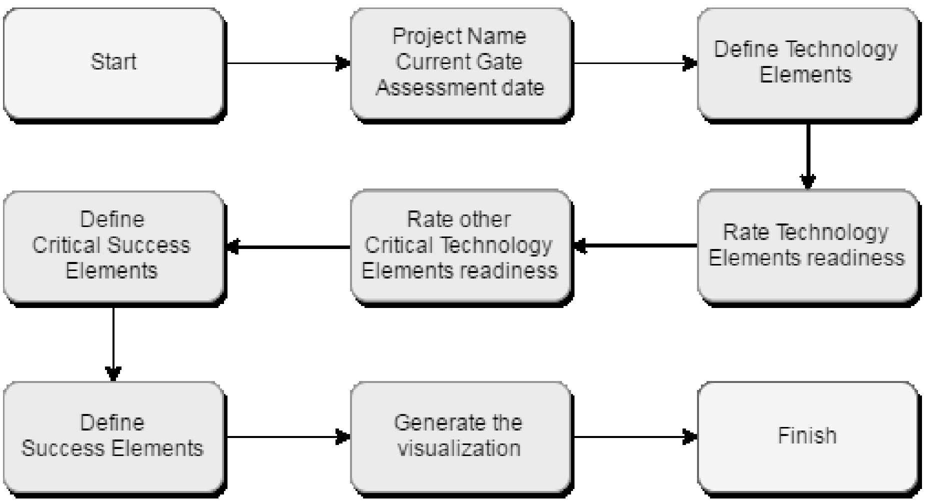


Figure 36 SRA process flow

There is a built in subjectivity included in this way of assessing the readiness. In order to overcome biggest edge of dishonesty it is recommended that the project manager is honest first to him/herself and then for the solution development project and people involved. Not being honest will lead to delays, budget overruns etc. as the readiness will be falsely communicated. This kind of behavior will null the added value created by assessment and flowing visualization. The subjectivity itself may not be bad at all since the project manager is the one understanding the status the best and the purpose of the whole assessment session is to visualize internal view of a manager and/or team to an understandable, well visualized format that is both standardized way of communication, able to provide clarity and able to guide the discussion to the hot topics that are lagging behind in the solution development project compared to e.g. schedule.

4.5.2 Visualization aspect

Based on Mankins (2009a) TRRA a visualization by a risk matrix was seen as critical success factor to provide clarity and simplified and standardized way to communicating the readiness of solution. When the illustration is included in status report/presentation the assumption is that it provides a holistic, systemic view into the maturity of the solution when compared to any set of slides with text, formulas or similar hard to catch elements. Additionally hypothesis is that by providing at-a-glance view into the readiness would also provide means for effective fact-based decision making. A simple graph tells much more of the status and brings the discussion right to the point, even eases the decision making as the end result. Selections such as the use of TRL scale and building a way to visualize the maturity made up a model that is very visual and provides uncertainty/risk level and status in compact package. These factors lead to the finalized model that utilizes TRL scale as basis for both x-axis. By adding an automated impact calculation for y-axis makes the core of the proposed model. The background of the x-y-plot, the outcome, of the assessment is the familiar risk map in a similar way that Mankins did when returning back to the TRL in pursue to make the original scale less subjective (Mankins 2009a.) Figure 37 shows the visualization described above, this is an empty illustration that will be populated with critical solution elements (CSE) during the assessment.

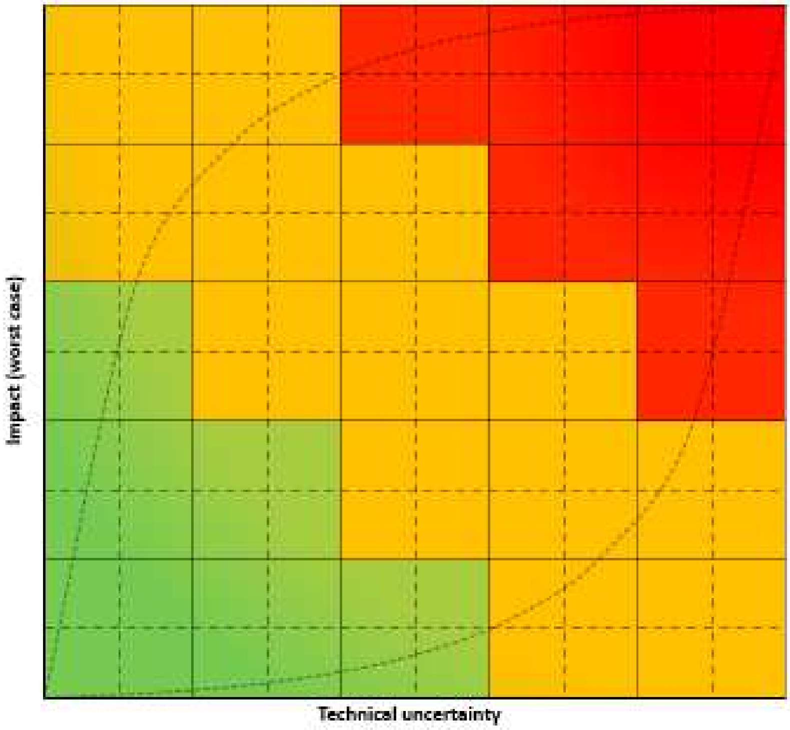


Figure 37 Empty Solution Readiness Assessment report – power of visualization

4.5.3 Critical Solution Elements - CSE

The visualization alone does not provide and guarantee means for providing meaningful content of the solution readiness. As in the original TRL the idea of defining Critical Technology Elements (CTE) was reused and *Critical Solution Elements* (CSE) were defined to provide an insight into the solution maturity from various viewpoints required for successful development and implementation of the solution. In the long run there’s also organizational growth and cumulative learning and knowledge management opportunities included as the socio-economic environment case company operates in requires many viewpoints that this kind of tool would easily include. Most of the CSEs come from case company’s selected diversification and cost-cut point-of-views e.g. *environmental impact*. The final Solution Readiness Level can be seen as a sum of all the CSEs. Reason for solution development comes directly from corporate strategy and competition. Technology readiness is an integral part of the solution and it was chosen to be plotted per *technology element* on the chart. The other elements cumulate from subcategories that relate more deeply into the challenges cumulating from the socio-economic environment e.g. *market area*, *customer need*, *user experience*, and *operations* like *installation* and *logistics*. In total there are included in proposed model 9 *Critical Solution Elements*. Each of these consist of 1-6 *subcategories*. Proposed *Critical Solution Elements* and their *subcategories* defined for assessment are listed in the Table 6.

Critical Solution Element	Subcategories
Technology Elements	0-10 Critical Technology Elements
Environmental Impact	Lifecycle energy efficiency (manufacturing, logistics, in-use) Materials selection acc. to internal/external rules Recyclability and/or reusability of materials defined Durability, lifetime End of life treatment for selected materials
User Experience	Usability
Robustness	Reusability of existing components Feasibility Simplicity of system/component
Customer Value	Market segment defined Market area defined and agreed Customer values defined
Business Goals	Business Case Full chain cost estimation (should-cost-analysis)
Product Compliance	Code compliance (market area, market segment) Patents and IPR
Solution Engineering	Characteristics defined Modeling architecture defined IT-architecture (security included) defined Modularity Requirements set Product modeling
Operations	Manufacturability Installation Maintenance

Table 6 Critical Solution Elements (CSE) and subcategories

Each CSE can receive a readiness value between 1 and 9, also non applicable is available in case that the specific CSE is not critical for the solution under development. The CSEs will be explained in more detail below. The order of CSEs in the Table 6 is exactly the order that the CSEs are gone through during the assessment. The order of appearance is critical because most of the criteria are intertwined and may require back-and-forth movement between CSEs during the assessment. It is easy task to think first technology related criteria and then dive deeper into understanding of the status and in some cases the scope. As the CSEs are receiving a grade between 1 and 9 and there are several subcategories under one CSE only the worst case is affecting the whole CSE figure which is then plotted on the graph. For example there can be a CSE with 3 subcategories of which 2 receive readiness level of 7 and the third receives a value of 3. In such case the overall CSE plotted in the illustration will be shown as 3 and impact based on the TRL and equation 2 or equation 3. Readiness level is always plotted as a worst case. An example shown in Table 7 where Life cycle energy efficiency for some reason has not been maturing together with the others lead to overall maturity of 3.

Environmental Impact	**Uncertainty**
Life cycle energy efficiency (manufacturing, logistics, in-use)	3
Materials selected according rules internal/external	9
Recyclability and/or reusability of materials defined	9
Durability, Lifetime	9
End of life treatment for selected materials	9
Critical Solution Element Readiness	**3**

Table 7 CSE worst case logic

Technology Elements

Technology elements form the frame for the whole assessment as the model was created for case company that is operating in the high-technology business. This is the way to pursue competitive advantage in the competition. These inputs are free fields during assessment and can include also project specific criteria if seen necessary e.g. safety.

Environmental Impact

Sustainability is becoming more and more critical in business. For case company it has been source for strategic diversification for a long time and the results are already positively seen in business. Customers have and will grow their environmental awareness, global agreements on reduction of e.g. carbon emissions, use of energy and sustainable growth have been agreed (Paris 2015.) This is essential for all businesses and a must in case company.

User Experience

Already before the ongoing transformation user experience has been an integral part of case company's strategy. Their vision. In future the user experience will grow its role even more as the direction is from b-2-b business to b-2-c and service development.

Robustness

Reliability is source of diversification in strategic level. The products of the case company require high level of usage as traditionally the different manufacturers are recognized in case of malfunction and/or failure. In case of failure cost may be high and even lethal accidents has been met in the industry that have forced companies to completely withdraw from certain market areas. There is also monetary value included in creating robust enough solutions. The primary business is selling new units, simplified design is cheaper from cost point of view and more reliable. Secondarily business benefit is coming from reduced amount of service repairs and safety & quality accumulating from more reliable solutions.

Customer Value

The baseline indicates certain difficulties in determining customer value, market area and market segment for the solutions under development. Customer value as CSE is a must for overall solution readiness assessment. There are both strategic and technological aspects supporting this as customers seek for value and enterprises task is to provide it in competition. Being in right market and correct market segment with the right product offers competitive advantage.

Business Goals

These are the money makers that provide revenue to an enterprise. Business Case is naturally familiar tool to case company and full chain cost must be understood in order to provide and improve cost-efficient installation and maintenance and spare part operations and delivery activities as a whole.

Product Compliance

Intellectual Property rights form a backbone for competitive advantage and set limits and boundaries to enterprises innovativeness. It is a natural selection for solution readiness assessment. Codes and standards form boundaries and limitations for enterprises as well. Therefore these must be included in the assessment to guarantee safe and compliant products to customers.

Solution Engineering

Solution Engineering includes everything immaterial that needs to be done in R&D project and organization during the development project and upkeep of immaterial data during the lifetime, product lifecycle management included. In solution creation needs to be assured that these activities are properly done and the solution is mature enough to be transferred for product lifecycle management function. Following the Systems Engineering principles and good project management practices it starts with definition of requirements and definition of order characteristics that define the framework for the whole solution (master offering.) To supplement this good engineering principles like modularity, modeling architecture and product modeling need to be followed to guarantee professional outcome. IT-architecture is another kind of subcategory to be followed in service development as it sets its own requirements for e.g. cybersecurity when developing solution for the new b-2c and overall service development.

Operations

The operations are backbone of successful business after the solution development. One may have the greatest innovation in the world but when it cannot be e.g. manufactured, installed, maintained, ordered or transferred to customer there will be no business. Only monetary loss as the customer promise needs to be fulfilled.

4.5.4 Defining impact on SRA

As Mankins (2009a) created TNV and R&D[3] to be used as factors that aim to describe time required to next TRL and measure of difficulty for an effective communication this model utilizes two different curves that communicate both the criticality for success (critical success factor, success factor) and simultaneously an impact that follows two predefined curves seen in the Figure 37. The curves are roughly following the uncertainty and TRL Figure 23. The purpose of this selection is to define whether the CSE is critical for a successful release of the solution or whether it is less critical, in other words, “a regular” one (business-as-usual.) The selection requires a solid understanding over the solution under development which serves greater success if the solution is released e.g. in required time. Based on their readiness level and calculated impact the illustration populates as the approximated values for impact are defined by use of the Equation 2. CSE’s on upper curve which represents critical success elements is populated by selected items and the approximated values for impact by using the value that is combination of readiness level as input to Equation 3.

$$y_{se} = \frac{8x^2 - 80x + 801}{-80x + 801}$$

Equation 2 Formula for a success element curve on SRA matrix curve approximation where x=2…8

$$y_{cse} = \frac{-8x^2 + 880x - 791}{80x + 1}$$

Equation 3 Formula for critical success element curve on SRA matrix curve approximation where x=2…8

X	SUCCESS ELEMENT (Y_{SE})	CRITICAL SUCCESS ELEMENT (Y_{CSE})
1	1	1
2	1,050	5,820
3	1,128	7,373
4	1,266	8,103
5	1,499	8,501
6	1,897	8,734
7	2,627	8,872
8	4,180	8,950
9	9	9

Table 8 Impact success elements and critical success elements

4.5.5 Calculating average for overall readiness plot

To highlight the overall solution readiness one point is defined to represent overall solution readiness. It is combination of readiness level average and impact average. The details for certain rules affecting the average calculation are described in this chapter.

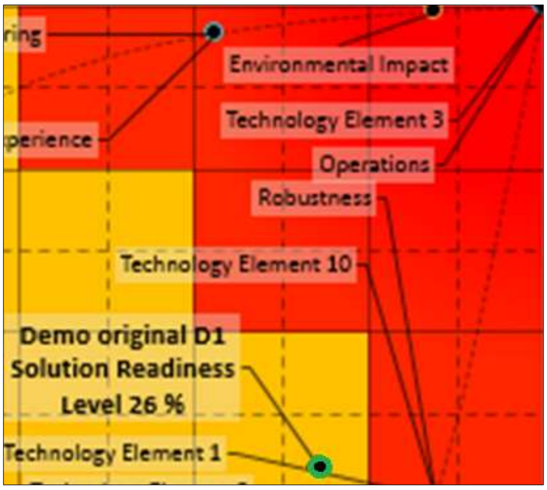


Figure 38 Overall readiness and impact plotted on visualization risk matrix

Readiness level 6 has been set in literature as recommended start for implementation. The average calculation will be defined in a following way to guarantee development in every CSE. The formulas shown in this chapter are excel 2013 compatible and validated to be functional.

– E9:E27 CSE readiness levels defined during assessment, range 1 - 9

To define E28 the first IF statement checks the amount of cells in the E9:E27 range with a readiness value <6. If at least one fits the criteria average of E9:E27 range when value <6 will represent overall readiness (x-axis.) Else if all the values are >=6 in E9:E27 range the average will be defined by calculating an average of values >=6 to represent overall readiness.

```
E28=IF(
    COUNTIF(
        E9:E27;
        "<6"
    ) > 0;
    AVERAGEIF(
        E9:E27;
        "<6";
        E9:E27
    );
    AVERAGEIF(
        E9:E27;
        ">=6";
        E9:E27
    )
)
```

– E9:E27 CSE readiness levels defined during assessment, range 1 - 9
– F16:F34 CSE impact, equation 2&3 with readiness level, range 1 - 9

Same logic applies when defining F28 the overall impact (y-axis.) E9:E27 is checked for values <6. If at least one value <6 the average of values <6 in F9:F27 range is calculated to represent overall impact (y-axis.) When all values on E9:E27 range are >=6 the average is calculated from average of values >=6 in F9:F27 range.

```
F28=IF(
   COUNTIF(
       E9:E27;
       "<6"
   ) > 0;
   AVERAGEIF(
       E9:E27;
       "<6";
       F9:F27
   );
   AVERAGEIF(
       E9:E27;
       ">=6";
       F9:F27
   )
)
```

	A	B	C	D	E	F
8		Critical Success Element	Critical Success Element	Success Element	Uncertainty	Impact
9		–		X	6	8,734
10		–		X	6	8,734
11		–		X	6	8,734
12		–		X	6	8,734
13		–		X	6	8,734
14		–		X	6	8,734
15		–		X	6	8,734
16		–	X		6	1,897
17		–	X		6	1,897
18		–	X		6	1,897
19		Environmental Impact	X		6	1,897
20		User experience	X		6	1,897
21		Ride Comfort	X		6	1,897
22		Robustness	X		6	1,897
23		Customer value	X		6	1,897
24		Business goals	X		6	1,897
25		Product compliance	X		6	1,897
26		Solution Engineering	X		6	1,897
27		Operations	X		6	1,897
28		Solution Readiness Level	1,0	0,7	6,0	4,4

Figure 39 Excel screenshot with ranges E9:E27 and F9:F27 for averages E28 and F28

4.6 First intervention

As planned the initial ‘dry-run’ was seen necessary to prove the usefulness of the model in its proposed state and see the illustration in real environment. The first intervention was performed with selected participants that represented the whole development from research phase to released product. Getting first feedback in this case is important in order to define whether or not the proposed model fits the case company and if it has all the ingredients for a successful implementation in place. Reason for this approach comes straight from the *RQ1 & RQ2.*

4.6.1 Selecting ‘dry-run’ cases for the first intervention

Seven development projects in different stages of the solution creation process in case company were chosen. Projects were mainly chosen randomly but it had to be taken into account that projects related to different technology categories of case company were present. Majority of the assessments were performed for Finnish projects, one case was managed by a Chinese colleague.

1. One system level project released Finland
2. One system level project early research Finland
3. One component project (major scope) end of research Finland
4. One component project (major scope) end of research Finland
5. One medium sized component project implementation Finland
6. One minor scope component project nearly released Finland
7. One minor scope component project research China

4.6.2 Dry-run - first intervention

The assessment was fast and successful in all the cases and most of the feedback was positive during the brief discussion that took place in the end. Discussion included questions What do you think about this? Would it be useful for you in the future? The aim was to find out if the tool was useful in case organization. The ultimate goal was to verify if the customer need recognized in the baseline study was correctly found. The negative side of the feedback was mainly related to guiding questions as the CSEs were only defined by this phase. Constructive feedback was also received for naming of the *Critical Solution Elements* since those were not clear enough for the first time users. Resulting feedback was an expected outcome as the questions were poorly defined in this stage, mainly following the NASA TRL descriptions ‘proven in space’ included. Regardless of guiding questions and naming related issues the tool proved its usefulness and ease of use as none of the project managers disliked being assessed with their project and were happy with the outcome. During other major component development project an issue with crowded figure was met. It was agreed that this is a clear sign of too big scope and a message for steering group that it needs to be cut. It was also agreed that too big projects need to be assessed in reasonable subproject contents. Another learning took place during the next assessment session where early research system level development project was assessed. The learning from previous assessment was taken into test and only on sub-technology of the full system was assessed. The assessment went well but it was agreed to be more clear when the full development project is first assessed and only then the relevant subprojects will be assessed.

> It would have required at least five slides to show the status and yet no one would have understood.
>
> Program manager

> That is exactly how I see the status.
>
> Project Manager

> Visualization is excellent
>
> Project Manager

> It's easy to use
>
> Project Manager

4.6.3 Interpretation of results

The first intervention was successful as the most common feedback being "This is exactly how I see the status." The finding with scope being too big and handling of large projects was valuable learning. Also visualization proved to be powerful. A component project in the end of research was looking in visualization so immature that it was returned back to research mainly because of the proper way to communicate the readiness. Assessment took roughly an hour and the visualization was available right after going through the process. The use of the tool that was created in excel was found to be friendly enough albeit percentage calculation of the average was not yet to be finalized.

All in all the model looked very promising already on the simulations. As minor iterations to the tool were done after each of the test assessments some minor feedback may have been lost along the way but above listed were the major findings. All findings and iterations took place based on the observations of both the researcher and assessed projects project manager right after the assessment. The iterations were either correcting mistakes and illogicalities or improving the model. Based on the positive feedback for the use of tool and its ability to clarify complex matters into a simple graph the second intervention with correction was agreed.

4.6.4 Summary

Targeted goals were met incredibly well with a model proposal in very early status. This proves that the baseline study findings were correct and that the vision set in the baseline study was fulfilled. A model proposal having risk matrix as a background seems able to visualize solution readiness in acceptable levels. The defined CSEs are good enough as no feedback is received concerning these. No additional requests other than correcting guiding questions that are not easy to approach in current state as those are taken directly from the NASA TRL descriptions. Model works and proves to be worth developing further. Positive feedback received for ease of use and added value for project manager's communication. *RQ1* and *RQ2* can be considered to be partly answered, verified. Early signs for *RQ3* communication part received as well.

4.7 Second intervention

The second intervention took place with findings from the first one in mind. The audience was bigger. The feedback from participants of first intervention was kept in mind and the naming of CSEs was changed to better match terms familiar in organization. Forming the questions was found out to be a challenging task as the CSEs differ largely from each other. The definitions for guiding questions were finalized during 4 workshops with the thesis' steering group and included in intervention as soon as a CSE was finalized. The intervention was global. The results of the second intervention were found out by a survey. Results were analyzed and conclusions done.

4.7.1 Second intervention – 'piloting'

The starting research and development projects were assessed systematically and the time usage of an assessment was steadily set around an hour. Some major development projects took half an hour more but two parallel projects sharing same platform were present. Piloting was global and included American, Chinese, Finnish, Indian and Italian development projects. The direct feedback was mainly positive and the survey was performed. Survey was launched right after the amount of piloted projects reached 23. Survey results were analyzed and improvement ideas, negative and positive comments were collected from the participants. The comments were given via survey (https://www.webropolsurveys.com) after the second intervention.

4.7.2 Selecting piloting cases for second intervention

The pilot projects for the second intervention, were selected randomly among starting and/or ongoing concept and/or development projects. The reason for this selection was that they'd get used to use the SRA (Solution Readiness Assessment) tool through the project lifecycle and most importantly to guarantee that no immature solutions were entering the implementation process.

4.7.3 Survey after the second intervention

The quantitative survey was generated and the numerical values were based on Likert scale. 23 invites. Survey had following questions (1-3) for qualitative analysis and statements (1—12) for quantitative analysis. Scale from strongly disagree to strongly agree and option for don't know/can't say was used:

1. Strongly disagree
2. Disagree
3. Agree
4. Strongly agree
5. Don't Know/Can't Say

Free fields

1. What in your opinion is best in SRA?
2. What would you change?
3. What is missing?

Statements

1. Solution Readiness Assessment is useful
2. There has been need for such a tool
3. I learned something new about my solution creation project
4. SRA helped me to understand the status of solution of my project
5. SRA helped me to prepare for steering group meeting
6. SRA helped me to communicate the status of my project
7. SRA helped me to identify new critical success elements of project
8. SRA is not waste of time
9. SRA increased focus in steering group meeting
10. SRA guided decision making in steering group meeting
11. SRA will lead to more mature solutions
12. SRA is simple enough to be done within a project team

4.7.4 Results

The response rate to survey was (14 out of 23 responses - 61%) which seems fairly good. The overall summary of results (Table 9) shows that preliminarily the added value of the model is strongly on the positive side. No direct conclusions may be taken from this amount of answers. Nevertheless the direction seems clear as the amount of negative (disagree) is rather small 12 in total which equals 9,3% of total without DK/CSs and 8,3% of all given answers. No strongly disagree answers received. What concerns is the amount of DK/CS's in the key questions like Q9 and Q10. Amount of DK/CSs is 18 and respectively 12,5% that might be a sign of too early timing for the survey. When leaving Q5, Q6, Q7 and Q11 out the amount is 11 and 7,6%.

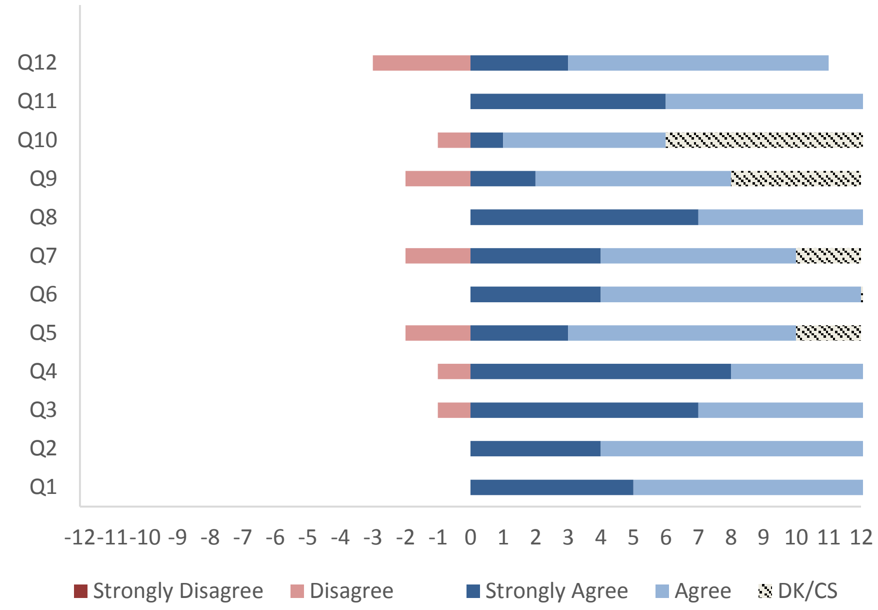


Table 9 Overall summary of survey

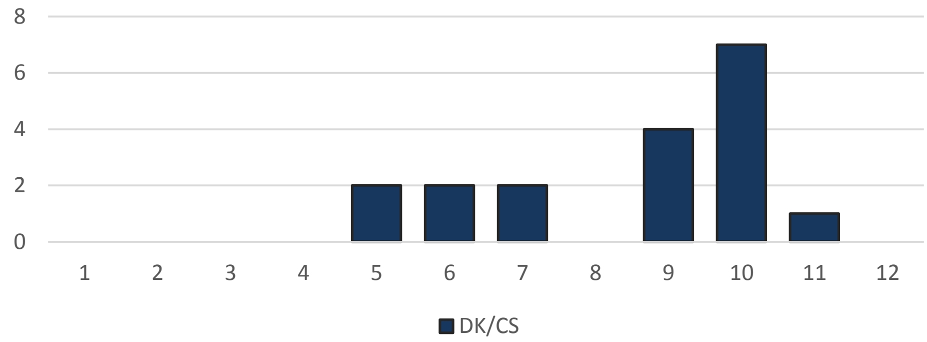
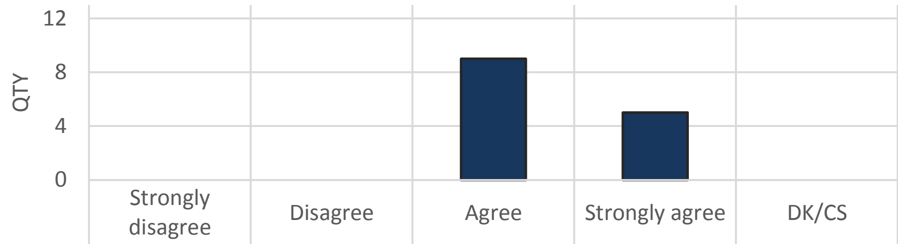


Table 10 Amount of answers in Don't Know / Can't Say category

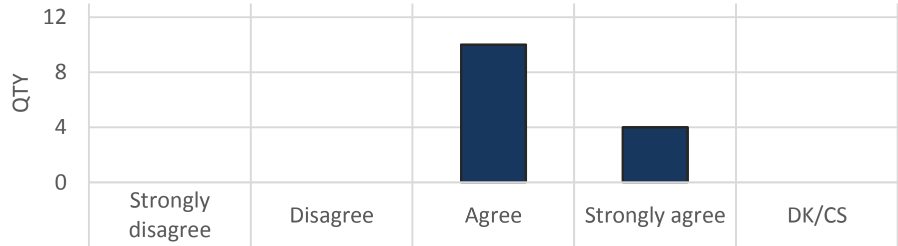
Table 10 describes the amount of DK/CS answers given in the survey. Q5, Q6, Q7 and Q11 are not of concern and can be treated as normal. Either the steering did not take place for the projects yet or the project manager is an experienced one. Q9 and Q10 may affect the final estimation of research success on *RQ3* as the statements are related to steering group behavior as only 10 answers for Q10 and 7 answers given for Q10. These need to be studied further to guarantee reliability of results.



	Strongly disagree	Disagree	Agree	Strongly agree	DK/CS
Q1	0	0	9	5	0

Table 11 Q1: Solution Readiness Assessment is useful (μ=3,36 σ=0,49)

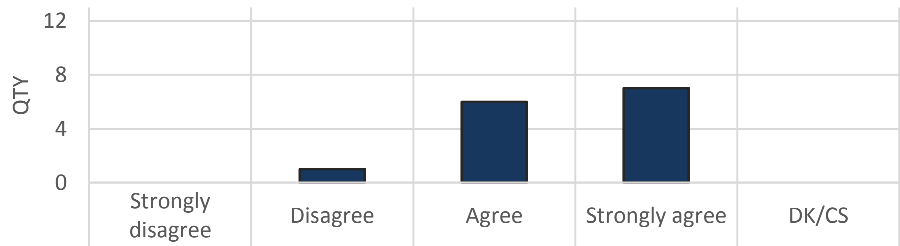
This statement was looking for users opinions on acceptance and the added value that the developed model is providing to their daily use. According to given answers the users opinions are supporting the use of model in case company



	Strongly disagree	Disagree	Agree	Strongly agree	DK/CS
Q2	0	0	10	4	0

Table 12 Q2: There has been need for such a tool (μ=3,29 σ=0,47)

The answers to this statement underline a strong opinion that the usefulness of the tool is on a good level to be able to ease ones everyday work. It also indicates that there has been a gap that is now filled with SRA.



	Strongly disagree	Disagree	Agree	Strongly agree	DK/CS
Q3	0	1	6	7	0

Table 13 Q3: I learned something new about my solution creation project (μ=3,43 σ=0,65)

Answers to this statement are probably dependent on the experience and knowledge. Some thought the tool helped to frame the development in business context. The result indicates an opportunity in this field e.g. in organizational learning due to large amount of strongly agree answers.

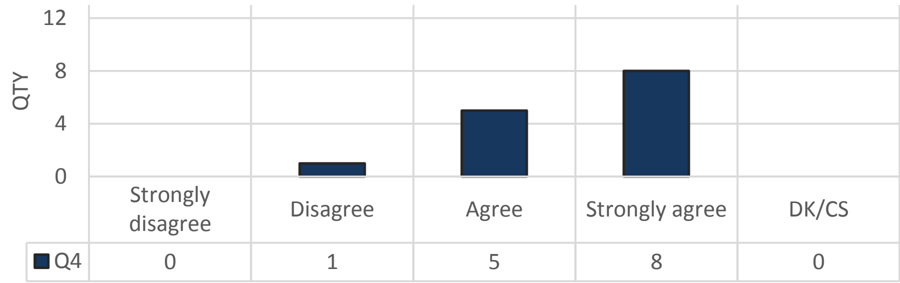


Table 14 Q4: SRA helped me to understand the status of solution of my project (μ=3,5 σ=0,65)

Here is an interesting result especially when put together with Q3. This indicates that CSEs relevant for case company's needs are properly defined and widen the viewpoints from traditional technology ahead mentality into a wider perspective of the company in its socio-economic environment.

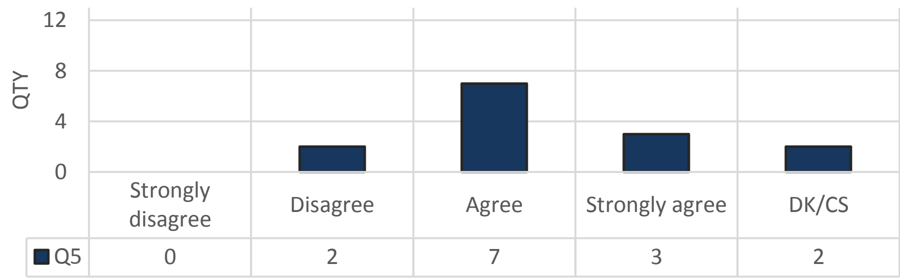


Table 15 Q5: SRA helped me to prepare for steering group meeting (μ=3,08 σ=0,67)

Amount of DK/CS answers in this makes it hard to judge and it would require more studies to directly interpret the effect. Overall agreement seems evident and probable reason for disagrees is the experience of an individual who has answered or there has not been steering meeting which leads to the topic of launching the survey too early.

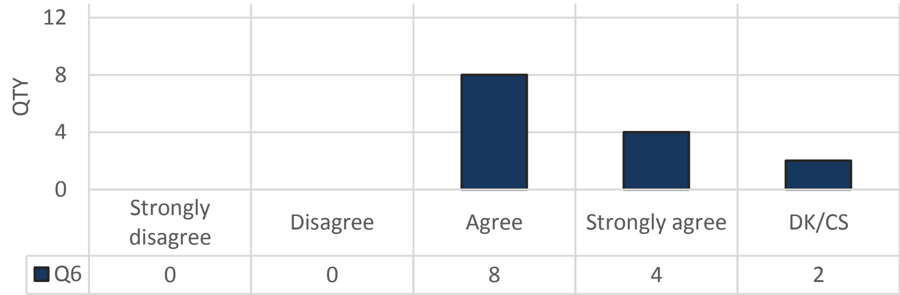


Table 16 Q6: SRA helped me to communicate the status of my project (μ=3,33 σ=0,49)

When Q6 is put together with Q5 the agree and strongly agree pop up as a majority. SRA itself may not help to prepare for steering meeting but it definitely does help in communication.

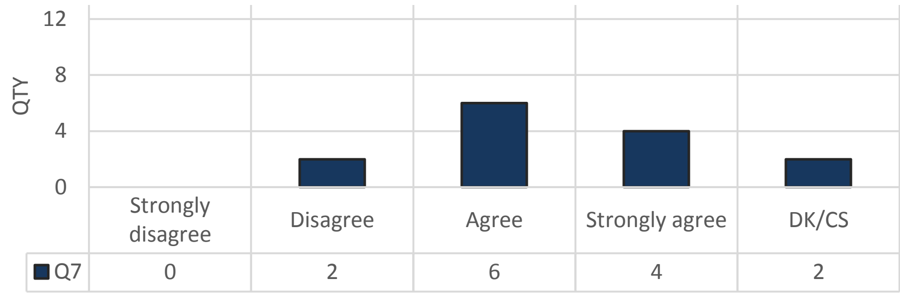


Table 17 Q7: SRA helped me to identify new critical success elements of project (μ=3,17 σ=0,72)

Either the statement is too difficult or Q3 and Q7 eventually measure different things. Q3 measuring learning seems more evident than Q7 measuring identifying new critical success elements. Nevertheless the answers are leaning slightly on the neutral zone as amount of disagrees is 2.

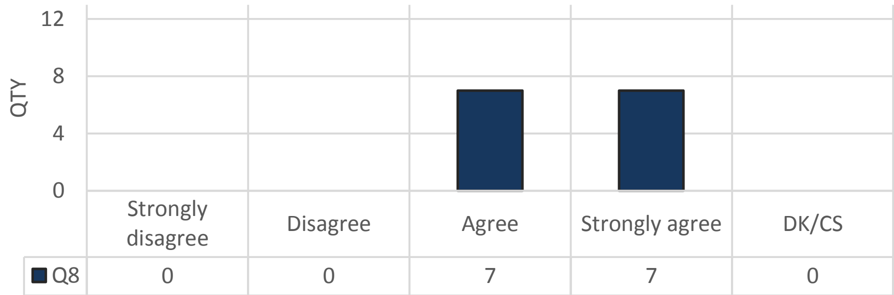


Table 18 Q8: SRA is not waste of time (μ=3,5 σ=0,52)

This supports that there has been both need for such tool and on the other hand it indicates the added value and ease for one's everyday tasks provided by SRA.

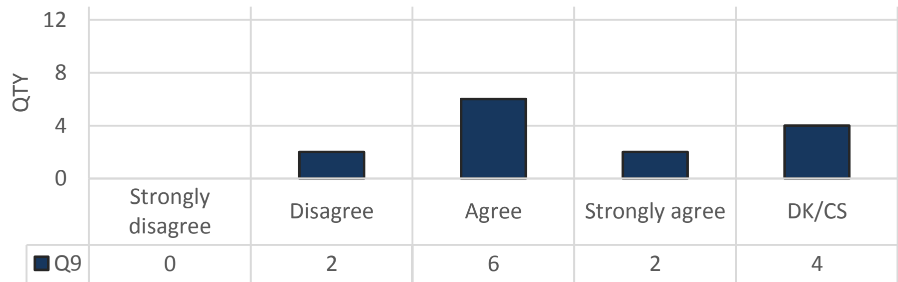


Table 19 Q9: SRA increased focus in steering group meeting (μ=3 σ=0,67)

An interesting statement that clearly was launched too early. Many answers indicate DK/CS, 2 indicate disagree. Still amount of agree seems to stand out from the rest. No final indication of focus increase in steering meetings can be given as mean stands in 3.

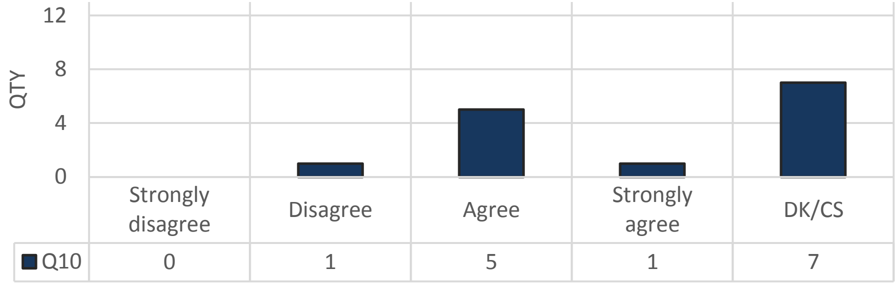


Table 20 Q10: SRA guided decision making in steering group meeting (μ=3 σ=0,58)

Another interesting statement from research point of view also indicates that survey was poorly timed. The amount of DK/CS answers stands out. On the other hand given answers indicate agree but mean stays in 3 with relatively big standard deviation.

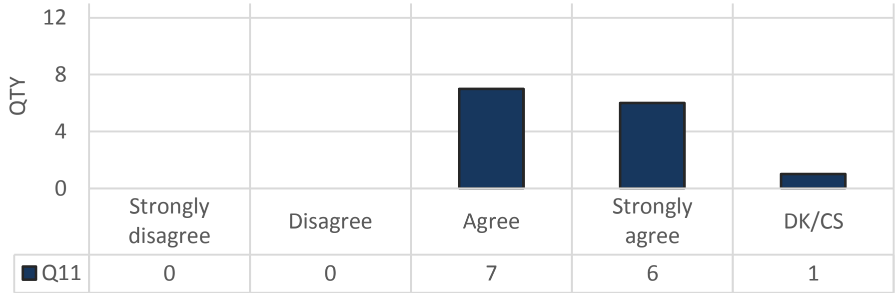


Table 21 Q11: SRA will lead to more mature solutions (μ=3,46 σ=0,52)

This provides proof for recognized learning opportunity as amount of agree and strongly agree is high. DK/CS will not matter in this case as there are no disagrees or strongly disagrees given. In the long run the SRA could also provide basis for accumulating knowledge on the holistic view to solution development.

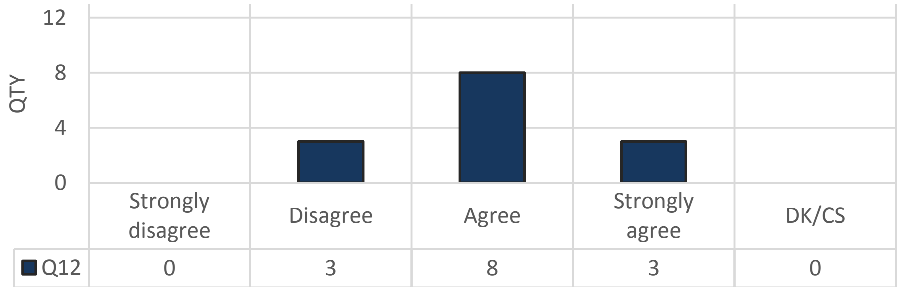


Table 22 Q12: SRA is simple enough to be done within a project team (μ=3 σ=0,68)

There might be cultural differences among the answers given for this statement. Overall satisfaction can be seen from the answers with a reservation for mean being 3 and relatively big standard deviation.

Q1: What in your opinion is best in SRA?

- *Better risk assessment is possible with the new template compared to the earlier known one*
- *This risk assessment covers the entire gamut of product development cycle including solution readiness in blue boxing. which is new to me*
- *The assessment criteria's give an insight for the upcoming blue projects how to holistically manage the risk on all area*
- *Visual impact of project readiness give the idea of what are next steps to be accomplished*
- *The harmonized way to communicate*
- *Explicit definitions*
- *I liked the unified image, where all the parameters were taken into account*
- *It seemed as if it was a work in progress, but I do feel such a tool is needed*
- *What is best in the SRA is the graphical way to show the readiness of the project. For steering members who maybe are not very involved in the technical part is very easy to understand the status of the solution in a very visual and simple way.*
- *It allows to easily visualize the status of the project in its different aspects along with the criticality of each aspect. This way, time and resources can be managed more wisely on the project*
- *SRA graph is very effective way to present the status of the project in Steering meeting*
- *The process of creating the SRA have been very quick and it has been good chance to discuss about project from different angles*
- *Discussing about the project with person outside the project help me also to find out some new interesting topic of the project that should be deeper analyzed for better understanding of the status*
- *Identify most critical issues in blue project*
- *Give a picture on where project is*
- *Provide common criteria for all the projects*
- *To get an overview of the concept maturity*
- *All the support what PM can get before Steering is important*
- *Best in SRA is agreed way how to measure and show status in Steering*
- *SRA is such tool we can easily understand and, do quick analysis of blue project to know the situation of critical items.*
- *We can use the tool to focus on weak points and get it ready before the steering.*
- *In general, it's easy, simple and useful*

When analyzing the most used words, the word project pops out since it's mentioned 12 times, word way is mentioned 6 times, SRA, status, steering and very 5 times. The comments are related to clarity of visualization which is mentioned several times. Also estimations on effective communication in steering meetings are mentioned. Adjectives used to describe positive sides of the tool are e.g. effective, best, visual, simple, wise, quick, standardized, harmonized and easy. Verbs used are related to means of communication e.g. to communicate, to show, to measure, to present, and to provide.

Q2: What would you change in SRA?

- *When we reviewed the project with this SRA template …there were occasion wherein 2 or 3 criteria's with no chronological order were suitable to select in a functional topic. This requires clarity*
- *I need to use it more to answer this question*
- *Bring up the system view*
- *Now it is coming in levels 4-6 but issues could be seen earlier than in implementation project*
- *The answers to the questions may be subjective and sometimes misleading*
- *The tool should be used with caution, because some answers maybe over-optimistic and some over-pessimistic, the steering should not give us at the deeper understanding of the project level, just based on the SRA final percentage*
- *When a project involves multiple technical changes it isn't easy to score the different changes together*
- *Although it is a user friendly tool, I would make criteria for selecting the readiness level more clear and visible for the user so there is no way to select a different level than the "real" one, since I consider some of them kind of confusing, i.e. be more specific on what is considered a relevant environment, operational environment or lab environment*
- *I think the file or template is not self-explanatory, it requires someone to teach how to use it. A small tutorial or pdf could be attached to the file and would be very helpful*
- *It's easy to use but it does require some instruction*
- *What could be improved is a way to understand what is the status compared to other real project currently in place or in general about project in case company*
- *An easy example of a project evaluated with method could be shown. This file/presentation would help to have a bit more clear understanding on how to use the template*
- *I did the assessment with xx so he was answering the questions properly. In case it is expected to be done by ourselves some examples could help*
- *Introduce more instructions on how to fill-in and link to terminology*
- *Move from Excel to dedicated tool, maybe in xx*
- *Projects are different, maybe we should check different details depending from the project type?*
- *Input table and report could be more visualized*

Analysis shows some degree of confusion and a clear need for a proper instructions. The unfinished questions pop out from the comments. System level view was also raised up for the first time. Most common words are 8 times project, 6 times more, could, use, with, this and different are mentioned also several times. Few comments relate to ordering of the criteria which is maybe not intuitive enough. An interesting comment is given for system level problem which was sort of expected based on theoretical studies on TRL. Also recognized subjectivity problem is mentioned. One comment claims that generic criteria is not suitable for all the projects. Technology Elements could be renamed as solution/technology elements to allow more movement for different kind of projects.

Q3: What is missing in SRA?

- *Recommendation summary to escalate steering and communicate to team is still needs improvised and after the business or project sponsor review again assessment to be updated for further follow-ups*
- *I need to use it more to answer this question*
- *Early warnings*
- *If something is seen as non-defined or having no requirements it should be taken right away to the discussion*
- *I liked that the ride comfort was included. I would also add questions about: was the solution optimized? Was the optimization done using simulated - virtual prototypes?*
- *Virtual prototyping (mechanical, electrical, acoustical, etc. simulation) would reduce the price of testing in the laboratory or on-site and would show the best solution from many points of view*
- *Not sure*
- *Up to this point I cannot think of an area/topic that has not been included there. Good Job!*
- *Tutorial or better instructions*
- *In blue box you can study some directions and then this directions for some reasons cannot be developed. For example there are not enough resources, business has changed opinion and so on. This workload of the project is not included here*
- *If we are excluding other potential developments, it means that the project is more mature*
- *A document explaining overall approach*
- *If possible to have automatic summary after analysis, to point out weakness area of project and indicator on report. Currently the SRA result is shown on graphic which is not so direct*

There were given comments for latest changes for CSE's. Ride Comfort was added due to it being an important success factor for case company from diversification point of view. Recommendation summary was requested but it is hard to generate automatically and on the other hand requires understanding from the project team to interpret assessment result. A few comments stated that there's nothing to add to current. Some commenting was for clarification of the questions. Tutorial was requested also as a solution for apparent confusion which also reflects from requests for summary report. Another important comment was given for visualization which might become a problem in some environment when compared to written summary.

4.7.5 Interpretation of results

Because statements were written for this survey only there is no historical or comparative data available. The approach is to first analyze mean and standard deviation then 95%confidence for the mean. Standard error and percentage distribution of agree and strongly agree are curiosities. Mean is calculated for each statement from Q1 to Q12 separately. The resulting values for mean and 95% confidence are shown on Table 23. Figure 40 Normal distribution with 95% confidence (visualization describes principle of 95% confidence that equals ±1,96σ. 1 equals strongly disagree and 4 equals strongly agree. Calculation includes answers not DK/CS. Analysis shows overall agreement on the statements and partially strengthens feeling of success with the model that is also assumption by participative observation.

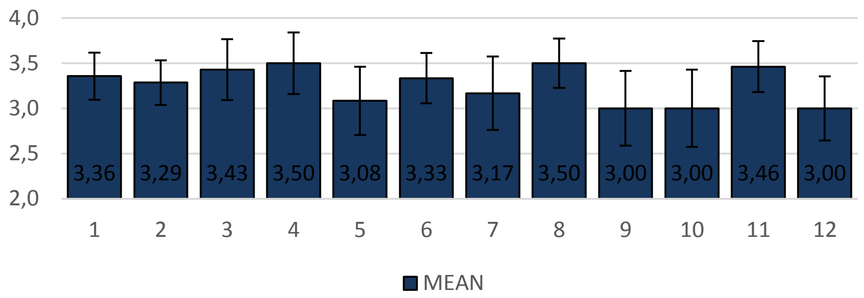


Table 23 Average with ±confidence [95%] of answers

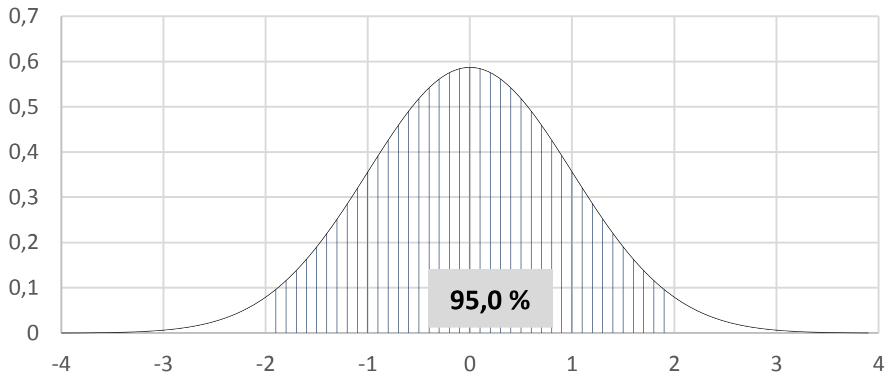


Figure 40 Normal distribution with 95% confidence (visualization)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
n	14	14	14	14	12	12	12	14	10	7	13	14
Mean	3,36	3,29	3,43	3,50	3,08	3,33	3,17	3,50	3,00	3,00	3,46	3,00
Std. Deviation	0,50	0,47	0,65	0,65	0,67	0,49	0,72	0,52	0,67	0,58	0,52	0,68
Std. Error	0,13	0,13	0,17	0,17	0,19	0,14	0,21	0,14	0,21	0,22	0,14	0,18
CV	15 %	14 %	19 %	19 %	22 %	15 %	23 %	15 %	22 %	19 %	15 %	23 %
95% confidence ±	0,26	0,25	0,34	0,34	0,38	0,28	0,41	0,27	0,41	0,43	0,28	0,36
Mean low 95%	3,10	3,04	3,09	3,16	2,71	3,05	2,76	3,23	2,59	2,57	3,18	2,64
Mean up 95%	3,62	3,53	3,77	3,84	3,46	3,61	3,57	3,77	3,41	3,43	3,74	3,36
No. Strongly Agree	5	4	7	8	3	4	4	7	2	1	6	3
%	36 %	29 %	50 %	57 %	25 %	33 %	33 %	50 %	20 %	14 %	46 %	21 %
No. Agree	9	10	6	5	7	8	6	7	6	5	7	8
%	64 %	71 %	43 %	36 %	58 %	67 %	50 %	50 %	60 %	71 %	54 %	57 %

Table 24 Survey results as a table

Analysis of the qualitative data shows that the observed success of the model/tool gets supported by qualitative analysis. Based on analysis the means of effective communication seems to be improved in steering meeting. The ease of use and perceived usefulness to project managers work has been recognized which has helped the acceptance of tool largely as Technology Acceptance Model by Venkatesh and Davis (1996) described. The written comments are mainly positive and some confusion and explanation, a tutorial pack is requested. Recognized problems are well described and few of them are reasonable. An automated summary generator may be done in a later phase when moving into a portfolio management tool used in case company.

4.7.6 Summary

Overall result is good. The need to communicate properly seems to have achieved by enabling a standardized and clear method for communication of solution maturity. Given the 95% confidence analysis the survey results are on the agree side even on the pessimistic scenario. Q5, Q7, Q9, Q10 and Q12 close to 2,5 at their lowest still receiving a hint of positive comments from qualitative data and participative observation. The timing of the survey was probably too early which may have affected the decision making related answers while participative observation, given answers to Q9 and Q10 support the hypothesis generated from the theory of TRRA, the visualization should improve decision making. Written comments were excellent source first to add depth for quantitative answers given and to bring clarity for further actions required.

4.8 Summary

The principles of the model defined in the baseline study were correct. Developed model hit into the soft spots in the organization and the defined criteria for no extra bureaucracy made the requirement for tool use clear. Gate model used in the case company fit great together with the TRL and therefore the model developed for the case company works seamlessly with the solution creation process of the case company. First intervention went well and nearly all the criteria was correct since day one. It is a remark that no criteria was removed but a few were added along the way. The model managed to form a sort of hype inside the organization in between the interventions. Due to time pressure the guiding questions development for the model did not succeed on-time to second intervention which might have effect on the overall outcome together with too early survey in form of requests for e.g. user instructions. Too early timing for survey becomes clear from both steering related statements' mean and written comments.

5 CONTRIBUTION

As the dry-run phase was rolling it became visible that the research was going to hit a jackpot. The customer need (urge to communicate effectively and to see the big picture) and the management (need to understand and to be able to decide and focus) was found. When one of the first test cases were run the comment from one program manager became really appreciated. When it comes to simplified presentation of the project/program status in the case company where the risk of immature technology/solution is always present the one slide presentation of the status becomes valuable. A glimpse should provide needful information to decision makers as their concentration span might be very short. The comments from the management side were pretty similar which helps to interpret results. The answers to *RQ1* and *RQ2* have been given with success. *RQ3* can be treated partly answered as the visualization was agreed to be effective way of communication, even improved it but decision making in steering meeting remains unclear. It would be worth repeating the survey after a one year of use to get an answer to decision making part of the *RQ3*.

> The risk chart was good
>
> R&D Senior Director

> It looks promising, I would like to see this in real use
>
> a Stakeholder

> I demand SRA graph to start the steering presentation with
>
> R&D Director

5.1 Finalized solution readiness assessment model for case company

A few changes to the risk matrix were done e.g. colors and progression of readiness were reversed so that level 1 would be on the left bottom corner "origo" and progression moving to positive direction, upwards. With minor modifications to risk matrix background more clarity and simplified looks were provided. The selection between critical success element and success element was instructed so that one must choose the path to be followed right in the beginning and not change it along the development project. This will improve the comparison afterwards. This will also force to think about the development project as a whole right from the beginning which is part of the target to reaching more mature solutions. It was left possible to apply for change of path in the governance meeting.

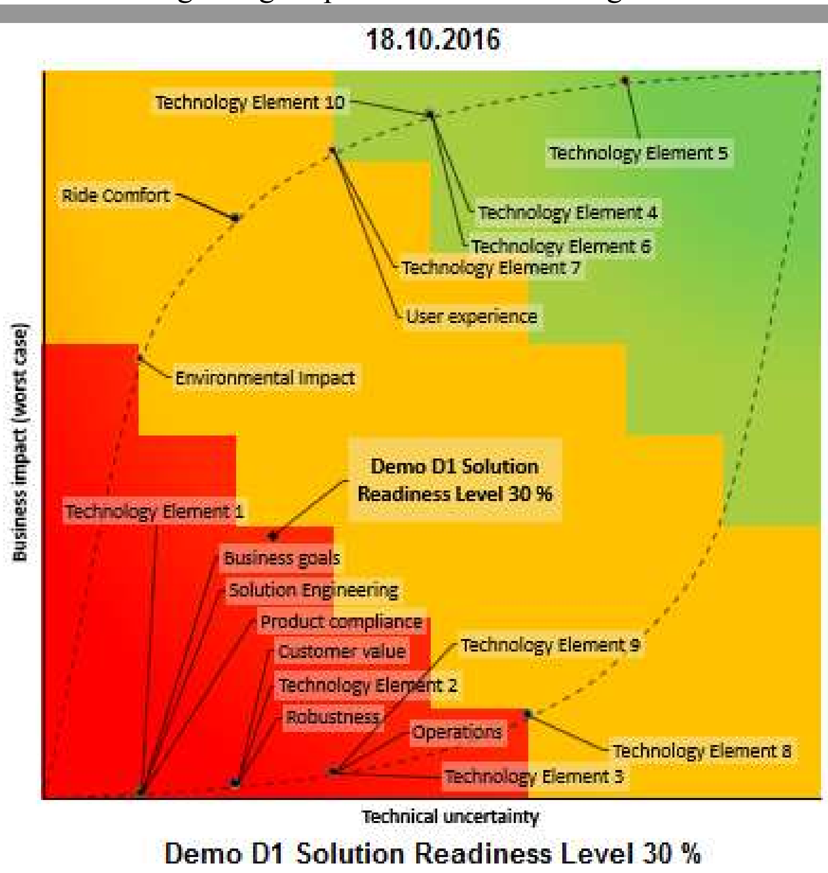


Figure 41 Finalized SRA visualization with all CTEs

Original working principle of the assessment process was kept intact and the process described in Figure 26 applies. For the finalized version the original 5x5 matrix was widened to 8x8 matrix in the late phase to improve visual looks and to better match the 1-9 scale. The finalized version includes the finalized questions that are embedded in the assessment tool. Appendices 1, 2 and 3 include the finalized critical solution elements and their respective questions per readiness level. In appendix 4 is shown the front page of empty assessment tool in excel. It will be populated during the assessment like the graph. As the case company seeks for differentiation e.g. from ride comfort it is an integral part of solution development in most of the development projects. Therefore it was added as 10th CSE with ride comfort subcategory. Also Business goals received a new subcategory in form of new business model for such cases were solution developed does not match an existing one and a new one need to be developed during the project. Finalized structure with CSE's and subcategories is shown in Table 25 and final CSEs with finalized guiding questions are listed in Table 26 - Table 35.

Critical Solution Element	**Subcategories**
Solution / Technology Elements	Critical Technology Elements
Environmental Impact	Lifecycle energy efficiency (manufacturing, logistics, in-use) Materials selected according rules internal/external (chemical compliancy included) Durability, Lifetime, Recyclability and/or reusability defined including end of life treatment of material
User Experience	Usability
Robustness / Solution simplicity	Simplicity of system /component Reusability of existing components Feasibility of specification
Ride Comfort	Ride Comfort
Customer Value	FOCUS on market segments, market area and customer value
Business Goals	FOCUS on business case, full chain cost estimation (life cycle) (SCA) and business model
Product Compliance	FOCUS on safety codes, patents and IPR
Solution Engineering	Needs and requirements defined Order Characteristics defined Modeling architecture defined IT-Architecture (security included) defined Modularity Product modeling
Delivery & Field Operations	Manufacturing Installation Maintenance Logistics

Table 25 Finalized Critical Solution Elements and corresponding subcategories

Solution / Technology Elements

1	Have you identified Technology Element's principle?
2	Have you done simulation and/or mock-up?
3	Have you understood the Technology Element's limitations and usage range (scalability)?
4	Have you verified the Technology Element in lab standalone?
5	Have you verified the Technology Element in relevant environment?
6	Have you verified the scalability defined earlier in relevant environment?
7	Have you validated production prototype?
8	Have you verified Technology Element's delivery process? Before Piloting (In-house-validation)
9	Have you validated Technology Element's delivery process? After Piloting (Lessons learned)
-	non applicable

Table 26 Solution / Technology Elements & guiding questions

Environmental Impact

1	Have you identified Environmental Impact scale?
2	Have you done simulation and/or mock-up?
3	Have you understood the limitations and usage range (scalability) from Environmental point of view?
4	Have you verified the Environmental Impact in lab standalone?
5	Have you verified the Environmental Impact in relevant environment?
6	Have you verified the scalability from Environmental point of view in relevant environment?
7	Have you validated production prototype from Environmental point of view?
8	Have you verified Environmental Impact in delivery process? Before Piloting (In-house-validation)
9	Have you validated Environmental Impact in delivery process? After Piloting (Lessons learned)
-	non applicable

Table 27 Environmental Impact & guiding questions

User experience

1	Have you identified end-user benefits and key user groups?
2	Have you described use scenarios with UX specialists? (*)
3	Have you understood special user groups (e.g. Blind persons) and special use situations (e.g. evacuation, fire alarm,) with special requirements? (*)
4 **5**	Have you involved relevant user groups in concept development? (*)
6	Have you validated UX requirements from different cultures, areas, markets, segments? (*)
7 **8**	Have you validated UX with relevant user groups? (*)
9	End-user benefits are documented and included in customer value propositions (*)
-	non applicable

Table 28 User experience & guiding questions (*) requires UX specialist

Ride Comfort

1	Have you understood the requirements of the customer?
2	Have you researched previous similar solutions and done simulation and/or mock-up?
3	Have you understood competitive advantage for company (differentiation, value)?
4	Have you verified the Ride Comfort in lab standalone?
5	Have you verified the Ride Comfort in relevant environment?
6	Have you verified Ride Comfort for relevant corner points?
7	Have you validated Ride Comfort of production prototype?
8	Have all corrective actions from prototype been implemented? Before Piloting (In-house-validation)
9	Have you statistically verified Ride Comfort from pilots? After Piloting (Lessons learned)

Table 29 Ride Comfort & guiding questions

Robustness / Solution simplicity

1	Have you understood simplicity of the solution?
2	Have you understood reusability of existing components in your solution?
3	Have you understood limitations and requirements set by robustness (scalability)? Have you understood simplicity of components?
4	Have you verified the robustness in lab standalone?
5	Have you verified the robustness in relevant environment?
6	Have you verified the scalability defined earlier in relevant environment?
7	Have you validated production prototype?(D3)
8	Have you verified robustness elements in delivery process? Before Piloting (In-house-validation)
9	Have you validated robustness elements in delivery process? After Piloting (D5/D6 Lessons learned)
-	non applicable

Table 30 Robustness / Solution simplicity & guiding questions

Customer value

1	Have you identified customer benefits and key market areas and segments ?
2	Have you understood customer value logics and drafted value propositions?
3	Have you understood competitive advantage for company (differentiation, value)?
4	Have you validated customer value with relevant customer group / customer insight ?
5	Have you updated value propositions according to concept development ?
6	Have you validated value propositions in different areas, markets, segments?
7	Have you validated value propositions with relevant customers ?
8	Have you updated value propositions according to concept development ?
9	Customer benefits and value propositions are ready for (to be utilized in) marketing
-	non applicable

Table 31 Customer value & guiding questions

Business goals

1	Have you understood strategic fit and market potential in different markets?
2	Have you drafted initial business case (with appropriate BL support)?
3	Have you understood competitive advantage and run sensitivity analysis (w Business Line)?
4	Have you updated business case according to customer/market feedback?
5	Have you understood company cost structure (Full chain)?
6	Have you done Should-cost analysis SCA, / full chain cost analysis
7	Have you updated business case with market potential & cost analysis (etc.)
8	Have you finalized pricing in tool?
9	Have you updated pricing based on the piloting feedback?
-	non applicable

Table 32 Business goals & guiding questions

Product compliance

1	Have you identified valid codes and standards?
2	Have you checked preliminary patent clearance with patent specialists? (*)
3	Have you checked codes and standards requirements with code specialists? (*)
4	Have you filed invention disclosures in concept development phases? (*)
5	Have you verified preliminary requirements in relevant environment? (*)
6	Have you validated codes and standards requirements from different market areas (local requirements)? (*)
7	Have you started the certification process? (*)
8	Have you finalized the certification process in piloting market areas? (*)
9	Have you finalized the certification process in all defined market areas? (*)
-	non applicable

Table 33 Product compliance & guiding questions

Solution Engineering

1	Have you identified where to collect needs and requirements ?
2	Have you identified main needs, requirements and characteristics?
3	Have you done preliminary requirements (min and max values for characteristics)? Have you done preliminary specification against the requirements?
4	Have you verified full solution range in respect to solution engineering elements?
5	Have you defined modeling architecture and respected re-usability of components in design (modularity)?
6	Have you done product modeling based on internal standards?
7	Have you validated product modeling?
8	Have you validated full solution range in respect to solution engineering elements?
9	Have you finalized full solution range in respect to solution engineering elements?
-	non applicable

Table 34 Solution engineering & guiding questions

Delivery & Field Operations

1	Have you identified all operative functions affected?
2	Have you checked the impact on operations during the lifecycle of the solution?
3	Have you understood relevant operations capabilities?
4	Have you drafted whole delivery process (tendering to maintenance)?
5	Have you verified operations capabilities?
6	Have you verified the impact in defined operations?
7	Have you validated production prototype in operations?
8	Have you verified delivery process for full solution range for all markets in operations?
9	Have you validated delivery process for full solution range for all markets in operations?
-	non applicable

Table 35 Delivery & Field Operations & guiding questions

When changing the logic of picture/illustration to be more logical also the success element curves needed to be changed. The equations are the same only the use is reverse.

$$y_{cse} = \frac{8x^2 - 80x + 801}{-80x + 801}$$

Equation 4 Finalized formula for critical success element curve on SRA matrix curve approximation where x=2…8

$$y_{se} = \frac{-8x^2 + 880x - 791}{80x + 1}$$

Equation 5 Finalized formula for a success element curve on SRA matrix curve approximation where x=2…8

X	CRITICAL SUCCESS ELEMENT (Y_{CSE})	SUCCESS ELEMENT (Y_{SE})
1	**1**	**1**
2	1,050	5,820
3	1,128	7,373
4	1,266	8,103
5	1,499	8,501
6	1,897	8,734
7	2,627	8,872
8	4,180	8,950
9	**9**	**9**

Table 36 Finalized impact success elements and critical success elements

5.2 Summary of results

The main target of the study was to improve both communication and guide the decision making by solution readiness assessment utilization. Concerning the utilization the initial selection of risk chart behind the illustration proved out to be very powerful way of communication, also from visualization point of view. Communication improvement was achieved by providing a clear and standardized way to describe solution maturity. These also get supported by interpretation of survey results. When it comes to decision making part use of provided method brings clarity and a standardized way to provide maturity information for a steering group which should lea into better decision making as well. This could not be verified totally but preliminary results indicate that there is a possibility to guide decision by the utilization of the tool developed.

5.3 Validity of results

Based on the gathered quantitative and qualitative answers and observations the validity of the research is on acceptable level. Timing of the survey was too early but the results indicate positive change on both the communication and decision making aspect. Communication seems more mature than the decision making where due to timing is left more uncertainty. Spoken feedback during dry-run sessions and piloting, observations of reactions to new method during trainings and comments in steering meeting support the research result for decision making though. The chosen method group discussion was correct for collecting information to form a baseline of existing issues and to map the opportunities. It proved also useful for providing a baseline for proposal for the tool. Naturally in some other environment the tool might have looked different as the ideas produced during the discussion were specific for the case company. This method when combined with theoretical frame serve well when trying to answer the *RQ1*.

5.4 Reliability of results

Based on the information derived from the group discussion the reliability of the first part is strongly case company and group discussion participant dependent. In other or even the same environment with another group participants the results might have been different. The reliability may be limited if the group discussion participants are different or if the experience of the case company way of working differs greatly from this group. In case of this research the participants average years working for case company was more than 20 years which was good for information gathering purposes but might have affected the result. Reliability of first intervention remain unclear as the results gathering was not conducted by a survey. Nevertheless the participants would have been different which supports that the method for gathering results from the first intervention was correct and the results are reliable. Survey timing reduces slightly the reliability of the second intervention. Amount of answers to the survey and quality of written answers contribute to further studies greatly. On the other hand the developed model could be reproduced in any other environment with company specific CSEs. This fact needs to be taken into account when developing the tool in form of scalability and a need to create a generic proposal instead of really fixed one. Nevertheless this conclusion may also be judged as neutral from the research reliability point of view as the use of participative observation during the research supports most of the information gathered and it’s notable that the researcher could recognize most of the topics that were discussed. Quantitative and qualitative data gathered after the second intervention proves that research is reliable in the case company environment.

5.5 Gaps of the research

During the dry-run phase the researcher was only able to touch the surface of the possibilities of use for such a tool. Regardless of this it was already visible in the early phases of the first intervention that the developed model for the case company is a success and will remain in use. As the researcher wanted to keep scope limited the theoretical study was maybe too limited to serve solution readiness as a whole. The effort was greatly put to the technology management side and an important topic organization and individuals role in it was left too small. In the end it is an individual who is responsible for the maturity of a solution, it's comprehensiveness, quality and safety among other things. Regardless of this the correct theories for success were recognized in a good enough level especially when combined with personal experience from the case company. It would have been fruitful to study further also manufacturing readiness, integration readiness and solution readiness levels. System level was raised up in the survey's written part which is an important topic when dealing with TRLs. There could have been more focus put into that area. The overall comprehensiveness of the tool seems appropriate enough as the written comments to the survey were not requesting for more CSEs.

5.6 Recommended further actions

The assessment should be further developed still keeping in mind that the ease of use was found to be one of the strengths of the tool. The researcher would also recommend finding an independent facilitator to run the assessments or to do assessments as a project team with a facilitator. The facilitator is needed to ground the subjectivity since people tend to present better readiness than it usually is. Some needs to challenge their opinions and make them think more deeply. As the tool is done by excel during the research it would naturally require an investment in order to implement the assessment tool into project portfolio management system widely used in case company. This would even be very advisable.

5.7 Recommendations for further studies

As the tool is already scalable and the basic principle works. The researcher would recommend to study further manufacturing and integration readiness levels in order to highlight the importance of these as an integral part of the solution development process in case company. After the integration readiness is clarified the natural step is to move into system readiness level development.

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Appendix 1

SRA CSEs AND GUIDING QUESTIONS 1 TO 3

	Solution / Technology Elements	Environmental Impact	User Experience	Robustness / Solution simplicity	Ride Comfort	Customer Value	Business Goals	Product Compliance	Solution Engineering	Delivery & Field Operations
1	Have you identified Technology Element's principle?	Have you identified Environmental Impact scale?	Have you identified end-user benefits and key user groups?	Have you understood simplicity of the solution?	Have you understood the requirements of the customer?	Have you identified customer benefits and key market areas and segments?	Have you understood strategic fit and market potential in different markets?	Have you identified valid codes and standards?	Have you identified where to collect needs and requirements ?	Have you identified all operative functions affected?
2	Have you done simulation and/or mock-up?	Have you done simulation and/or mock-up?	Have you described use scenarios with UX specialists?	Have you understood reusability of existing components in your solution?	Have you researched previous similar solutions and done simulation and/or mock-up?	Have you understood customer value logics and drafted value propositions?	Have you drafted initial business case (with BL support)?	Have you checked preliminary patent clearance with patent specialists?	Have you identified main needs, requirements and characteristics?	Have you checked the impact on operations during the lifecycle of the solution?
3	Have you understood the Technology Element's limitations and usage range (scalability)?	Have you understood the limitations and usage range (scalability) from Environmental point of view?	Have you understood special user groups (e.g. Blind persons) and special use situations (e.g. evacuation, fire alarm,) with special requirements?	Have you understood limitations and requirements set by robustness (scalability)? Have you understood simplicity of components?	Have you understood competitive advantage for company (differentiation, value)?	Have you understood competitive advantage for company (differentiation, value)?	Have you understood competitive advantage and run sensitive analysis (w Business Line)?	Have you checked codes and standards requirements with code specialists?	Have you done preliminary requirements (min and max values for characteristics)? Have you done preliminary specification against the requirements?	Have you understood relevant operations capabilities?

Appendix 2

SRA CSEs AND GUIDING QUESTIONS 4 TO 6

	Solution / Technology Elements	Environmental Impact	User Experience	Robustness / Solution simplicity	Ride Comfort	Customer Value	Business Goals	Product Compliance	Solution Engineering	Delivery & Field Operations
4	Have you verified the Technology Element in lab standalone?	Have you verified the Environmental Impact in lab standalone?	Have you involved relevant user groups in concept development?	Have you verified the robustness in lab standalone?	Have you verified the Ride Comfort in lab standalone?	Have you validated customer value with relevant customer group / customer insight?	Have you updated business case according to customer/market feedback?	Have you filed invention disclosures in concept development phases?	Have you verified full solution range in respect to solution engineering elements?	Have you drafted whole delivery process (tendering to maintenance)?
5	Have you verified the Technology Element in relevant environment?	Have you verified the Environmental Impact in relevant environment?		Have you verified the robustness in relevant environment?	Have you verified the Ride Comfort in relevant environment?	Have you updated value propositions according to concept development?	Have you understood company cost structure (Full chain)?	Have you verified preliminary requirements in relevant environment?	Have you defined modeling architecture and respected re-usability of components in design (modularity)?	Have you verified operations capabilities?
6	Have you verified the scalability defined earlier in relevant environment?	Have you verified the scalability from Environmental point of view in relevant environment?	Have you validated UX requirements from different cultures, areas, markets, segments?	Have you verified the scalability defined earlier in relevant environment?	Have you verified the scalability defined earlier in relevant environment?	Have you validated value propositions in different areas, markets, segments?	Have you done SCA, / full chain cost analysis	Have you validated codes and standards requirements from different market areas (local requirements)?	Have you done product modeling based on internal standards?	Have you verified the impact in defined operations?

Appendix 3

SRA CSEs AND GUIDING QUESTIONS 7 TO 9

	Solution / Technology Elements	Environmental Impact	User Experience	Robustness / Solution simplicity	Ride Comfort	Customer Value	Business Goals	Product Compliance	Solution Engineering	Delivery & Field Operations
7	Have you validated production prototype?	Have you validated production prototype from Environmental point of view?	Have you validated UX with relevant user groups?	Have you validated production prototype?(D 3)	Have you validated production prototype?	Have you validated value propositions with relevant customers?	Have you updated business case with market potential & cost analysis (etc.)	Have you started the certification process?	Have you validated product modeling?	Have you validated production prototype in operations?
8	Have you verified Technology Element's delivery process? Before Piloting	Have you verified Environmental Impact in delivery process? Before Piloting		Have you verified robustness elements in delivery process? Before Piloting (In-house-validation)	Have you verified robustness elements in delivery process? Before Piloting (In-house-validation)	Have you updated value propositions according to concept development?	Have you finalized pricing in tool ?	Have you finalized the certification process in piloting market areas?	Have you validated full solution range in respect to solution engineering elements?	Have you verified delivery process for full solution range for all markets in operations?
9	Have you validated Technology Element's delivery process? After Piloting (Lessons learned)	Have you validated Environmental Impact in delivery process? After Piloting (Lessons learned)	End-user benefits are documented and included in customer value propositions	Have you validated robustness elements in delivery process? After Piloting (D5/D6 Lessons learned)	Have you validated robustness elements in delivery process? After Piloting (Lessons learned)	Customer benefits and value propositions are ready for (to be utilized in) marketing	Have you updated pricing based on the piloting feedback?	Have you finalized the certification process in all defined market areas?	Have you finalized full solution range in respect to solution engineering elements?	Have you validated delivery process for full solution range for all markets in operations?

Appendix 4

MAIN PAGE OF ASSESSMENT IN EXCEL

SOLUTION READINESS ASSESSMENT - SRA

PROJECT NAME	Gate	Date
Demo	B1	18.10.2016

Critical Solution Element - CSE	Critical Success Element	Success Element	Uncertainty	Impact	
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Solution Readiness Level	1,0	0,7			