MARMARA UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES
IN PURE AND APPLIED SCIENCES

DEFINING TECHNOLOGICAL READINESS LEVELS FOR ENTERPRISES

SÜLEYMAN YAMAN

MASTER THESIS
Department of Industrial Engineering

Thesis Supervisor
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Dr. Semih ÖZEL

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ÖZET

İŞLETMELERİN TEKNLOJİK HAZIRLIK SEVİYESİNİN BELİRLENMESİ

Son zamanlarda, Teknoloji Hazırlık Seviyeleri (THS), teknolojik alt yapının çıktıları olan ürün / hizmetin olgunluğunun yeterince sağlandığından emin olmak için ölçüm aracı olarak kullanılmaktadır. Olgun teknolojik kapasite, işletmelerin müşterilerinin ihtiyaçlarına en uygun hizmet ve ürünleri üretmesini mümkün kıldığından, konuyla ilgili teknoloji kullanımının öz yeterliliğini artırmak için de yoğun bir şekilde gündemde tutulmaktadır.

Bunu başarmak için işletmelerin THS'si pazar dinamikleri ışığında değerlendirilmeli ve teknoloji ile ilgili yatırımlarda teknolojik olgunluk yararına net bir yol haritası tanımlanmalıdır. Literatür taraması, işletme düzeyinde teknoloji değerlendirmesine ilişkin az sayıdaki çalışmayı gösterdiğinden, daha kapsamlı ve etkili yöntemlerin tanımlanması ve uygulanmasına ihtiyaç duyulmaktadır. THS analizinin önemi nedeniyle, bu çalışma genel bir değerlendirme çerçevesi oluşturmaya ayrılmıştır. Bu çalışmada önerilen model hem servis hem de üretim endüstrisinde kullanılmak üzere tasarlanmıştır. İlgili literatürün gözden geçirilmesinden sonra, değerlendirme modeli SWARA kullanılarak, her kriterin ağırlıklarının önemlilikleri ile tanımlanması için oluşturulmuştur. Teknolojik altyapı, kültürel etkiler, yatırım planlaması ve işletme sonuçlarına ulaşma konularına odaklanan bir model geliştirilmiştir. Bu modelin bazı hizmet sağlayan kurumlardaki ilk etkileri, teknolojik iyileştirme ve kullanım hakkında ortak bir anlayış geliştirmenin yanı sıra değerlendirme modelinin olası iyileştirmelerini teşvik etmeye ve vurgulamaya yardımcı olur. Önerilen bu modelin doğrulanması amacı ile bir üretim işletmesinde uygulanması sağlanmış ve ilgili işletmenin THS'si ölçülmüştür.

Önerilen modelin teknolojik ilerlemeye, sektör çapında veya kurum çapında düşüncelerine uygun olarak esnekliğini ve uyarlanabilirliğini artıracağı düşünülmektedir.

Anahtar Kelimeler: Teknoloji Hazırlık Seviyeleri, SWARA, İşletmelerin Teknolojik Hazırlığı, Teknolojik Olgunluk

ABSTRACT

DEFINING TECHNOLOGICAL READINESS LEVELS FOR ENTERPRISES

Recently, Technology Readiness Levels (TRLs) are used as a measurement tool to identify product/service maturity for assuring that the outcome of the technological infrastructure is mature enough. Since mature technological capacity makes it possible for enterprises to produce services and products fitting well for the needs of their customers, relevant studies keep their agenda heavily busy to improve self-capability of technology utilization. For achieving this, TRL of enterprises should be evaluated in the light of market dynamics, and a clear road map in technology-related investments should be identified for the sake of technological maturity. As the literature survey indicates a few studies related to enterprise-level technological assessment, there is a need for more comprehensive and effective methodologies to be developed and implemented.

Due to the importance of TRL analysis, this study is devoted to generating a general assessment framework. Although applicable to service industry, the proposed model is particularly designed to be utilized in manufacturing industries. After a comprehensive review of the literature, the assessment model is generated by using SWARA to identify the weights of each criterion with their relevant importance. Particular attention is paid to technological infrastructure, cultural effects, investment planning and achievement of business results. Early implications of the proposed model in some service-providing institutions help develop a common understanding on technological improvement and utilization as well as encourage and highlight further possible improvements of the assessment model. However, the proposed model is operated to verify an implementation with a manufacturing enterprise. The study continues along this line and the model is continuously improved by embedding more criteria. It is believed that this will improve the flexibility and adaptability of the proposed model in accordance with technological progress as well as sector-wide or enterprise-wide considerations.

Keywords: Technology Readiness Levels, SWARA, Enterprise Technological Readiness, Technological Maturity

SYMBOLS

s_j: Comparative importance of average value

k_j: Coefficient

$w_{j:}$ The relative weights of the evaluation criteria

q_j: The recalculated weight

ABBREVIATIONS

TRL	Technology Readiness Level
THS	Teknoloji Hazırlık Seviyesi
DoD	American Department of Defense
ISO	International Standard Organization
NASA	National Aeronautics and Space Administration
SWARA	Step-Wise Weight Assessment Ratio
ETRL	Enterprise Technological Readiness Level
GAO	Government Accountability Office
US	United States
RMS	Root Mean Square
SRL	System Readiness Level
IRL	Integration Readiness Level
R&D	Research and Development
AHP	Analytic Hierarchy Process
ESD	Earth Science Division
ICT	Information and Communication Technology
SMR	Small Modular Reactor
LWR	Large Modular Reactor
NETL	National Energy Technology Laboratory
RD&D	Research, Development and Demonstration
IT	Information Technology
CEO	Chief Executive Officer
HR	Human Resources
MCDM	Multi-Criteria Decision-making
MAVF	Middle Attribute Value Function
ANP	Analytic Network Process
SMART	Specific, Measurable, Achievable, Realistic, Timely
KPI	Key Performance Indicator

EBITDA	Earnings Before Income Tax, Depreciation and Amortization
PLC	Product Life-Cycle
ERP	Enterprise Resource Planning
MES	Manufacturing Executive Systems
MRP	Material Resource Planning
TRIZ	Teoriya Resheniya Izobreatatelskikh Zadatch
PUGH	Palm Users Group in Hokkaido
SCAMPER	Substitute, Combine, Adapt, Modify, Put to Another Use, Eliminate, Reverse
CAD	Computer-Aided Design
CNC	Computer Numeric Control
TPM	Total Productive Maintenance

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1. INTRODUCTION

Enterprises have changed in the past several decades. The later decades are characterized by the term "information age" due to the availability of information and knowledge management capabilities available to operations. This term comes with technology, and technology provides sustainable improvement for the enterprises. Competitive business environments for the existence of enterprises cause some difficulties due to the competitiveness of technological capability. The competition among enterprises, on the other hand, depends on the adaptation capability to rapid technological change as well as major-scale measures on honing internal processes related technology, organization and management (Teece, Pisano and Shuen 1997). While enterprises are developing a new technology, there is an understanding that basic and applied research is carried out before the design, development, integration and test prior to certification and deployment. This process so called the life-cycle of technology development process is directly based on the basic elements of enterprises such as infrastructure, management approach, and cultural activities.

Common understanding of the technological capabilities is ensured by the technological infrastructure for the purpose of building an efficient and effective business applications in both hardware and software (Broadbent and Weill 1997). That is the reason for the leaders of enterprises today to carefully evaluate the value of future technology investments. Furthermore the following takes the attention of scientific community in performing the overall assessment especially for technological readiness.

- It is important to highlight that work in cultural approach -although based on cultural meaning of market orientation- has conceptualized and measured with regard to behaviors (Moorman *et. al.* 1993).
- Enterprises are not only keen to compete each other, but they also want to reach the highest rating of customer satisfaction.
- Enterprises are also conducting technology management activities in order to have competitive advantage. This directly implies that the level of technological

readiness should be properly assessed.

According to the literature, technology can be measured by many techniques to standardize a common methodology. The technology readiness levels (TRLs) assessment is a popular and widespread measurement way than the others for this assessment [Islam and Brousseau (2014), Mankins (1995)]. Note that TRL has a full background in NASA and the American Department of Defense (DoD) in designing, producing and testing new technologies (Defense Technical Information Center, 2009). Similarly, according to ISO 16209-E, Technology Readiness Levels (TRLs) are employed to define the technological maturity of an element that is possible to take part in a mission. Mature technology means the highest TRL, in other words, TRL 9, or flight-proven elements (Austin, et al. 2017),(GAO 2012),(NASA 2018).

TRL is described as the systematic scale/measurement system which performs assessment of the maturity of the "technology". The scale provided a more precise tool for describing a necessity to which a study and technology program is followed by the enterprise. Although this necessity has been met indirectly by some methods in the literature, these methods are not enough to explain all views of technological readiness of enterprises. This is why defining the TRL of an enterprise should be based on the common understanding of many factors such as infrastructure, culture, financial, management and business results. Although there are some studies on measuring the TRL of a project/program or a system, the methodology for assessing the technology readiness level of an enterprise is not clearly tackled in the literature.

When enterprises want to make a gap analysis for their own technological readiness, there is a lack of a mature model in order to determine their readiness in their business environment. This in turn leads to the lack of strategies such as,

- mapping technology to management decisions,
- building the processes with supported technology,
- adopting technology to make daily task as easy as possible,

- defining how much to invest in technology, etc.

Keeping this in mind, since, the management usually takes some risks in making technological investments, an assessment model is required to evaluate the technological capability of the enterprises pointing out the areas to be improvement and justifying the respective investments. In this study, a self-assessment technologic readiness model for the overall enterprises is. It is based on a set of weighted criteria for which the weights are acquired through implementing a methodology so called SWARA (Karabasevic, et al. 2015)

Depending on the increase in the use of technology more and more in digitized world, the relationship between the "technological maturity" and the "technological readiness level" has been remarkably increasing. Recently, Technology Readiness Levels (TRLs) has been thought to be a measurement tool that could be used for identifying product/service maturity or phases to ensure that the outcome of the technological infrastructure reaches advanced maturity. This is due to the fact that, the mature technological capacity makes it possible for the services and products to fit well for the needs of the respective customers. This obviously triggers studies on technological readiness and maturity levels of the enterprises.

It should be noted that it is necessary to sustain a certain level of technological readiness to make it easy to manage self-capability of technology utilization. In order to achieve this, Technology Readiness Level (TRL) should be measured and evaluated in the light of market dynamics. This way, companies may define their road map in technology-related investments in order to reach the technological maturity that is required. Due to the importance of TRL analysis and assessment for an enterprise, this study is devoted to generating a general assessment framework. The proposed model is designed to be utilized in the manufacturing industry. The Information on Global Technology Competitive Index is used while defining the set of criteria for different TRLs.

This study first involves the review of the relevant literature to establish a good scientific baseline, and then a criteria-based assessment model is proposed by using SWARA to

identify the weights of each criterion with relevant importance. During the study, a specific attention is paid to the technologic infrastructure, cultural effects, investment planning and achievement of expected business results. Early implications and implementations of the proposed model in some service-providing institutions help develop a common understanding on technological improvement and utilization as well as encourage and highlight further possible improvements of the proposed assessment model.

The model also provides common understanding of technology management to be comprehended by managers. As implied above, the Enterprise Technology Readiness Levels (ETRLs) may be considered as a scale to measure the rating, usability and maturity of the developing technology. The study should continue along this line and the model should continuously be improved through embedding more criteria in accordance with enterprise, products, services and customer expectations. It is believed that this will improve the flexibility and adaptability of the proposed model in accordance with technological progress as well as sector-wide or enterprise-wide considerations.

1.1 Main Motivation of the Thesis

In the literature, there are many model for enterprise assessment. However, these models are not usually particularly concentrates on identifying accurate technological capabilities. Enterprises need to learn whether they are technologically ready or not for contemporary and future developments as well as customer expectations requiring certain technologies to be implemented. Proposed the Enterprise Technological Readiness Levels (ETRLs) in this thesis focus on five main criteria to perform this assessment from different perspectives. These include technological infrastructure, technology culture, management aspects for technology and technology investment and business results criteria set.

1.2 Scope of the Thesis

For the sake of proof of concept, a generic enterprise assessment model is proposed, while it may be used to evaluate any kind of manufacturing enterprises. The model is validated by implementing it in a manual manner on several manufacturing enterprises. The first part of the thesis highlights how the model in question was inspired by TRL and provides a general

introduction. Following this, definition of technological readiness of enterprises with respective set of criteria and respective business rules as well as implementations. Then, the thesis provides a case study in order to verify and validate the proposed model. Finally, the results and possibilities for future work are discussed to complete the thesis.

2. LITERATURE REVIEW

In this section, a comprehensive literature review on ETRL and related studies are provided. The assessment of the enterprise is verified by using SWARA, a multi-criteria decision making methodology, There have been various criteria that were used for assessments. The most frequently used ones are investigated and following are identified.

- Technology readiness level
- Technological infrastructure
- Technology culture and management concepts
- Technology investment
- Business results
- Multi-criteria decision-making

2.1 Technology Readiness Level

In recent years, Technology Management has been widely studied to get the costs under control and make schedules more sensitive. The increase in the research interests along this line could be motivated by generating a model for Technology Readiness Level (Islam and Brousseau, 2014). This is because technology cannot be well-managed when the readiness levels are not understood. So, defining TRL for enterprises is important in terms of several dimensions such as intellectual and technological competitiveness, finances, usability and strategic competency.

The TRL could be defined as: "A systematic metric/measurement system supporting the evaluations of the maturity of a certain technology and the conforming comparison of maturity among different technology types based on which the methodology was expected to yield a more accurate tool to describe the depth on which a study and technology program is to be followed (Broadbent and Weill, 1997)".

Technology Readiness Levels (TRLs) were introduced for the first time by NASA (NASA 2018) to measure the maturity level of technologic capabilities of military systems. This approach is also standardized for measuring the respective technological levels. According

to ISO 16209-E, TRLs are performed to measure the technology maturity status of an intended element for producing each cycle. Mature technology refers to the highest TRL, (in other words TRL 9, or flight-proven elements). The highest TRL that could be obtained as a result of the assessment is called mature technology.

According to NASA, there are 9 Technology Readiness Levels TRL 1 being the lowest and TRL 9 being the highest. A new technology readiness level is defined when a technology implementation within an enterprise begins as scientific research and the results are transferred to future R & D activities. When basic principles are studied, and practical applications are applied to initial findings, TRL 2 is obtained, which is speculative since there is little or no empirical evidence of concept for available technology (Islam and Brousseau, 2014).

Once active research and design start in the enterprsie, the technology readiness level is assumed to increase to 3rd level (TRL 3). In general, analytical and laboratory investigations are considered to be necessary at this stage to observe whether a technology is viable and ready to progress via developmental processes. During TRL 3, frequently a proof-of-concept model is structured. When multiple components/pieces of products or processes are tested against each other, then TRL 4 is achieved. This level is followed by TRL 5, but a Level-5 Technology is defined as a breadboard technology, which has to be tested more rigorously than a technology on TRL 4. At this level, simulations are extensively used in settings that are as similar to real-life conditions as possible. Similarly, in TRL 6, a capability to prototype the technology demonstrating that the systems are full-functioning is the main requirements. in TRL 7, a working model or a prototype is to be set up. When TRL 8 technology is tested and so-called "flight-qualified" that is the certification of systems for real use. Once this level is achieved, the systems developed are ready for implementation of already-existing technology or technological system. When a technology is "flight-qualified" in a successful mission, then it may be considered TRL 9 (NASA 2018). Earlier TRLs were used only for defining the maturity of acquisition firms (Seablom and Lemmerman, 2012).

In a full collaboration with NASA, the United States Air Force and the Department of Defense, the levels were purified and generalized. The TRL definitions that are now used by the U.S. Department of Defense are the most general and well-fitting to be adapted by other study fields (Leitão, et al. 2016).

However, TRLs as defined only concentrate on the technological development and as proposed by Dissel, et al. (2009), TRLs are introduced as staged sub-systems or components for deciding whether outsourcing enterprise satisfies technological needs.

Many tools and methods provide the assessment of early-stage technologies; however, just evaluating and defining TRL is not enough for most decision-makers for assessing the nature of the technological progress within the enterprises.

Almost all assessment approaches focus on financial data and respective quantitative methods. Some descriptive decision theories such as "discounted cash flow" and "decision trees" are employed. These analyze the potential outcomes under uncertainties involved for the decision-makers. Technologies' maturity levels can be considered as early, medium and high. When the technology has been defined the be on a medium/high readiness level, uncertainty about assumptions is fewer in the early-phase technology. Nevertheless, in quantitative methods, the other aspects are qualitative based evaluations such as scorecards and brainstorming. However, enterprises that use financial methods or quantitative methods have higher levels of performance in comparison to companies using just qualitative or quantitative methods. On the other hand, there is little knowledge on how the methods deal with the early-phase technology. Most enterprises avoid employing formal evaluation methods until the technology is proven to be mature (Dissel, et al. 2009). Consequently, enterprises need techniques or methods to decide investment decisions and road mapping for early-level technology.

The approaches for assessing TRLs evaluate systems and technologies in order to describe the necessary elements of a certain application, data reliability and system adaptation to field conditions. Some researchers investigated the effects of using space exploration and defense procuration on the performance in relation to the requirements (Boulart, et. al., 2010).

TRLs are also employed by the Department of Defense (DoD) and the Government Accountability Office (GAO) to define technology and design readiness and to implement the model proposed by Katz et. al (2015). Note that this model also has 9-level ordinal scales each having different views or form of definitions.

The GAO guide shows that all crucial technologies must show TRL bigger than or equal to 7, and this should be implemented in an operational environment (GAO 2012). Yet, the DoD guide shows that all crucial technologies demonstrate a TRL bigger than or equal to 6 (DTC, 2009).

Hence, TRL is a scale between 1 to 9, and it defines the degree of readiness of technology. Moreover, while the first phase of scientific research is represented as TRL 1, TRL 9 means that the technology is being used in a system the most favorably, concurrently with the applied assignment of TRLs in a program to assess maturity level and milestone judgment.

However, TRL does not assess design of technology; contrarily, it estimates whether the system engineering methodology is sufficient or not for performance of the required functions. Consequently, when a technology meets the needs from TRL 1 to TRL 9, the technology can pass through the development phases into production processes. The first purpose of TRL is to help track technology management until product lifecycle management. TRL is a measurement of different technology maturity levels where each level is numbered from 1 to 9 as mentioned above. This provides very useful information for decision-makers about respective technology development and management. Dion-Schwartz (2010) gets the attention of readers for possible use of TRLS as the following;

- Generating a common language of technology readiness status,
- Bringing what has been achieved with the contemporary technology,
- Supporting technical risk management,
- Supporting decision-making before the technology funding and transition
- Providing scope acquisition programs and their needs,
- Establishing as a basis for certification under statute details of maturity attributes of a technology. (Sharif, 2014)

Although TRLs have some shortcomings in the status of system growth, Mankins (1995) claimed that measurement of the difficulty was expected to be faced in the readiness of each technology should be made clear in order to supplement the Technology Readiness Levels (TRLs) that already exist. Hence TRLs are a technical measurement scale that evaluates the readiness of a specific technology or differences of maturity between various types of technologies (Malone and Wolfarth, 2012). For example, in 2007, NASA dismissed all slow technologies as a result of the assessment of push/pull systems in two distinct technologies. When a technology is dismissed, it needs estimation of technology to reach more maturity. Then, studies such as multi-criterion optimization studies indicate also that push/pull systems sometimes perform well.

While TRL assesses the technology, this procedure provides a perspective on how the sector is to be transitioned and positioned. So, before transition from development to production, enterprises that both own and purchase technology apply the lessons that are learned from each phase in a project/program. A research project that is appointed TRL 3 creates a proof of concept which provides a conceptual solution. Yet, a prototype project designation TRL 6 yields "a requirement-driven, working system". A project that reaches TRL 6 has completed functional testing, demonstration and the early phases of accreditation. The end of a successful project spends more time to test than the early phases, it must be worth for accreditation, and it also supports end-user requirements for instruction (O'Brien, et al. 2011).

TRL's definition was came up with by space and defense industry acquisition by Mankins (1995); however, the Goddard Space Flight Center provided it in 1980s as a technique to evaluate the readiness and risks of space technology (Austin, et al. 2017). From found until now, enterprises such as NASA, DoD, UK Defense Procurement Agency make decisions on technology in terms of readiness for usage. Even NASA incorporates the TRL approach into the NASA Management Instruction 7100 to easily estimate and apply the technology planning process.

TRL principles make comparative analysis of the criteria sets and identify relationships with success in technologies. This analysis is useful for the initial phases of a project in estimating the requirements and risks. TRL definitions have various meanings, and many industries modified NASA's definitions. Generally, the levels go up TRL 9, but rarely, TRLs have three distinct levels. For example, TRL definitions in cyber physical systems are measured between 1-9 in which TRL 1 is mined to basic principles seen such as literature research, TRL 2 represents conceptual formulations, TRL 3 refers to empirical concept proof, TRL 4 represents technology validated in the lab, TRL 5 refers to technology validated in a suitable environmental-testing real-life, TRL 6 represents technology shown in relevant environment-industry environment in key-enabling technologies, TRL 7 refers to the system prototype demo in an operational setting, TRL 8 refers to a system that is complete and qualified, and TRL 9 represents an actual system proven in an operational environment-competitive production in key-enabling technologies (Katz, et al. 2015).

There are many studies in the literature about Technology Readiness Levels. According to Mankins (1995), TRLs are an assessment concept to compare between different technologies and the concept includes a lifecycle stage to produce technology. Additionally, it allows defining technology maturity levels for common understanding. The study provides a conceptual framework to define the technology as provided in his paper.

Terril et al. (2015) used TRLs as a basis for prediction and improved costs in flight preparation, as supported by this study with a deviation of approximately 30% root mean square (RMS) from the ideal. While investigating TRL step size, independently of the total cost, they find meaningful difference between many factor-dependent tasks. They proposed calibration of TRL scales with an S-curve shape because of the variance between real-world and TRL assumptions. The study proposed production of any technology below control costs and schedules. TRLs do not only define technology but also evaluate options about the supplier. Eckhause et al. (2009) evaluated real options for reducing technical risk in public sector R&D. TRLs are advanced criteria, they offer an- effective method which public sector managers may use to define the best supplier. This study proposed an overall

formula of such competitions which might be resolved via dynamic programming to define the most suitable vendors to purchase and exercise. Then, the study allows flexibility in budget; and multiple finding levels might increase program success probability.

Mankins (1995) claimed in another study that TRL is not a static measurement tool. The tool is continuously progress itself upon studies on TRLs in the last 30 years. A prospective future direction with past observations is proposed. This paper provides a retrospect on the history of "TRLs" during the past thirty years with selected observations. Engle et al. (2009) discussed various GEOINT-focused performance assessments also related to TRLs, and then provided a summary introduction for feasible multi-sensor data fusion framework.

The TRL of the system must be as high as its lowest TRL unit. Furthermore, maturity must be tested between low-high TRL (without omitting a level) in the face of previously determined criteria. This could save time and money while concentrating the work on real program developments instead of repeating the existing work. Moreover, this paper proposes saving time and cost with the definition of technology lifecycle before the release.

Magneye, et al. (2010) provided a discussion on the probable use of the most appropriate plan to follow-up and control the advancement of developing systems. For the proposed study, the IRL and SRLs must first be confirmed and validated by employing real life systems with real data on resources necessary to go between readiness levels (Sauser, et al., 2010). Finally, the study proposed a development model for planning to innovate a system.

Edmund (2009) handles TRL coefficients using the Analytic Hierarchy Process, which presents a methodology regulating the TRL ordinal scale coefficients, critiques a methodology that exists already and that relates ordinal TRL values to schedule slippage and that discusses some shortcomings. Consequently, the approach provides calibration of TRLs to reach more accurate values.

Altunok and Cakmak (2010) studied the adequacy of TRL. Firstly, they reviewed academic studies and applications of military and civil organizations about TRL. Then, at the end of their study by interviews and evaluation surveys, an applicable algorithm of TRL calculation was proposed for the Turkish defense industry. The paper is based on the face to

face interview method by using criteria set including R&D capabilities, project history, supports, information systems, quality wards and certification, training and specialty in staff experiences, as well as creativity. The study recommends a TRL calculator algorithm that may be beneficial for both Turkish defense industry and for defense industries of developing countries. The validity and reliability of the TTRL v1.0 application have been shown and it might be employed by those who develop technology, and the managers of technology and project easily. The application works in an errorless state, and it may be used for the prepared algorithm. It is possible to save the data in a desired way and show the result in a display. It assists stakeholders in better understanding the capture technology's rate of development and how it can reach the marketplace by capturing technologies at different stages. One criticism of the TRL framework claims it does not include the capability to communicate the effort level or difficulty needed for the success of the next TRL in a development cycle, which limits the TRL use tool for comparing the effort level, or for resource requirements among a field of mature technologies that are similar. El-Khoury and Kenley (2014) published their study in the literature on monitoring trend costs and time trends. However, their study offered a theoretical framework to allocate the analysis models based on the predictions and modify the model's useful estimations. Moreover, they used the estimations in the paper, developing a TRL model taxonomy based on the increasing assumptions made by these models. Conrow's (2011) calibration in the cost of the subjective inputs were carried out by AHP.

Unlike until now, Seablom et al. (2012) aimed to define the shortcomings evident in recent deployment technologies of NASA's Earth Science Division (ESD). The paper focused on using space technologies problems for benchmarking budgets and cost effectiveness.

Sarfaraz et al. (2012) purposed a more informed decision-making method to help managers measure and monitor the risks involved in progress and maturity evaluations. To achieve this, maturity pieces define the information pieces that decision-makers need to make informed- decisions and are matched to the system-architectural items. When the inaccuracy, uncertainty, or the lack of knowledge based on the complexity of engineering

systems are considered, this present study aims to develop decision-making on maturity evaluation by giving more information for better-based decision.

Fast-Berglund et al. (2014) expressed how TRL may be employed for design support for ICT-tools for operators in production in Sweden. Although TRL is a method to identify technological capability, it can also be employed for designing ICT tools for Swedish production operators. TRL helps decide designing of products for operators. While laboratory tests were carried out at university, external tests were completed in two industrial case studies for their paper. Although the TRL model provided good solutions in the paper, it had difficulties regarding use in different contexts.

El-Khoury and Kenley (2014), showed the accuracy of TRL assumptions with a four-level classification of models. The models clarified the assumptions, reviewed proof which supported the assumptions, proposed alternative or improved models. The approach investigated two new methodologies for sound prediction of median transition times and for forecasting transition times using historical data, and a set of recommendations for TRL-based regression models. The study suggested 4-level TRL-based model taxonomy. When they conducted their study on TRL cost and schedule models, they found out that various models stemmed from different assumptions and the only way of consistently evaluating and comparing those models. Unlike evaluating and designing technology, the application of the TRL scale on systems and equipment of Small Modular Reactor (SMR) helps identify the maturity and insufficiency of a certain SMR design. Referring to *in vitro* analyses, it provides an almost 10-year-long effort needed for the leading Light Water Reactor (LWR)-based SMR to reinforce the end-form and operate in full range of commissioning conditions (El-Khoury and Kenley, 2014).

Lalienė and Sakalas (2014) compared development studies with helping overestimation of the basic sciences. The study involved a process of evaluation of research institutions in Lithuania; for this reason, the improvement of this process led them to create effective innovation.

The advanced evaluation system allowed more effective use of scientific and infrastructural potential. With reference to TRL, with an implementation on research organizations, the study aimed to ensure successful knowledge-based development. This paper presents a modelling approach which allowed identifying the coverage of R&D activity types depending on the strategic goals of the research organization and what predestined the indicators of their performance evaluation. Thanks to some criteria such as R&D capability, project history, support, information system, quality award and certification, education and specialty of staff, experience, creativity, R&D type, activity type level, product type, the paper presents the modelled tool that allows identifying the coverage of R&D activity types that depend on strategic goals of study organization, they identified what predestined their performance evaluation indicators.

Furthermore, using TRL as a basis for predicting improved costs in flight preparation was supported by this study with a deviation of approximately 30% root mean square (RMS) from the ideal. While investigating TRL step size, independently of the total cost, Terril et al. (2015) found a significant difference between several factor-dependent tasks. They proposed calibration of TRL scales with an S-curve shape because of the variance between the real-world and TRL assumptions.

Straub (2015) discussed the definition and adequacy of TRL. He claimed that a higher TRL category is needed to refer to a proven technology demonstrated by long running processes. Eventually, the study contributed a higher level named TRL 10. This paper considered the need for the augmentation of the NASA technology readiness level scale with a new TRL 10 level and discussed the uses and disadvantages of TRL 10 level.

One of the reasons for the complexity of a project or system is that it has a lot of components, but there is an occurring constituent process such as a rocket engine. Hence, operational risk requires reduction via increased development of technological readiness associated with both structural performance and processes enacted of their functions. Analyzing the project or system with the TRL scale, identified correlation of the complexity of the technology on a subsystem level with development of technology readiness for performance reliability.

Predicting the readiness level of a system with several technologies in the current situation, the SRL method combines the TRL in each technology with Integration Readiness Levels, which requires that each of these technologies are integrated into other systems. The matrix algebraic approach is employed for estimating the readiness level of the system for the intended system. Knaggs et al. (2015) provided a successful pilot study, where the lessons learned and the potential of supporting the technology development of the SRL method were explained. By examining the TRL system comprising nine TRLs, it was aimed to classify technologically prominent characteristics of all devices included by evaluation. The assessment model proposed by Tapia-Siles et al. (2016) was adopted to assign a level for micro-robots/ devices as substitutes for screening colonoscopy.

Smoker et al. (2007) showed that TRL provides forecasting for future technology to be used in projects/programs to determine the rate of cost growth across time in projects/programs. This methodology should be considered by contractors, program offices and government oversight organizations as an addition to their basic estimating toolkit to handle costs related to maturing technology over the development and procurement life of all programs.

Rybicka et al. (2016) contributes to understanding the expansion and systematization of composite recycling technologies in terms of maturation. This paper contributes to the expansion and systematizing the information about maturity and understanding composite recycling technologies. The authors hope to inform industry and research organizations on the existing recycling technology field for supporting decision-making in industry-led recycling technology development.

Héder, M. (2017) defined TRL scales as related to concreteness and sophistication pointing out that it is decreased as its use became widespread except for its original context i.e. space programs. This paper summarized the background of TRL scale from its first development to recent years, when it was adopted by the EU as a means to organize innovation policy and funding.

The information about TRL as provided above indicates how the aims of employing TRL have evolved. TRL is not only considered as a tool for technology measurement, but inputs

or outputs of technological processes are also defined or evaluated for their current maturity. Carmack et al. (2017) proposed a classification model to assign maturity of nuclear fuels and materials. The result of the article contributed to defining attribution and categorization for nuclear fuel system technology readiness level definitions. Knowing the difference between TRL evaluations and technical risk is important. TRL gives us a measure of technology maturity compared to the end-objective of large-scale deployment.

Analyzing a system, a view of equality, equivalence and consistency in the identification and collection of technology subsystems (co-existence) technologies can be ensured to ensure consistent and comparable assessments of system preparation to effectively track the progress towards the goal of system readiness in the development of complex system designs. (Knaggs, et al. 2015)

Likewise, Dissel et al. (2011) investigated TRLs to view the development of the technology and the tools to categorize a technology that is used. Additionally, this helps define operations in the future. The case study reported the potential this new approach brings to early-stage technology evaluation, how this approach supplements existing approaches, and revealed some uses. We conclude with suggestions for future studies to develop the value road mapping technique further.

2.2 Technological Infrastructure

Technological infrastructure has spread in daily life throughout the early ages of technological improvement. The definition of technological infrastructure is in part of science as the historically defined set of mutually supporting sets of artifacts and structures without which the improvement and refinement of scientific knowledge are not possible (Solomon, 1998). Technological infrastructure is a platform on which applications work. Namely, each system which makes human activities easier or provides alliance societies can be identified as technological infrastructure. Additionally, technological infrastructure provides systematization to improve human activity.

Technological infrastructure contributes heavily to the common basis of the technological capabilities in order to build business application layers. Furthermore, the platform can be built up as two layers: one layer can define hardware topics, and so the layer includes the technological components such as computers and communication devices. Another layer refers mostly to the software together with shared services like the data processing management (Duncan, 1995). Technological implementation of the infrastructure on the platform is described in terms of three key words; reach, range and grasp. Platform connectivity is defined as "reach". This word refers to whom and what can be accessed (i.e. people, things, organization or data). Platform sharing is represented by the term Range, which is the "automatic sharing between applications and systems". On the other hand the term Grasp is used to represents the structure of the platform and describes the "context and meaning information about knowledge" (Henderson, 1992). Technological infrastructure is also identified in the literature as the IT resources that provide a basis to enable present and future business applications (Duncan, 1995). When an organizational infrastructure is screened in analogy, the technological domain may be specified with 3 dimensions (Haeckel, 1990). These are as follows:

a. Architecture that consists of application, datum, and technologies, "formulated through hardware, software, and communication configuration" (Morton, 1994).
b. Work processes that are the focal point of the operations of the technological infrastructure like system development, maintenance, monitoring and control systems,
c. Skills involving knowledge and capabilities needed for effective management of the technological infrastructure. IT infrastructure, as defined in this thesis, technology configuration, IT work processes, and shared services building and sustaining present-future business applications (Solomon, 1998).

Technological infrastructure can also be defined in a more intangible manner. Requirements are less coherent, and meanwhile, more differentiated and specific, serving narrower constituencies. The role of TI in growth is comprehended better in a structuralist

perspective, as one of several preconditions for structural change (Teubal, et al. 1996), These include the asset of the essential conventional infrastructure (transport, communication, power), human capital- infrastructure (e.g. a large-enough capability pool), and institutional infrastructure (e.g. a reusability system); the asset of capabilities that are based on firms in production, investment and innovation; and the resolution of the implicit interdependencies of investment decisions on which structural change depends. Considering these, the diverse nature of technological infrastructure shows up clearly: capabilities that are supplied collectively, specific and industry-relevant intended for several applications in two or more businesses or user organizations, which are concretized in the form of human capital (both formal training and experience) and also include physical capital elements (e.g. equipment) and knowledge (Teubal, et al. 1996). Technological infrastructure and morphological change lead enterprises to leave the routine provision of technological services aside.

In a traditional (low or mid-tech) industry development, there might be based only neither supply nor demand for essential skills, the technological infrastructure plays an active role of organizational developments. The basic role of technological infrastructure mediates among the technological requirements of the industry and potential supply sources. The technological infrastructure produces solutions to answer sector needs, it intensifies on the need to determine and build new and commercial supply sources for new technologies.

2.3 Technology Culture and Management Concept

Culture is known as a difficult concept to describe. In 1952, American some anthropologists took a very close look at the concepts and definitions of culture and brought together a list of 164 different definitions (Slócum, 1971). The definitions of culture include knowledge, belief, art, morality, norm, politics, community behavior and other skills (Apte, 1994). Culture can be compiled with clear, natural, behavior-gained or transmitted examples of symbols or gestures that constitute the changing success of human society; in other words, culture can be thought of as the products of action, the conditional elements of future action, while the culture requires the necessary core of traditional ideas (Adler, et al., 2008).

Culture consists of organized, learned, or created experiences, including the interpretation and coding of a population, past, current, or individual created by themselves (Avruch, 2004).

Culture brings people together, enabling them to collectively program their minds (Hofstede and Minkov 2010).

Culture refers to a hazy basic prediction and value set, orientations for life, laws, beliefs, policies, procedures, and behavioral conventions shared by people which affect the interpretation of each person's behavior and the "sense" of other people's behaviors (Spencer-Oatey, 2008).

While the culture is largely contributed by the intellectual capital of the culture, an organization culture can also influence the development of intellectual capital (Bass and Avolio, 1993).

Organizational culture provides following of existing rules, procedures, and norms to employees. Entrepreneurial founders create an organizational culture to reach alliances and business results

Organizational culture provides following of existing rules, procedures, processes, lessons learning, standards and norms to workers with some approaches. The following of existing cultural activities, the enterprise provides easily with technological infrastructures or technological improvements Entrepreneurial founders create an organizational culture to reach alliances and business results (Woodrow and Guest 2014).

The success or failure of an association depends on the philosophical beliefs of the builder, the existing changes and limitations faced by the foundation. Some founders create an agency culture they have to leave for others, but generally facts are contrary to this. The United States in the 1980s, the 3/4 of the CEOs of the fastest growing companies were founders of their companies and more than 80% did not have any retirement plans. Top management is required to make the necessary changes to the culture of an organization. The appropriate leadership for the organization should have consistent behavior with the followers (Murray, et al. 2002). It is likely that an expert of the members of the

organization will show the best style of leadership. Whenever the experts believe to level up existing technological improvements, the enterprise can have shaping technological capability.

The term "Organizational Culture" is widely used and causes some ambiguity. It is remarked that the culture concept was originally derived from a metaphor of the organization as 'something cultivated'. For decades now, most academicians and practitioners investigating organizations suggested that the culture concept is the setting and practice organizations develop with their relations with other people, or the promoted values and statements of beliefs of an organization (Bass and Avolio, 1993). For this reason, culture shows organizations a sense of enterprise identity and determines the way "things are done here" via the legends, rituals, beliefs, meanings, values, norms and language of the organization. The culture of an organization means what it is good at and what it has done in the past, which may be accepted without investigating by long-term members of an organization. One initial thing a new employee learns is the legends of the organization. Legends may remain in an organization and may become part of the founded method of doing things (Bass and Avolio, 1993). It is highlighted that there are visible-invisible corporate culture levels (Watson, 2006).

Organizational culture, then, is built up of more 'superficial' views like patterns of behavior and visible symbols and ceremonies, and deeper-seated and underlying values, assumptions and beliefs. Some people who are in favor of this claim that organizational culture can be changed by focusing on the more observable aspects such as rites and rituals because they help shape behavior. On the contrary, some other people claim that this is a misinterpretation of culture and that the 'detailed' sides of culture like beliefs and feelings must be considered while dealing with organizational culture and potential changes to culture. Understanding of organizational culture and cultural types help us to understand why managerial reforms might have different effects in and between organizations. Practitioners in private and public sectors have come to realize that organizational change often necessitates changing the organization's culture and learning. Developing a culture in

which career progression and development of staff are cared for pose an important retention and motivation means (Schein, 2004).

While there is growing interest in organizational culture among behavioral scientists and practitioners, there is no consensus on the definition of the term. Organizational culture is related to the causality that members impute to organizational functioning. We subsequently note the range of alternative definitions of organizational culture available in the literature.

Management Systems define an enterprises' culture as composing of the attitudes, beliefs and standards which effect the behavior of humans. Some researchers have shown that culture is a key factor contained in the that contribute to organizational success over the long-term. Additionally, enterprise culture may have an important effect on the "bottom line" of technological results; furthermore, it may have a significant effect on corporate success.

Some studies have reported 5 basic elements or dimensions in corporate culture that are linked to financial results in a statistical manner; and for this reason, they must be included in formal culture expressions and must be managed in an explicit manner. These 5 dimensions are:

1. Customer-Client Orientation - the method, the enterprise considers and advises its stakeholder/ customers.
2. "People Orientation" or Orientation Toward Employees – the approach the organization consider about and advise its human.
3. Standards of Performance and Accountability – the enterprise's standards for accomplishment and what humans are held accountable for.
4. Innovation and Commitment to Change – how the enterprise views, responds to, and manages innovation and change.
5. Company Process Orientation – the aspect that humans in the enterprises have of such processes as planning, decision-making, communication, and what we term "corporate citizenship" or "social responsibility."

Enterprises may own powerful or weak cultures, functional or non-functional cultures. A powerful culture is one in which all humans understand and act consistently with company values, beliefs and norms. In a weak culture, people do not understand what the culture is and/or do not adopt it. A functional culture has a positive effect on the success of the company. A dysfunctional culture is the ability of a company to be successful in the long run in a sustainable manner.

In Management Systems, a differentiation between a company's "real" (or "current") and "desired" (or "strategic") culture is to be made. Real culture is one which influences the behaviors of people, and desired culture is the one which company wants to have to support the achievement of its long-term targets. Successful organizations are the ones in which real and desired cultures are aligned.

A business organization is required to have an effective culture management for the purpose of achieving and maintaining a high-degree alignment between real and desired cultures.

There are many definitions of workplace bullying and organizational culture, these concepts were studied by multiple researchers. Therefore, most authors identify culture as a multidimensional concept including the individual's values, beliefs and assumptions building an organization. Enterprise culture influences thoughts, solving to problem methods, focusing areas and serves to augment the benefits of the strategic goals and shared responsibility. The nature of organizational culture varies at every workplace and is reliant on the personnel and the recognized principles, procedures, policies and practices at the given organization (Pascale and Anthony, 1981).

Prosperous organizations align employee interests and goals with organizational goals (Pascale and Anthony, 1981). The efficient organizational leaders deliver mechanisms, infrastructures and community systems in their company, expanding productive employee relationships and lessening workplace struggle and bullying (Kochan, 2013). In the absence of such organizational leadership, the organizational culture tends to be more confrontational and unfriendly, resulting in augmented levels of employee conflict, bullying and hopelessness among the staff (Fischer and Martinez 2013).

Leadership and the management relate to the existence of workplace bullying; an organization where bullying prospers can be a result of tyrannical management. Non-autocratic management and leadership improve employee performance, which can advance business overall success and profitability (Tambur and Vadi, 2012), (Pilch and Turska, 2015). Managers and organization leaders can contribute towards positive work environments, if they can restrain their adverse behavior. If the leaders take part in workplace bullying, the occurrence becomes normalized and can lead to decreased staff self-confidence and overall organizational efficiency (Ashraf and Khan 2014). To sum up, technological adoption is among organizational topics, and it depends on an organizational view. Hence, the organizational culture plays a role to adopt a technological improvement for the enterprises. The enterprises become successful when its culture tend to stand for technological developments. Likewise, the technological improvements are related to managerial topics, as the management view effects on making decision about technological improvements of enterprises.

2.4 Technology Investment

The significant participation of technology in financial developments was admitted so far. Financial investments in technology were a strategic topic in financial development. A few case studies remark the uses of such investment for the finance of the society. For instance, Adeoti, et al., (2012) traced the link among firms regarding their investment in technology and exports. Moreover, some studies discuss that innovation and technological improvement were carried out by entrepreneurial companies, which are liable of employment and productivity growth in enterprises. In recent years, new entrepreneurial firm's formation or improvements based on financial parameters are highlighted by most of scientific research. Nevertheless, a study on the impacts of hesitation and risk issues on investment determinations has endured little. Enterprises' investment on technology is very incomprehensible to consider worrying about the welfare for the financing of an enterprise. Likewise, Keen (1991) figured out the learning level for assessment on the benefits of technological investments. Since IT investments are assessed by a comfortable period's framework, the assessment process of investments on IT infrastructure is mostly difficult.

In the literature, Hochstrasser and Griffiths' questionnaire was employed by authors to measure this (Apostolopoulos and Pramataris, 1997).

Previous research investigated enterprises' investments in innovation in uncertain situations. The original model of this state belongs to Dixit, et al. (1994), who proposed the irretrievable investment model, which is an expansion by the feasible investment strategy on the oligopolistic market model. Based on the model claimed that investment to threshold proved that there is a relationship between the threshold and even the breaking and the monopolistic investment threshold.

Reassuring similar views, Keuschnigg and Nielsen (2001) discussed that the investment threshold makes the enterprise break eve. Most other simple case studies investigated the effects of method investments on uncertainty innovation. For instance, Caggese (2012) investigated 11,417 Italian manufacturing enterprises using a new simulation model of entrepreneurial enterprises and provided testable estimations affecting the relationship between financial markets, uncertainty and the decisions to undertake risky productivity-enhancement projects.

IT investments have an interrelated impact on company value. For this reason, managers must reconsider the uncertainty innovation investments because the value of shareholders priority is maximized by managements. Due to significant applications of the company value approach, we may understand that many IT managers consider industry- and company-specific effects on IT investments, competitive advantage, and its effect on company value and investment risk (Dehning, et al. 2005).

2.5 Business Results

Business results have more conventional types of results related to volume, batch, cost, feature and quality of products or services. All enterprises produce results from the activities of transaction data, information and knowledge between two or more shifts daily. All activities of every employee are designed to add value to the business, and therefore, influence performance and the specific conclusions the enterprise achieves.

2.6 Multi-Criteria Decision-making (MCDM)

MCDM is an approach completely identifying the formal steps employed to facilitate decision-making for complicated problems. MCDM aims to unify the measurement processes with value judgments by trying to make the assured subjectivity more visible in complex problems (De Lange, et al. 2006). The MCDM view is based on the relationship deciding on the best alternative from a list of choices on which a set of criteria will be evaluated.

There are manners of approaches to MCDM, some of which can be summarized as follows (Belton and Stewart, 2002):

- The MCDM programs the goal, aim and reference point techniques.
- The well-known types of MCDM are multi-attribute
- Analytical hierarchy process (AHP) and value function (MAVF) are the well-known types of MCDM and these approaches have multi-attributes.
- Game theory approaches based on MCDM.

There are some methods to solve multi-criteria decision-making problems. AHP is one of the most practical methods in the literature. Although there are many techniques available for solving MCDM problems, AHP, which was proposed by Saaty (1979) in 1970s, is a more practical technique to overcome complexity. However, AHP is inadequate in reaching an optimal solution. According to the type of the problem, MCDM methods have variety to solve problems. For example, fuzzy AHP has more advantages to overcome problems than AHP.

2.7 Step-Wise Assessment Ratio Analysis (SWARA)

Various ways are employed to determine values of attributes and their weights like objective, subjective and integrated attribute weights. Merely well-founded weighing elements should be used because they are always subjective, and affect the solution (Karabasevic, et al. 2015).

The weights of attributes may be determined by applying:

- subjective methods (AHP – Analytic Hierarchy Process),
- expert judgment method based on the expert assessment),
- objective methods (Entropy),
- Integrated methods (which are combinations of several methods).

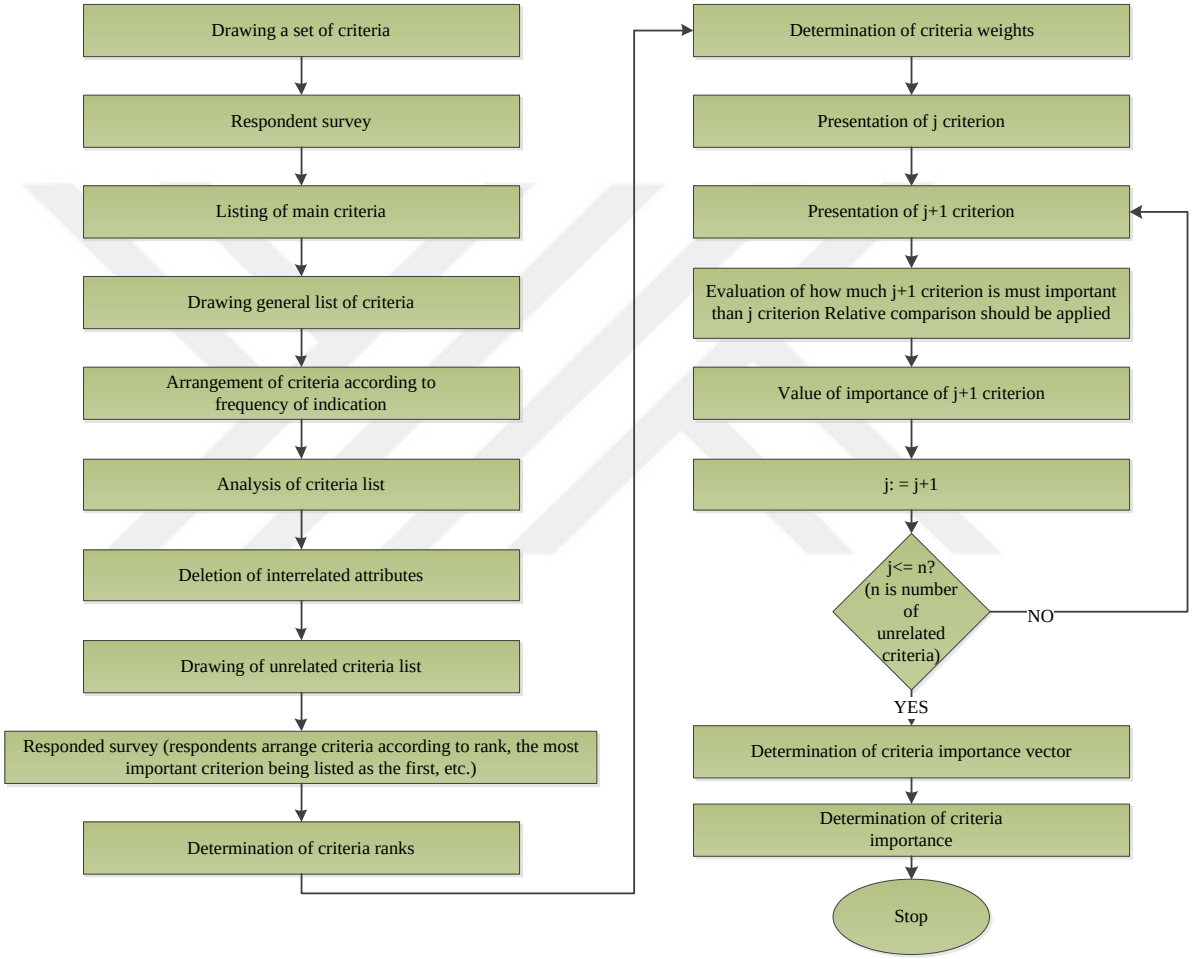

Figure 2.1 Determination of Criteria Weights Using the SWARA Method

It is known that the SWARA method reaches the solution with less comparisons of features than AHP method. This feature makes the SWARA method more attractive than the AHP and ANP methods. As schematized in Figure 2.1, the SWARA method involves five steps as the following:

Step 1

Belief and views of the experts are sought and tabulated for generating the weights. At frst step, it is aimed to rank from the most important to the least important criteria for each expert in relation to the subject. The experts are asked which criterion is the most important to them and their answers are noted in the first line of the table. Secondly, the criterion that the experts can qualify as second most important is then asked, and the relevant criterion for the answer is noted in the second line of the table. Then, the criterion that the expert can qualify third most important than the second one is asked, and the relevant criterion for the answer is noted in the third line of the table. The table is created in the same way until the last criterion.

Step 2

Starting from the second criterion, the rating of how the second criterion is more important than first criterion is identified by the decision-makers. Moreover, a binary comparison is done between the next criterion and the last criterion by the decision-makers. The number of "sj" is the comparative importance degree of criteria relative to each other. This number is expresses with a percentage. Because there is not criterion before the first criterion, and binary comparison cannot be performed, the side column of the first criterion is therefore left blank. Decision makers are then asked to answer how much the first criterion is more significant by percentage than the second criterion. After the judgment, the value is written in the next column of the second criterion. The expert is asked how much more important the second criterion is from the third criterion, and the answers are written in the side column of the third criterion.

Step 3

Firstly, the coefficient "k_j" is determined where "k_j" value of the first criterion is always 1. Additionally, the second criterion's value of "k_j" is found by increasing one more the "s_j" value of the second criterion which is obtained in the previous step. As shown in Eqn. (1), this calculation is continued until the last criterion.

$$k_j = \begin{cases} 1, & andj = 1 \\ s_j + 1, & andj > 1 \end{cases} \quad (1)$$

Step 4

This step involves the determination of the so called "criteria importance" vector. The criteria importance vector "w_j" is determined by the evaluators. The importance coefficient "w_j" of the first criterion is always 1. The coefficient "w_j" of the second criterion is obtained by dividing the number 1 by the value of "k_j" of the second criterion. These calculations are continued in the same way until the last criterion. As seen below in Eqn. (2),

$$w_j = \begin{cases} 1, & andj = 1 \\ \frac{x_{j-1}}{k_j} & and \quad j > 1 \end{cases} \quad (2)$$

Step 5

The weights of the evaluation criteria are determined as shown in Eqn. (3). The "q_j" weight of the first criterion is calculated dividing 1 by the sum of all the "w_j". The "q_j" weight of the second criterion is calculated by dividing the importance vector of the second criterion by the sum of all "w_j". The "q_j" weight of the third criterion is obtained the same way with the "q_j" weight of second criterion. The value of "q_j" in a decision-making problem with n criteria, shows the jth relative importance of the criterion.

$$q_j = \frac{w_j}{\sum_1^n w_k} \quad (3)$$

3. PROPOSED TRL ASSESSMENT MODEL

3.1 General Structure of the Model

In order to generate an assessment model, the criteria set was first generated by the gap analysis among the literature models. The set was weighted with the SWARA technique before calculation of the ETRL because of the criteria significance levels. Figure 3.1 provides an outline of the research process that was followed in this study. The process started with a literature scan of the definitions of technology readiness levels, technological readiness level meanings, technological performance criteria and methods of weighting the criteria for the ETRLs. Although gap analysis of nonconformity in the literature was described and a plan to navigate the shortfall was developed and discussed with mentors, the framework was proposed to provide a common understanding of ETRL among different enterprises.

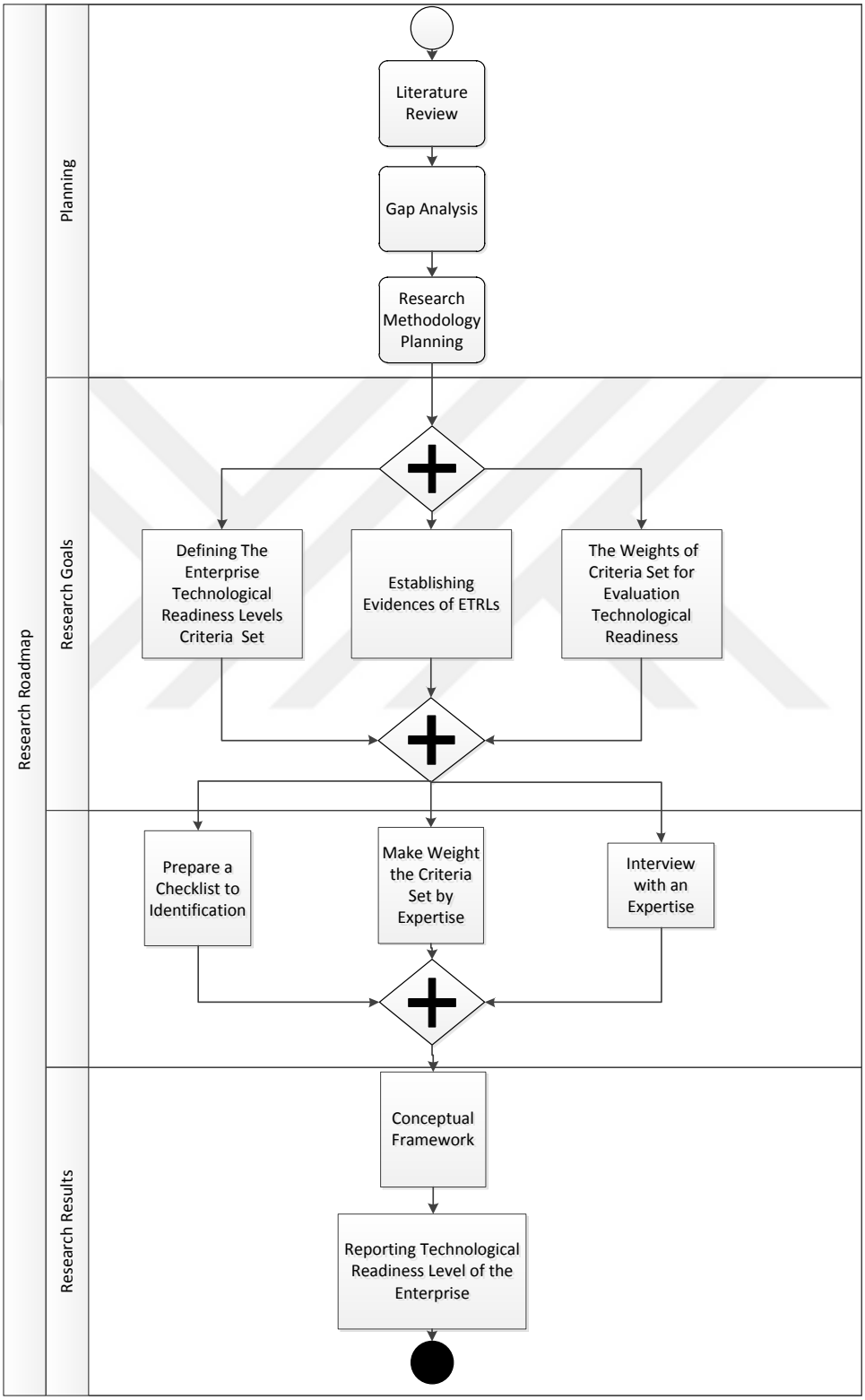

Figure 3.1 Research Roadmap

To collect comparable data from the interviewers, a new ETRL checklist was introduced. The checklist was updated along the course of the study to improve its ability to collect evidence data. The checklist was designed to provide an insight into the attitudes and knowledge of senior high-level chief and system engineers as well as program managers as in the case of NASA's TRLs and manufacturing activities that enable the assessment of the enterprise technological capability during an ETRL road mapping.

It covers a prioritization of criteria set, as seen in Figure 3.2, that is related to the technological capability of the conceptual model. which is named Enterprise Technological Readiness Levels as proposed.

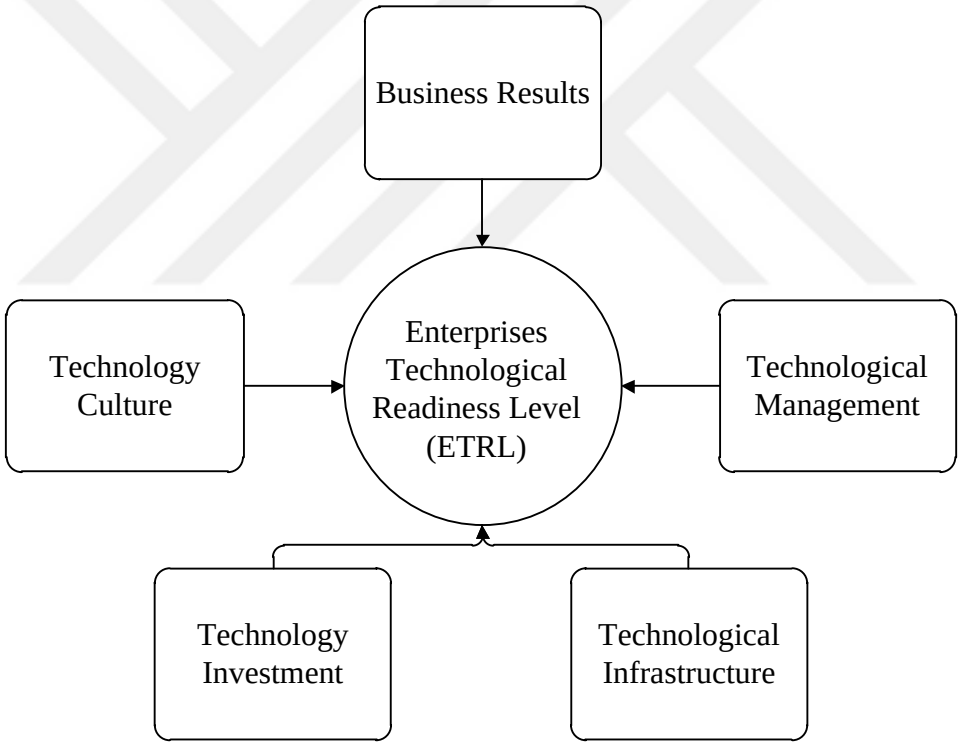

Figure 3.2 Components of the Enterprise Technological Readiness Level (ETRL) Model

In the next section, detailed description of each component is introduced.

3.2 Components of the Model

The suggested model concept is clarified in general. The reason for querying the 5 criteria of readiness is explained supporting the idea with the current literature as *seen* in Figure 3.3 in terms of manufacturing enterprises.

After the decision of main criteria set, an enterprise is evaluated to identify capability with the ETRL Checklist.

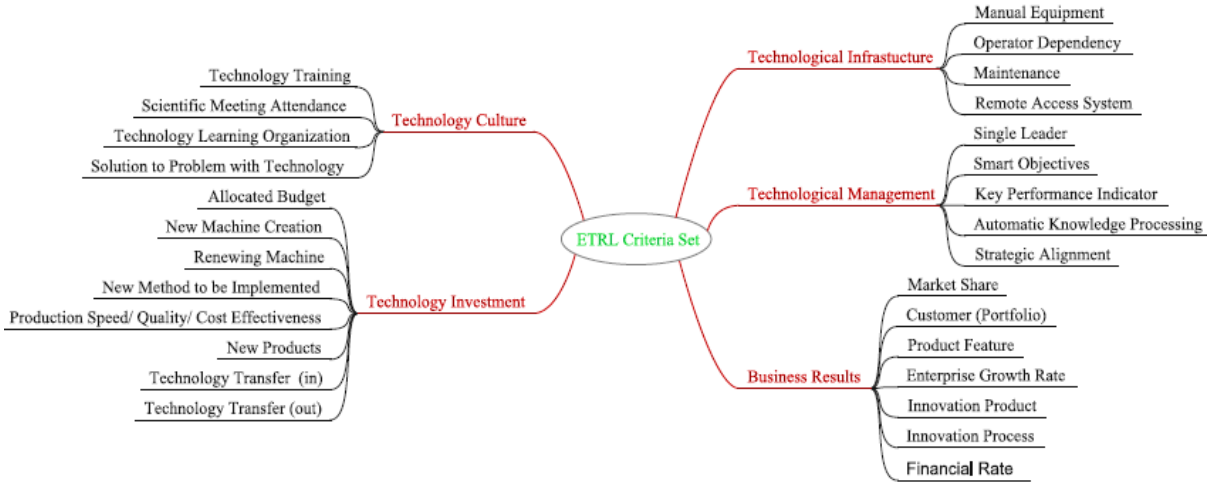

Figure 3.3 An Aspect of Overview ETRL with Components

3.2.1 Technological Infrastructure

A technological infrastructure is a platform on which applications work. This provides the common foundation of the technological capabilities for building business applications and the platform can be built up as two layers. One of the layers includes technological components such as machines, computers and communication technology equipment. The other layer is shared services like data processing management. However, technological infrastructure provides a systematic approach to improve human activities. Hence, while defining ETRLs, how much the criterion utilized, contributes to be higher technological capability and maturity of enterprises. The infrastructure is assessed from the following viewpoints.

Manual Equipment

Manual equipment is controlled or manipulated by an employee/operator. These tools are powered by human or animal muscle power. The manual equipment is a sub-criterion and is worked usefully in each lifecycle of products.

Operator Dependency

Operator dependency is a concept that shows how much a human factor is needed when a process or activity is carried out.

Maintenance

Maintenance is an activity required to retain or restore equipment, machinery, or system to the predefined operable condition for the purpose of achieving maximum useful life.

Remote Access System

Remote access is an ability to reach a network, or another computer-based machinery over a network. All connection-type access is remote access because data are downloaded from a remote server. Providing remote control is also called a remote access system.

3.2.2 Technology Culture

AS stated earlier, the corporate culture brings people together. It provides the collective programming of their minds. The organization's culture contributes in large part from its intellectual capital while the culture of an organization can also affect the development of its intellectual capital. Organizations can have different views on culture; strong or weak cultures; functional or dysfunctional cultures. A strong culture provides each employee with consistency in understanding and behaving on values, believes and norms. This type of culture contributes to adoption of systematic technology. If employees are not speaking in terms of common items of, they have a weak culture. This type of culture has a chaotic approach to adaptation to and learning of technology because of inconsistent decisions. The technology culture is assessed from the following viewpoints.

Technology Training

Technology training is a concept about training of staff about the technologies that the enterprise has or is likely to have.

Scientific Meeting Attendance

Scientific meeting attendance refers to the scientific conferencing participation that businesses have or is associated with their own technology.

Technology Learning Organization

Technology learning organization refers to the application of technology trainings that are acquired by the enterprises in their processes or activities.

Solution to Problem with Technology

Solution to problem with technology refers to technological solutions that have been implemented or are likely to be implemented to solve the problems that arise in the business.

Market-Related Innovativeness and Flexibility

This term refers to the degree of flexibility that enterprises exhibit against innovative products / solution delivery offerings or innovative products emerging in the marketplace.

3.2.3 Management of Technology

Management describes all managerial activities of the enterprise strategies and processes to coordinate employees to achieve organizational objectives though the implementation of available resources. The Managerial capability of the enterprise is assessed from the following viewpoints.

Single Leader

Single leader is a concept which means that in all processes, only one person is the final decision-maker. They make decisions by themselves.

Smart Objectives

SMART is an acronym that it used to describe the successful goal setting.

To ensure the enterprise's goals are clear and reachable, these goals should also be:

- Specific (sensible, significant, simple)
- Measurable (meaningful, motivating)
- Achievable (attainable, agreed)
- Relevant (result based, realistic, reasonable)
- Time-bound (time base, time-limited, time sensitive)

Key Performance Indicator (KPI)

KPI is a measurable value that shows how effectively and efficiently an enterprise is achieving key business objectives (defined as SMART objectives). Enterprises use KPIs on multiple levels to assess their achievement of succession targets. High-level KPIs may focus on the overall performance of the enterprise, while low-level KPIs may focus on processes in departments such as production, quality, sales and marketing.

Automatic Knowledge Processing

Automatic knowledge processing capability means analyzing knowledge to solve shortfalls. It replaces the Knowledge Engineer with a program that produces a list of rules which generate the same decisions given the data. Technologically capable enterprises are able to utilize automated knowledge manipulation tools.

Strategic Alignment

Strategic alignment refers to the process of harmonizing the actions of an organization and its staff with the goals of the organization. The ability of most businesses to achieve their strategic objectives will make use of from a strategic alignment to ensure that departments and employees work toward jointly identified targets.

Strategic alignment helps organizations determine what drives the organization the most, including small businesses, and then creates a roadmap to achieve the organization's goal. Strategic alignment requires a workforce that is responsible and provides planning, re-auditing, and regularly achieving regulatory and organizational goals.

3.2.4 Technology Investment

Although there are two basic meanings of investment based on money undertaking or owned machine or facility for future income in the literature, this concept means fixing income investment, or variable income investment. In economics, investment refers to creation of capital or goods that may produce other goods or services. Spending on training and health is recognized as an investment in human capital, and research and development is considered as an investment in intellectual capital. Return on investment is a key element in the performance of an organization. The technology investment capability of the enterprise is assessed from the following viewpoints.

Allocated Budget

Generally, budget allocation is made to departments and program units. This allows following easier identification of the resources allocated to specific programs and functions. We consider evaluation of scientific budget allocation as technology investment levels.

New Machine Creation

As mentioned, manufacturing is bases machinery utilization. Hence, when creating new machines, both innovation and cost reduction are preferable, while this criterion refers to budget allocations in creating (a) machine(s).

Renewing Machine

Renewing machine represents allocation of budget for the enterprise's available machines.

New Method to be Implemented

The enterprise needs to optimize or want to increase effectiveness or efficiency for producing and managing business processes. Allocating a budget for deciding on a new approach is making an investment in a new method to be used.

Production Speed/ Quality/ Cost Effectiveness

Production features are more important for assignment of technological readiness. The features are changeable based on technological investment levels. This criterion refers

optimizing production speed/ quality/ cost effectiveness according to the evidence based on this criterion.

New Products

This criterion means investing the new product as categorized by technological investment. Hence, the investment evidence indicates whether the enterprises is ready.

Technology Transfer (in and out)

Two main classes of technology transfer are getting adopted by different enterprises, and the enterprise also transfers the production technology to any enterprise. This criterion represents the levels of investment in technology transfer.

3.2.5 Business Result

Enterprises that are successful and retain outstanding results meet or exceed the needs and business expectations of their customers/stakeholders. Businesses results add value to internal customer/processes and external stakeholders/customer. Hence, business results refer to deciding on both how the outputs are effective and efficient, and whether the enterprise is ready for more attributiveness to value-added and higher technology. The business results of an enterprise are assessed from the following viewpoints.

Market Share

A market share represents deciding on technological readiness levels as business result categorizations. Hence, a market share criterion changes remarkably depending on the condition of the product on the market.

Customer (Portfolio)

Enterprises address a variety of customer segments. Their products also focus on answering customer needs. Furthermore, this criterion decides whether products are adequate for customer needs or not.

Product Feature

Product feature means a concept's complexity of function. This criterion assigns levels of product multi-functionality.

Enterprise Growth Rate

Enterprise growth rate refers to deciding upon the output level of product in customer segmentation. It is also adaptive to product feature. This criterion assigns technological readiness levels for business results.

Innovation Product

An innovation product represents as assignment of products based on customer requirements. It means innovations to achieve goals from profitability to multi-functionality between levels by readiness.

Innovation Process

An innovation process is a concept to assign technological readiness for business results. It refers to generation of new and value-added activities to optimize results. This concept also changes product segmentations from profitability to multi-functionality.

Financial Rate (EBITDA)

EBITDA is an indicator of the financial performance of an entity, and it is used as a proxy for an earnings potential, which may have disadvantages. EBITDA exposes the cost of debt capital and tax effects by adding taxes to interest and earnings.

3.3 Business Rules / Implementation Issues

As considered, describing the technological readiness level for enterprises, a model needs to identify the technological level according to main criteria. These levels help define technologically readiness by using a criterion set. However, the criteria do not also have the same impact in assigning the final ETRL values. Therefore, the criteria need to be identified by weighting with a multi-criteria decision-making. As identified, SWARA, a multi-criteria decision-making method, weights the identified criteria set to build an enterprise technological readiness model. The weighting rate is more important to assign specific technological readiness levels. The ratings of levels provide decisions which effect the criteria in the Enterprise Technological Readiness Level model.

Furthermore, the model can be applied on a variety of cases in the manufacturing sector. The model aims to identify specific enterprises' technological readiness levels.

3.3.1 Technological Infrastructure Levels

The adequacy of the technology is considered as to whether the technological infrastructure of an enterprise is ready to run IT and other hardware (including machines) with contemporary technological capabilities. The checklist is provided in order to decide the respective level of an enterprise as shown in Table 3.1.

Table 3.1 Technological Infrastructure Levels

Degree of Level	Technological Infrastructure Levels	Definitions
4	Autonomous System	An autonomous system means categorization of a machining system which works without a human. The systems also should have sensor technology, and the data should be analyzed by artificial intelligence methods. These segmentation technologies have artificial intelligence, smartness, fuzzification and heavily, PLC.
3	Automatic System	An automatic system refers to a system that is controlled only by start-stop commands by a human. Without human power, the systems perform all processes. The categorization of technological infrastructure should have PLC or Computer-Aided Design. The systems need human intelligence.
2	Semi-Automatic System	A semi-automatic system refers to neither an automatized system nor a manual system. The system needs both human intelligence and human power together to operate.
1	Manuel Machine	A manual machine refers to using the power of the machine operate any part/product, but an operator provides the systematization of the process. Hence, the operator does not use muscles, but they control each activity such as holding the machine, feeding the part, loading the line, quality control, and other mostly primitive tasks.
0	Manuel Tools	Manual tools are traditional working equipment which are used in daily life to be easily finishing a job. However, even now, these tools are used to output business value by enterprises. The work carried out with the equipment is performed by human power only. These are most not used to complete the process, but to help more easily accomplished activities.

3.3.2 Technology Culture Levels

An enterprise should carry technology prone cultural view for the adoption of a new technologies without delay. A cultural view as defined in Table 3.2 is more significant in defining the enterprise's technological readiness level.

Table 3.2 Technology Culture Levels

Degree of Level	Technology/ Culture Levels	Definitions
4	Innovation and Renovation Based Society and Culture	The culture of the enterprise supports generation of a new idea and creation of a new solution, product, etc. An enterprise's culture which also improves an innovativeness idzea is a renovation-based culture. Briefly, an enterprise's culture is based on innovativeness-thinking and renovation-thinking, the enterprise produces a new idea/product and improves the idea/product.
3	Knowledge Based Society and Culture	Knowledge-based culture means the level to which the enterprise culture provides support to view knowledge as valuable assets, logs, records and resources. A knowledge-based culture uses a knowledge-based management tool to analyze recorded data.
2	Experimental Society and Culture	An experimental culture describes a work environment where people are encouraged for working via trial and error. This segment of enterprises supports taking risks in tasks and contributes to learning.
1	Traditional Approach to Society and Culture	Traditional culture does not need to change things such as variety of products, customer portfolios and new processes. A traditional culture consists of acceptances, beliefs, dependencies and practices. A traditional human group is based on traditions that have been passed down from ancestors.
0	No Noteworthy Observed	This level means that there is nothing worthwhile.

3.3.3 Levels for Management Approach to Technology

A management approach for technology in organizations is an important indicator to define technological readiness. As mentioned above, enterprise management provides support or sponsorship to be utilized in the business process. As seen below in Table 3.3, management levels help make decisions the defining technologic readiness of an enterprise.

Table 3.3 Management Levels

Degree of Level	Management Levels	Definitions
4	Strategic Management (Enterprise Wide Management, Process Alignment)	Strategic management is based on an enterprise's resources used to obtain goals and objectives. Strategic management includes setting goals, analyzing key performances and internal process, assessing strategies and ensuring that the management rolls out the strategies across the organization.
3	Process Oriented (Cross Functional Management in Business Process)	Process-based management is a kind of management methodology that views a business as a set of processes managed to reach an expected result. These processes are managed and improved by the enterprise with the purpose of achieving their vision, mission, strategy, core value and KPIs.
2	Management by Objectives (Analytical and Analyses)	Management by objectives is a kind of a management approach to view goals assigned by strategic planning. Then according to the objective, evaluation of achievements is carried out.
1	Functional Management (Experienced Based)	Functional management is kind of management which top management decisions are sent down to be the objectives of business activities.
0	Shop Management	Shop management is the real-time management of resources and orders in the workshop to realize a production plan.

3.3.4 Levels on Technology Investment

An investment on technology is one of the most significant measures in deciding on technological readiness of an enterprise. The inadequacy of technology investment is a decisive indicator based on the allocation of budget. As seen below, Table 3.4 shows the definition criteria that provide a decision about ETRL.

Table 3.4 Technology Investment Levels

Degree of Level	Technology Investment Levels	Definitions
L4	Remarkable Investment on R&D of Technology Market	The enterprise has used almost all the budget they allocate to research and development. These enterprises have Remarkable Investment on R&D of Technology Market level
L3	Investment on Generating New technology in the market	The enterprise is planning to spend the budget they plan to produce on their own machines / machines in the marketplace.
L2	Remarkable investment on available technology	The enterprise remarkably invests in renewing the available technology.
L1	Partially Investment on available technology	The enterprise partially invests in renewing the available technology.
L0	No Noteworthy Investment	The enterprise invests in its basic needs to produce outputs.

3.3.5 Levels for Achieving Business Result

The business results are important due to their value-added. As seen below in Table 3.5, the definitions of levels are used to identify technological readiness for an enterprise with this respect.

Table 3.5 Levels regarding Business Results

Degree of Level	BR Levels	Definitions
4	Multi-Functional and Cost Effectiveness Products	This describes the product has one more functional technological features, and a base of cost effectiveness.
3	Product Variety and Globalization	It is the products addressed for the global customer in a diverse product portfolio.
2	Dominated Market and Competitive Advantage	DMCA refers to how much the enterprise focuses on dominating the market and gaining advantages with its product portfolio.
1	Profitability	Profitability level means that the enterprise aims to increase profit only.
0	No Significant Results Obtained	This level means the enterprise aims to produce products. Hence, its production is the only intended business result.

3.4 The Aim of ETRL Checklist Implementation

Awareness of the implementations of the ETRLs, provide a general knowledge about the manufacturing industry, aims to reveal the technological readiness systematics of enterprises.

Therefore, there is designated objectives as well as two auxiliary objectives.

First objective is to collect information on the technological readiness of enterprises, and to reveal how they reflect systematic infrastructure, culture, management, investment and business processes, a checklist is to be provided. This brings about the enterprises to use increasingly systematic processes for technological readiness as well as awareness of the overall process.

The secondary goal of the checklist is to see whether or not enterprises are aware of their TRL, since their experiences that reveal such a difference. Although the corporate taxonomy of business proceedings of enterprises reflects the systematic ETRL approach, this systematic is not reflected on their business proceedings. This study examined the technological differences by considering the infrastructural capability, cultural approach, management aspects, investment allocations and business results between the sides.

The checklist has a set of criteria for five categories as shown in Figure 3.2. This include 37 sub-criteria.

The first group of criteria was prepared to reveal the technological infrastructures of enterprises. The criteria investigated four segmentations as autonomy system, automatic machines, semi-automatic machines, manual machines and manual tools. As previously mentioned, the first set was consolidated to identify the infrastructure using machining tools, presence of operator and software dependency, maintenance methods and remote control of systems. During the implementation on the case study, evidence on the age of each technology was reviewed in terms of technology development as seen in Table 3.6.

Table 3.6: Evidences for Each Level of Technological Infrastructure

Technological Infrastructure		SUB-CRITERIA				
LEVELS		Manual Machining	Operator Dependency	Software Dependency	Maintenance	Remote Control
L4	Autonomous System	• NO	• NO	•Heavily PLC+ FLC •Digitalization •Integrated IT infrastructure •Integrated ERP to MES and PLC	• Monitoring maintenance Warning (Artificial intelligence model) • Autonomy maintenance planning	• Command machines by both same and different network technologies
L3	Automatic System	• NO	• NO	• PLC • Non-integrated Corporate application (ERP, MRP, Integrated Document Management System, Task Management System, etc.) • Management Decision Support Systems	• Periodically Maintenance Plan • Warning by Different System Such as database etc. • Kaizen	• Remote control same network
L2	Semi-Automatic System	• Processing controlled by operators • Interfere against unintended consequences • Feeding on machine by operator • Optimization Cross Functional Operation	• Machine makes almost all activities without feeding on, start and stop machine.	• Easily PLC	• On Demand Maintenance Plan • Human Tracking Maintenance Plan	• NO
L1	Manual Machine	• Power-Tools (Milwaukee Drills, Impact Tools, Automotive Tools, Snap on Power Sanders, etc.) • Using engine power control by hand craft • Handling complex relativity	• Making all activity with engine power	• NO	• Maintenance is required, when system/ machine is broken down	• NO
L0	Manual Tool	• Hand-Tools (Hammers, Wrenches, Ratchets, Pliers, etc.) • Only manpower • Minimum safety systems • No technological component	• All Function Controlled by Operator	• NO	• NO	• NO

The second set of criteria represents the organization's cultural aspect regarding technology. This group of criteria consist of five levels, are categorized as innovation and renovation based, knowledge based, hierarchical (experimental), traditional and no noteworthy levels. The evidences were categorized to identify cultural approach more specifically. Like technological infrastructure, each technology culture criterion contributes to making decisions on cultural capability for technological improvement and adoption details. Besides evaluation, the cultural view of enterprise uses sub-criteria set as technology training, scientific attendance meeting, and technology learning organization, solution to problem with technology, market-related innovativeness and flexibility. After the criteria were set, during the interviews, these were evaluated using the evidences as shown in Table 3.7. As mentioned, the sub-criteria were tabulated to analyze the identified levels. When the model is considered as a manual machining factor, the assessment shows that business processes are based on the automation rate.

Table 3.7 Evidence for the Levels of Technological Culture

Technology Culture		SUB-CRITERIA				
LEVELS		Technology Training	Scientific Meeting Attendance	Technology Learning Organization	Solution to Problem with Technology	Market-Related Innovativeness and flexibility
L 4	Innovation and Renovation Based Society and Culture	• Innovative Machine/ Equipment Training • Innovations and Creativeness Think Courses (TRIZ, PUGH, SCAMPER, etc.) • Sharing Documentation of Innovativeness Courses in Internal Customer	• Attendance Innovativeness Seminar/ Conferences • (Made Presentation Product on Showroom, Prepared Scientific Study about precuts, organization model such as an article, proceeds, etc.	• Research of innovation technologies (article, Proof of Concept, etc.)	• An artificial Intelligence model approach or innovative technique implementation to solve problem	• Predict innovation
L 3	Knowledge Based Society and Culture	• Knowledge Based Tool Training • Knowledge Based Management Modelling Training • Lessons Learning Management and Tool Courses • Modelling Processes Training	• Taking Best Practice product effectiveness about from Stakeholder Meeting • Solving All Problem or Customer Needs by Scientific Method Meeting	• Using Knowledge Management Tool on experiences, lessons learned, performance indicator • Educating employees throughout using the tool	• Knowledge based approach to solve problem	• Needs analysis innovativeness on market
L 2	Experimental Society and Culture	• Knowledge Log Training • Defining and Modelling Function of Organization Training	• Discussion of Scientific Approach to Develop Product Meeting	• Experiences log on any tool • Define technology learning procedure	• Arranging meeting to solve shortfall with technology	• On demand innovation from market and making decision by board of director
L 1	Traditional Approach to Society and Culture	• NO	• Being unaware of solving problem by scientific meeting	• NO	• NO	• On demand innovation from market and making decision by a single leader
L 0	No Observed	• NO	• NO	• NO	• NO	• NO

Then, a group of specific criteria is generated for assessing the managerial aspect regarding the technology. The criteria in this group are categorized as strategic management, process oriented, and management by objectives, functional management, and shop management levels. Besides evaluation, the managerial view of enterprise uses sub-criteria set as single leader, smart objectives, KPI, automatic knowledge processing, strategic alignment, the need for integrated software, performance assessment, and periodic assessment. Furthermore, organizational management provides inclusive approaches using technology in the business process. Although using technology is more cumbersome for employees, thanks to management, the enterprise easily achieves adoption of technology for daily using in its activities. The evidence for the managerial aspect of technology is given in Table 3.8.

Table 3.8 Evidences for Management Levels

Management		SUB-CRITERIA							
LEVELS		Single Leader	Smart Objectives	KPI	Automatic Knowledge Processing	Strategic Alignment	The Need for Integrated Software	Performance Assessment	Periodic Assessment
L 4	Strategic Management	• NO	• Specific, Measurable, Accepted, Realistic (SMART) • Timely	• Gathering Data by Agents • Assigning to track Strategic Objectives	• Business Intelligence tools • Integrated CRM to Other Functional System	• Objectives aligned with strategy at personal level	• Fully integrated	• Strategic performance assessment at all levels	• Periodically Supported by Autonomous Systems (Strategic Target Evaluation Meeting and Review • KPI Assessment Meeting) • Produced Report Any Time • Evaluation Meeting Every Month
L 3	Process Oriented	• NO	• SMART • Shared Objectives	• Gathering Data from System • Assigning to track Process Objectives	• Business Intelligence tools • Integrated CRM with Other Functional System	• Objectives aligned with strategy at process and/or department level	• Functions Integrated	• Process Performance Management	• Rarely Periodic Assessment Supported by Automatic Systems Process KPI Assessment • Process Tracking • Produced Report When Execute the Report • Every Quarter
L 2	Management by Objectives	• NO	• SMART	• Gathering Data from Semi Manual System • Assigning to track Process Objectives	• NO	• Defined objectives	• Analysis integrated	• Only strategic performance assessment	• Assessment by Semi-Automatic • Not Periodically • Produced Report When Collecting Data Distributed System • Every Quarter
L 1	Functional Management	• if the official document is signed by one or two persons • In the organizational chart absence of the top board, the board etc.	• NO	• NO	• NO	• NO	• Communication tools	• Financial and production assessment	• Not Periodically Assessment Just on Demand • Produced Report When Collecting Phone Conversation, Mail Traffic Every Year
L 0	Shop Management	• The official documents are signed by only an authorized person	• NO	• NO	• NO	• NO	• NO	• NO	• NO

Furthermore, without passing investment criteria performing technological readiness would not be complete. Therefore, the investment in technology is a decisive criterion to determine ETRL as described in Table 3.9. The enterprise technological readiness is related to the view of investment aspect for technology. While making a decision on ETRL, the evidence of investment sub-criteria helps designate the level. This group of criteria assesses the technological investment aspect regarding technology. The criteria set in this group, which consist of five levels, are also categorized as remarkable investment on R&D of technology market, investment on generating new technology in the market, remarkable investment on available technology, partially investment on available technology, and no noteworthy investment. Otherwise evaluation, the managerial view of enterprise uses sub-criteria set as allocated budget, new machine creation, renewing machine, new method to be implemented, production speed/ quality/ cost effectiveness, new products, and technology transfer (in/out). This table of investment evidences provides identifying readiness level for enterprise.

Finally, the business results' evidences consist also eight sub-criteria as market share, number of customer (portfolio), renewing machine, new method to be implemented, production speed/ quality/ cost effectiveness, new products, technology transfer (in/ out) to define technological readiness levels for an enterprise. These categories are related to the view of value- added outputs of the enterprise. Hence, this group of criteria assesses the business results aspect regarding technology. In addition, an output of any enterprise shows to have technological capabilities of its enterprise. Hence the technology of own the enterprise effects directly on the business results. During the reviewing of the checklist it is required to designate business results of the technological readiness level. The list of evidences in these regards are provided in Table 3-10.

Table 3.9: Evidences For Assessing Technological Investments

Technology Investment		SUB-CRITERIA							
LEVELS		Allocated Budget	New Machine Creation	Renewing Machine	New Method to be Implemented	Production Speed/ Quality/ Cost Effectiveness	New Products	Technology Transfer (in)	Technology Transfer (out)
L4	Remarkable Investment on R&D of Technology Market	• Items of expenditure focus on R&D	• Creating New Machine, but no exists on Market (Tailored Machine, Cost Effective Machine, Innovativenes s Machine, etc.)	• NO	• Create an integrated new method for usage the new technology market	• 120% Increased Speed and more • 50% reduced cut downtime • Data from sensors can • be used to monitor every piece produced rather than using sampling to detect errors -error-correcting • machinery	• Smart Product • Heavily Innovativen ess Product	• Partially R&D on Technology Transfer Project	• R&D Department • R&D employees/ engineering • Technology Transfer Office Department • Getting Funds from Government and Agency
L3	Investment on Generating New technology in the market	• Allocated Budget for Generating New Technology	• Producing New Machine already existing on the market because of cost, size, etc.	• NO	• Create an integrated new method with Existing Technology	• 100% Increased Speed	• Innovativen ess Product or Part	• Increase Up Volume on Assembly Line	• Project Teams on Demand • Consultant to Produce a New Technology
L2	Remarkable investment on available technology	• Heavily Allocated Budget Already Available Technology on Market	• Open a usage functional feature on available technology	• Purchasing remarkably the available technology	• Improvement and Implementation new method on almost all available technology	• 80% Increased Speed	• Innovativen ess Part/ Feature/ Function	• Increase Up Volume on Manufacturin g Line • Design of new process line(s)	• NO
L1	Partially Investment on Available Technology	• On Demand Renew Available Technology	• NO	• Purchasing partially the available technology	• A few improvement and implementation on available technology	• 60% Increased Speed	• NO	• NO	• NO
L0	No Noteworthy Investment	• NO	• NO	• NO	• NO	• NO	• NO	• NO	• NO

Table 3-10 Evidences For Assessing Business Results

Business Results		SUB-CRITERIA						
LEVELS		Market Share	Number of Customer (Portfolio)	Number of Product Feature	Enterprise Growth Rate	Number of Innovation Product	Number of Innovation Process	Financial Rate (EBITDA)
L4	Multi-Functional and Cost-Effective Products	• 80% percent and above • Extra solution of customer needs	• 80% increased trend based on last year	• 80% increased number above before last year referenced • Cost Effectiveness	• 80% percent increasing trend based on last year • Extra shift to produce available product	• 80% and above of new product	• 80% and above improved process • Only more and more production and sales	• 60% and above
L 3	Product Variety and Globalization	• 80% percent and below • Extra solution of customer needs	• 80% increased trend based on last year	• 80% increased number before last year referenced • Cost Effectiveness	• 80% percent based on last year • Extra shift to produce available product	• 80% and below of new product	• 80% and below improved process • Only more and more production and sales	• 60% and below
L 2	Dominated Market and Competitive advantageous	• 60% percent and below • Extra solution of customer needs	• 60% increased trend based on last year	• 60% increased number before last year referenced • Cost Effectiveness	• 60% percent based on last year • Extra shift to produce available product	• 60% and below of new product	• 60% and below improved process • Only more and more production and sales	• 40% and below
L 1	Profitability	• 40% percent and below • Extra solution of customer needs	• 40% increased trend based on last year	• 40% increased number before last year referenced • Cost Effectiveness	• 40% percent based on last year • Extra shift to produce available product	• 20% and below of new product	• 40% and below improved process • Only more and more production and sales	• 10% and below
L0	No Significant Results Obtained	• Now 20% and below • Only Minimum Requirement Based Product	• Increasing Trend Number of Customer referenced by last year	• 20% increased number before last year referenced • Cost Effectiveness	• 20% percent based on last year • Extra shift to produce available product	• 10% and below of new product	• 20% and below improved process • Only more and more production and sales	• 5% and below

In summary, the model given in Figure 3.2 for each component of the assessment model proposed was generated to designate the technological readiness levels. Firstly, the main criteria set was established, and respective sub-criteria were identified. Taking the lists as a reference, evidences were used to assign rating for the related technological readiness levels. Although it is sometimes stayed indecisive, auditor decision was accepted as the final decision heuristically for assignment of the levels. Before the auditing, the criteria list was weighted according to each main and sub-criterion to make a more sensitive decision. Then, after all the reviews of the criteria set, evaluation was made to define enterprise technological readiness levels.

3.5 Determining The ETRL

The proposed model requires a segmentation of enterprises. When the literature was reviewed, it was observed that the businesses were classified to facilitate their roles in directing the market. In this respect, it is possible to claim that some of these businesses lead their sectors while some others follow them from behind. However, some of these businesses do not need to make any changes in their business activities and technologies. As shown in Table *3.11*.

The enterprises were divided into groups for analysis of their technological readiness.

Table 3.11 Enterprise Technological Readiness Levels (ETRL)

L5	**Most Mature and Moderate Technology**	**Leading Enterprises**
L4	**Mature, Aligned, and Moderate Technology**	**Guiding Enterprises**
L3	**Pre-Mature and Addictive Technology**	**Following Enterprises**
L2	**Unmatured Technology and Well Addictive Technology**	**Classical Enterprises**
L1	**Poor/Base Technology**	**Exhausted Enterprises**

Technological readiness level is defined by using the Equation as given below.

$$\alpha = \sum_{n=1}^{n} \lambda n * \beta n$$

Where λ_1 is the technological infrastructure level, λ_2 is the culture level, λ_3 is the management level, λ_4 is the technology investment level (Figure 5.4), λ_5 is the business results level, β_1 is the weight of technological infrastructure, β_2 is the weight of culture, β_3 is the weight of management, β_4 is the weight of technology investment and β_5 is the weight of business result.

4. CASE STUDY

The study started by viewing the checklist for the enterprises. During the interview of enterprises' authorized officers, the ETRL checklist was explained in order for him to understand the assessment model for better cooperation.

The proposed ETRL model was validated by performing an evaluation of a business organization called KAS VALVE of KAYALAR ARMATUR SANAYİ which is a company operating in the metal industry. As introduced, KAS VALVE is a manufacturing firm which produces valves, brass fittings and faucets. During the auditing and interviewing, it technological readiness levels were evaluated. According to the criteria set, the level each criterion belonged to was observed. While making decisions, the evidence was assessed.

Despite the fact that the suggested model has a usual construction, this practice gives information on the applicability of the model in the production sector. It is important to consider the fact that the model requires sector-based weight values to identify the importance of each component of the model for the defined sector. A score for each technological level of the model was defined for KAS VALVE by comparing the business information of the company.

4.1 Information about KAS GROUP

KAS is an enterprise in Kayalar Group, which was founded in 1970, and which consists of three companies; KAS-VALVE, KASPA and KAS-STOCK. KAS Group has a variety of production, mainly radiator valves and brass fittings for fixtures. KASPA is an enterprise selling the products whereas KAS-STOCK supplies raw materials to KAS factories. The KAS Manufacturing unit is placed across an area of 12000 square meters in Sancaktepe in Istanbul, with two distinct facilities for the core product families, fixtures and flexes.

There are two core processes in the flex production facility: in-house production and flex production. One of them is in-house production on the second floor of the unit (raw

material iron pipes come in here). These are cut to specific sizes in workshops. These half-worked materials turn into finished products on the first floor in flex production.

4.2 Implementation of the ETRL Method on KAS Valve

The defining technological readiness level of the proposed model would be used to identify technological abilities of not only the production facilities but also all the organizational activities. In the next chapter, gathering the data allowed us to illustrate the technological readiness description of KAS Valve.

4.3 Implementation of the SWARA for ETRL Method

SWARA method was implemented for weighting the criteria set. The method based on aspect of experts. Additionally, this assessment technique defines weighting value by its algorithm as mentioned the literature review chapter (Karabasevic, et. al., 2015).

4.3.1 Background Information of Assessment Experts

The talents, attributes and qualifications of experts are an important phenomenon that increases the quality of the results revealed by the multivariate decision-making methods. All experts, as seen Table 4.1, have sufficient knowledge of defining technology readiness level or technological assessment topics. During to in this study, the assistance of experts was needed for weighting the criteria.

Table 4.1 Background of the experts' information

Category	Classification	Number of assessors
Working Background	• Quality Management Departmant Manager	1
	• System Engineering Departmant Manager	1
	• Manufacturing Enterprise Owner	1
	• Strategic Planning Specialist	1
	• Lecturer	1
Education Level	• Bachelor	1
	• Master	2
	• Ph.D.	2
Sex	• Male	1
	• Female	4

4.3.2 Collect Data from Experts

As seen in Table 4.2, in order to determine the importance levels of the main criteria, five experts were selected. These main criteria were placed in order of significance starting from the most important one to the least important one. Moreover, the whole sub-criteria weighting was shown Appendix 1.

Table 4.2 Weighting of Main Criteria Set

	A	B	C	D	E
Technological Infrastructure	1	1	1	3	1
Culture	2	5	2	1	5
Business Results	4	3	3	4	3
Management	3	4	4	2	2
Technology Investment	5	2	5	5	4

5. IMPLEMENTATION OF THE MODEL

In this chapter, the proposed model is assessed to verify it on a manufacturing enterprise by defining KAS Valve's ETRL value. This approach is inspired by the TRL scale for enterprises. However, this methodology differs from the other assessment model by using the SWARA method. Past researches showed that the models in the literature do not provide a roadmap to be technologically ready for enterprises. Furthermore, these models provide both common understanding, and give some hints to comprehend for making a technological plan or a roadmap.

As stated earlier, the objective of the study proposes a model to evaluate manufacturing enterprises. By implementing SWARA approach, the model's criteria were weighted to show their impact on the organization's ETRL level. This model was employed in KAS Valve with the help of company experts in order to define their TRL.

5.1 Weighting Criteria Results of Implementing SWARA

As provided by SWARA calculation, the weighting of ETRL criteria set was identified as shown in Table 5.1 in order to assess how much impact each criterion possessed by the respective enterprise (Karabasevic, et. al., 2015). Before the weight of criterion, it was firstly calculated an expert's views to be shown an example of SWARA algorithm. Furthermore, the comparative importance values are given in Appendix 2.

Table 5.1: Describing Weights Criteria of ETRL Model Parameters

Attribute/ A	**Comparative Importance of average value s_j**	**Coefficient k_j**	**Recalculated weight w_j**	**Weight q_j**
Technological Infrastructure		1	1	0.35
	0.6			
Culture		1.6	0.63	0.22
	0.2			
Business Results		1.2	0.54	0.19
	0.2			
Management		1.2	0.36	0.13
	0.1			
Technology Investment		1.1	0.33	0.12

Attribute	**A**	**B**	**C**	**D**	**E**	**Final Weights qj**
Technological Infrastructure	0,34	0,35	0,35	0,19	0,37	0,32
Culture	0,21	0,12	0,22	0,31	0,12	0,20
Management	0,18	0,14	0,13	0,22	0,22	0,18
Technology Investment	0,13	0,23	0,12	0,13	0,13	0,15
Business Results	0,15	0,17	0,19	0,14	0,17	0,16

Besides, there were sub-criteria which were the components of ETRL. The model utilizes sub-criteria for assessment of the main criteria as well. As SWARA algorithm, Results of this assessment is also given in Table 5.2, Table 5.3, Table 5.4, Table 5.5, Table 5.6 respectively.

Table 5.2: Describing Weights Sub-Criteria of Technological Infrastructure

Sub-Criteria	**Comparative Importance of average value s_j**	**Coefficient k_j**	**Recalculated weight w_j**	**Weight q_{Aj}**
Operator Dependency	0.08	1	1	0.27
Manual Machining	0.35	1.08	0.93	0.25
Software Dependency	0.22	1.35	0.69	0.19
Remote Control	0.1	1.22	0.57	0.16
Maintenance		1.1	0.51	0.13

Technology Infrastructure Sub-Criteria	**A**	**B**	**C**	**D**	**E**	**Final Weight qj**
Manual Machining	0,21	0,15	0,15	0,23	0,23	0,19
Operator Dependency	0,34	0,18	0,18	0,24	0,24	0,23
Software Dependency	0,18	0,21	0,21	0,21	0,21	0,20
Maintenance	0,13	0,23	0,13	0,18	0,15	0,16
Remote Control	0,15	0,24	0,34	0,15	0,18	0,21

Similarly, as seen in Table 5.2, the weights sub-criteria of technological infrastructure were defined from the most important to the least significant ranking. While the most important criterion is found operator dependency, assigned value 0.27, to define technological readiness of infrastructure. Then, the manual machining criterion constant as 0.25 is following to operator dependency criterion for identification infrastructure. Furthermore, the software dependency constant value is 0.19, and the remote-control weighting value is 0.16. Finally, the least important criterion is maintenance, assigned value is 0.13.

Table 5.3: Describing Weights Sub-Criteria of Culture

Sub-Criteria	Comparative Importance of average value s_j	Coefficient k_j	Recalculated weight w_j	Weight q_{Aj}
Solution to Problem with Technology		1	1	0,29
	0.18			
Market-Related Innovativeness and flexibility		1.18	0.85	0.25
	0.35			
Technology Learning Organization		1.35	0.63	0.18
	0.24			
Scientific Meeting Attendance		1.24	0.51	0.15
	0.1			
Technology Training		1.1	0.46	0.13

Technology Culture Sub-Criteria	A	B	C	D	E	Final Weight qj
Technology Training	0,13	0,16	0,14	0,19	0,13	0,15
Scientific Meeting Attendance	0,15	0,10	0,08	0,12	0,18	0,13
Technology Learning Organization	0,18	0,19	0,21	0,24	0,26	0,22
Solution to Problem with Technology	0,29	0,21	0,26	0,21	0,27	0,25
Market-Related Innovativeness and flexibility	0,25	0,33	0,31	0,25	0,16	0,26

With the same manner, as given in Table 5.3, the weights sub-criteria of culture were defined from the most important to the least significant ranking. While the most important criterion is found market-related innovativeness and flexibility, assigned value 0.26, to define technological readiness of the culture, the solution to problem with technology criterion constant as 0.25 is following to solution to problem with technology criterion for identification cultural technology readiness level. Furthermore, the technology learning organization constant value is 0.22, and the technology training weighting value is also 0.15. Finally, the least important criterion is scientific meeting attendance and assigned weight value is 0.13.

Table 5.4: Describing Weights Criteria of Management

Sub-Criteria	Comparative Importance of average value s_j	Coefficient k_j	Recalculated weight w_j	Weight q_{Aj}
Smart Objectives		1	1.00	0.24
Strategic Alignment	0.33	1.33	0.75	0.18
KPI	0.23	1.23	0.61	0.14
Performance Assessment	0.15	1.15	0.53	0.12
Automatic Knowledge Processing	0.21	1.21	0.44	0.10
	0.37			
Periodic Assessment	0.05	1.37	0.32	0.08
The Need for Integrated Software	0.12	1.05	0.31	0.07
Single Leader		1.12	0.27	0.07

Management Sub-Criteria	A	B	C	D	E	Final Weight qj
Single Leader	0,07	0,05	0,05	0,05	0,05	0,06
Smart Objectives	0,24	0,19	0,19	0,19	0,19	0,20
KPI	0,14	0,12	0,12	0,16	0,16	0,14
Automatic Knowledge Processing	0,10	0,18	0,18	0,12	0,12	0,14
Strategic Alignment	0,08	0,16	0,16	0,18	0,18	0,15
The Need for Integrated Software	0,07	0,14	0,09	0,07	0,07	0,09
Performance Assessment	0,18	0,09	0,14	0,14	0,14	0,14
Periodic Assessment	0,12	0,07	0,07	0,09	0,09	0,09

Table 5.4 represents the weights for sub-criteria of management which were also defined from the most importantly to the least significant ranking. While the most important criterion is found to be “smart objectives” with weight value 0.20, to define technological readiness of the management, the strategic alignment criterion constant as 0.15 is following to smart objective criteria for identification managerial technology readiness level. Furthermore, the weight values for KPI constant value is 0.14, and the performance assessment is also 0.14. Moreover, automatic knowledge processing criterion constant is following with 0.14 value, the periodic assessment constant value number is 0.09 and the need for integrated software criterion value number is also 0.09. Finally, the least important criterion is single leader, assigned weight value is 0.06.

Table 5.5: Describing Weights Criteria of Technology Investment

Sub-Criteria	Comparative Importance of average value sj	Coefficient kj	Recalculated weight wj	Weight q_{Aj}
Production Speed/ Quality/ Cost Effectiveness	0.28	1	1.00	0,24
Allocated Budget	0.37	1.28	0.78	0,19
New Method to be Implemented	0.15	1.37	0.57	0,10
Renewing Machine	0.21	1.15	0.50	0,12
New Machine Creation	0.2	1.21	0.41	0,14
New Products	0.12	1.2	0.34	0,08
Technology Transfer (out)	0.03	1.12	0.30	0,07
Technology Transfer (in)		1.03	0.30	0,07

Technology Investment Sub-Criteria	A	B	C	D	E	Final Weight qj
Allocated Budget	0,19	0,08	0,18	0,06	0,18	0,14
New Machine Creation	0,14	0,14	0,12	0,10	0,10	0,12
Renewing Machine	0,12	0,13	0,07	0,08	0,12	0,10
New Method to be Implemented	0,10	0,16	0,09	0,13	0,14	0,12
Production Speed/ Quality/ Cost Effectiveness	0,24	0,08	0,07	0,31	0,28	0,19
New Products	0,08	0,25	0,14	0,11	0,08	0,13
Technology Transfer (in)	0,07	0,06	0,16	0,17	0,05	0,10
Technology Transfer (out)	0,07	0,10	0,17	0,04	0,06	0,09

In Table 5.5 the weights sub-criteria of management were defined from the most important to the least significant ranking is provided. Amount of the rank increases following order; Production Speed / Quality / Cost Effectiveness, Allocated Budget, New Method to be Implemented, Renewing Machine, New Machine Creation, New Products, Technology Transfer (out), Technology Transfer (in).

Table 5.6: Describing Weights Criteria of Business Results

Sub-Criteria	Comparative Importance of average value sj	Coefficient kj	Recalculated weight wj	Weight qj
Number of Customer (Portfolio)	0.35	1	1.00	0.25
Number of Product Feature	0.22	1.35	0.74	0.19
Number of Innovation Process	0.26	1.22	0.61	0.15
Market Share	0.3	1.26	0.48	0.13
Enterprise Growth Rate	0.15	1.3	0.37	0.11
Number of Innovation Product	0.1	1.15	0.32	0.09
Financial Rate (EBITDA)		1.1	0.29	0.08

Business Results	A	B	C	D	E	Final Weight q_i
Market Share	0,13	0,15	0,10	0,25	0,25	0,18
Number of Customer (Portfolio)	0,25	0,11	0,08	0,05	0,12	0,12
Number of Product Feature	0,19	0,08	0,14	0,14	0,15	0,14
Enterprise Growth Rate	0,11	0,18	0,12	0,07	0,07	0,11
Number of Innovation Product	0,09	0,25	0,23	0,12	0,05	0,15
Number of Innovation Process	0,15	0,19	0,25	0,10	0,11	0,16
Financial Rate (EBITDA)	0,08	0,13	0,05	0,03	0,05	0,07

Last but not least Table 5.5 indicates the weight values for sub-criteria of management. This ranking is increasing in the following order; Market Share, Number of Innovation Process, Number of Innovation Product, Number of Product Feature, Number of Customer (Portfolio), Enterprise Growth Rate, Financial Rate (EBITDA).

5.2 Results

After the interview which was carried out, the check list records were evaluated to define the KAS VALVE Enterprise Technological Readiness Level. During the assessment, firstly, the technological infrastructure level was evaluated, and an automatic system defined on level 3 was realized. The assessment result was 63.50 percent. This means that the enterprise had a quite automated system in its infrastructure, but it also means that there were still semi-automatic systems. In the scope of the technological infrastructure criteria,

the whole organizations should handle all sub-criteria to carry out a gap analysis to reach the top level. To begin with, manual operation was seen among the automatic systems; however, enterprises need not only manual ones, but they also need integrated systems, artificial-intelligence-based models and processes that are ready for autonomous systems.

Then, when another criterion, i.e. the operator dependency was audited to assign a technological readiness level, it was seen that the enterprise had a semi-automatized level with operator dependency. The evidence of semi-automatic operation is that almost all machines have an operator, and initially, the operator must be working on the machine from the initial moment to stopping of it. If KAS VALVE wants to reach upper levels, some activities can be automatized in feeding, loading, controlling by machine; and the infrastructure can also be integrated to or built on artificial intelligence, thus adjusting the systems for the Autonomous System Level. Another sub-criterion is the software dependency, and KAS VALVE is on an automatic system level. When the criterion was used to obtain evidence, KAS VALVE had systems and machines which were PLC-modelled and used computerization systems such as not-fully-integrated ERP and CAD. If the enterprise wants to step towards a higher level, it can base its operations heavily on PLC systems, digitalization infrastructure, integrated IT systems, etc. One of the technological infrastructure sub-criteria was the maintenance. The sub-criterion was evaluated to assess the elements of infrastructure such as machining systems and manufacturing support systems. Although some machining systems were maintained on demand, the evidence led to the assignment of the automatic level, because almost all maintenance processes were planned. However, predictive systems can be integrated, maintenance can be planned autonomously, and automatic maintenance warnings can be set up. Moreover, the remote-control criterion was not observed in the manufacturing infrastructure, and the designated level was manual commands in almost all machining. Furthermore, machine scrap was quite low in production of the same family products in the sector because of the three-sigma level of scrap, which provides the designation of a semi-automatic system. In short, the enterprise had automatic press holdings, milling machines and CNC milling machines in the manufacturing infrastructure. On the other hand, it also

had advanced ICT technologies such as MRP systems and support systems for easy communication. If the enterprise wants to reach a higher position than where it is now, it may need to review its detecting the defects modelling and technological infrastructure. The last sub criterion is the *Down Time Loss*. The criterion level is a semi-automatic system because of waiting five days a month. The enterprise can improve the *Down Time Loss* to define the procedure and log in the measurement to improve.

$$\boldsymbol{\lambda_1} = 0.27 * 4 + 0.16 * 3 + 0.20 * 4 + 0.22 * 3 + 0.15 * 1$$

=3.17

The Maturity Rating (MR) is calculated as;

$$\text{MR}=\frac{3.17}{5} * 100$$

= 63.5%

Figure 5.1 indicates this maturity level graphically where filled stars indicates full implementation and empty stars indicate no implementation at that level.

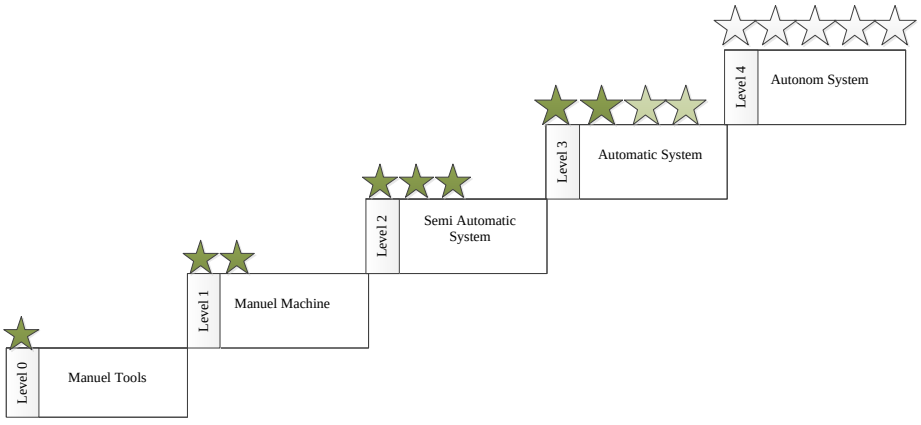

Figure 5.1: KAS VALVE Technological Infrastructure Level

As seen in Figure 1, KAS VALVE did not have a completely technological infrastructure because of the stated value of 64 percent. It had four stars but two of them were lighter green.

Secondly, an important main criterion was the technology culture of the enterprise. The criterion had five sub-criteria to assess a view of angle of the enterprise. In this section's scope, KAS VALVE was evaluated to designate ETRL as a cultural approach. Firstly, during the interview, the review of the cultural evidence for the enterprise was completed. To begin with, technology training was seen among the knowledge-based society and culture, and the enterprise needs innovative machine/ equipment training, innovativeness and creativeness thinking courses (TRIZ, PUGH, SCAMPER, etc.), sharing documentation of innovativeness courses in internal customer to be ready for innovation and renovation-based society and culture. then, when another criterion, scientific meeting attendance was audited to identify cultural adoption, namely defining for a technological readiness level of the enterprise culture, the enterprise had an experimental society and culture level with scientific meeting attendance. The evidence of experimental society and culture is that the enterprise's scientific meeting attendance records were seen on interviewing, and some exposition records were also investigated by content-oriented. Finally, it was proposed that the enterprise should increase numbers of attendance innovativeness seminar/ conferences. The result of cultural achievement of technology was 65 percent. Although this rating was on the limit, the ETRL for culture can be acceptable as Knowledge Based Society and Culture for the enterprise. However, it was not completely adequate in having capability for a knowledge-based society and culture. If the enterprise wants to go up one more level or even more, it can take on technology training, attendance of scientific meeting or solution to problem with technology approaches which have innovation-based topics or content. For example, the enterprise can organize knowledge-based methodology training, tool courses to learn management of data by knowledge-based management. Furthermore, if KAS VALVE wants to get to a higher level, it can prefer knowledge-based technology learning organization or market-related innovativeness and flexibility. Hence, KAS VALVE can be modelled to illustrate an impact against market relativeness improvements by a knowledge-based or artificial-intelligence-based modelling.

As a result, evaluation of culture for KAS VALVE is seen below;

$$\boldsymbol{\lambda}_2 = 0.25 * 4 + 0.26 * 3 + 0.22 * 3 + 0.13 * 3 + 0.15 * 3$$

$$\boldsymbol{\lambda}_2 = 3.28$$

The Maturity Rating (MR) is calculated as;

$$MR=\frac{3.28}{5} * 100$$

$$= 65\%$$

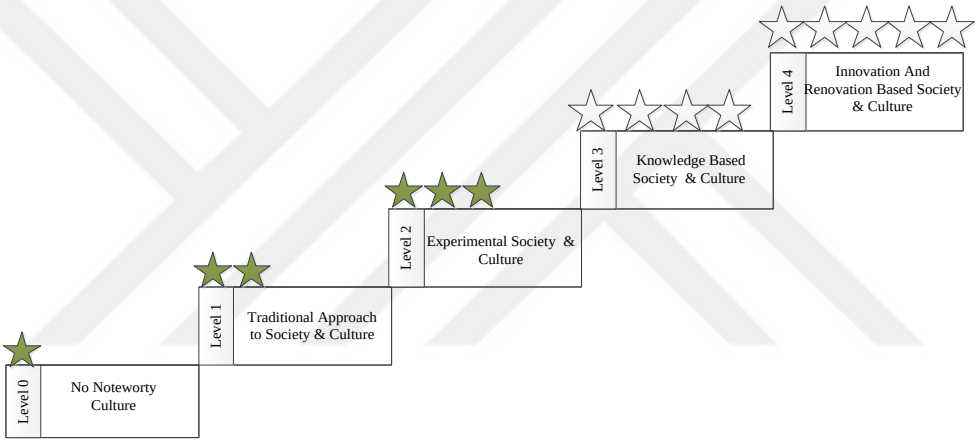

Figure 5.2: KAS VALVE Culture Criterion Level

Another main criterion for defining ETRL was the management concept for adapting technology. In the case-study auditing, the management criterion had eight sub-criteria, describing technological improvement impact on enterprises. Besides, KAS VALVE had a management level of Management by Objectives regarding its technology. If the enterprise wants to go up to higher levels, it can take care to improve each sub-criterion itself. Firstly, the single leader, Smart Objectives, KPI, Performance Assessment, Performance Assessment or Periodic Assessment criteria can be handled to conduct a gap analysis, and the results of analysis can be studied to reach a higher degree with some actions. To begin with, all criteria were investigated, the KAS valve enterprise was defined TRL by management approach (Figure 5.3) as each criterion for example; performance assessment, periodic assessment and smart objectives were assigned Management by Objectives (Analytical and Analyses). However, single leader, KPI, automatic knowledge processing,

strategic alignment, the need for integrated software were also assigned the functional management (experienced based) level. Because some strategic decisions were taken by boss, and the enterprise needs BPM tools with integration business intelligence tools for automatic knowledge processing, Strategic alignment with processes, SMART measurements integrates processes also strategies, intelligent based tools for manufacturing, remove completely the single leader approach, strategic performance assessment at all levels (personal, worker, manager, process, strategic, etc.) to be ready for management by objectives (analytical and analyses), process oriented(cross functional management in business process), strategic management (enterprise wide management, process alignment). The actions of process-oriented management can be eliminated by single leader, SMART measurements, intelligent based tools, integrated tools with processes, aligned with strategy to processes and process measurement approached. Additionally, the enterprise can have a strategic management level, while it tries to identify a flexible SMART measurement set, remove the single leader approach, use business intelligence tools, fully integrated tools, etc. On the other hand, KAS VALVE needs to get to a higher degree to optimize the other criteria for management. For example, the enterprise can make improvements on an automatic knowledge processing level to buy BPM tools, or fully integrated tools. Moreover, the strategic alignment criterion can be optimized to get to a higher degree, the management based on defined objectives for management by objective, objectives aligned with strategy at process and/or department level or objectives aligned with strategy at personal level to achieve strategic management level. Finally, KAS VALVE management had a level of management by objectives level in regard to technology because it had a rating of 46 percent.

As seen below in Figure 3, the level 2 is highlighted by two dark green stars and a light green a star.

$$\boldsymbol{\lambda}_3 = 0.20 * 2 + 0.14 * 3 + 0.14 * 2 + 0.09 * 2 + 0.14 * 2 + 0.15 * 2 + 0.09 * 3 + 0.06 * 3$$

$$\boldsymbol{\lambda}_3 = 2.31$$

The MR is calculated as;

$$\text{MR} = \frac{2.31}{5} * 100$$

$$= 46\%$$

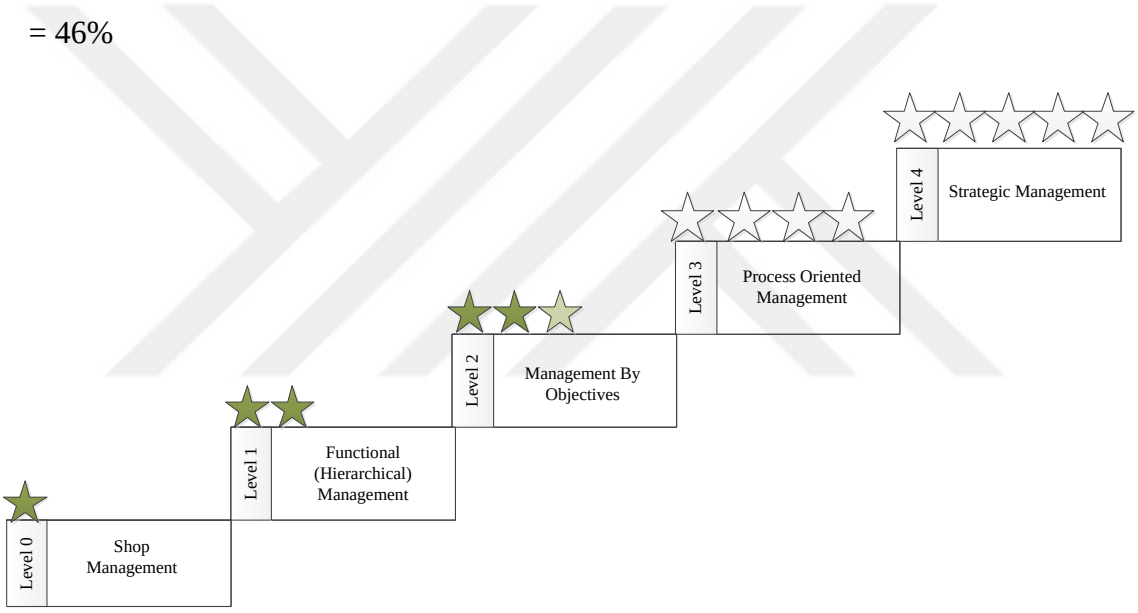

Figure 5.3: The KAS VALVE Management Approach

As mentioned, it was required to review the financial aspects to define the technological readiness level for the enterprise. In the scope of this study, the technology investment identified one of the main criteria that concluded a rating of 57 percent to describe technology investment capability. The main criterion had eight sub-criteria as allocated budget, new machine creation, renewing machine, new method to be implemented, production speed/quality/cost effectiveness, new products, technology transfer (in), technology transfer (out). When these constraints' results were examined, during the auditing is viewed some evidences such as heavily allocated budget already available technology on market, opening a usage functional feature on available technology, existing

improvement and implementation new method on almost all available technology, producing innovativeness product or part, increasing volume up on manufacturing line, completing design of new process line(s), increasing volume up on assembly line, demanding by project teams to produce a new technology. The results of interview, KAS VALVE had a level of remarkable investment in available technology. This level indicates that the KAS VALVE made investment generally in its own technologies. Furthermore, the rating of 57 percent represents maturity on the levels. Hence, the enterprise achieved investment in its own technologies. KAS VALVE can also make investments to reach the level of investment on generating new technology in the market because of its saturation of remarkable investment on available technologies. This needs some changes on the technology investment roadmap. For example, if the enterprise wants to jump a level, it can allocate its budget for creating new technologies such as machines and ICTs. It can focus on items of expenditure in R&D to reach the top level about the allocation budget sub-criterion. Besides, if the enterprise wants to get closer to a higher level about the new machine creation, it needs to create a new machine to improve process activities, but the machine does not exist on the market (tailored machine, cost effective machine, innovativeness machine, etc.). As considered, it is necessary to generate an integrated new method to be implemented with available technology for increasing the possibility to have investment on reaching the level of generating new technologies in the market. Another possibility for higher levels of readiness can be the level of generating an integrated new method for usage in the new technology market about investment.

Additionally, the production speed/quality/cost effectiveness sub-criterion had more significant contributions both in being higher in the ETRL model and producing more technological business results. Surely, the speed, quality and cost are distinguished elements both in terms of meaning and function. When it is evaluated from an investment point of view, the elements are considered to completely optimize production efficiency by investing in things such as facilities and people. In this case study, the enterprise production systems need to increase by 100 percent or higher in production speed with harmony improvement on integrated systems such as applying kaizen, TPM and lean production.

Additionally, all implementations can be supported by sensor technologies, which indicate mature remarkable investment on R&D in the technology market. However, the level of production speed/quality/cost was remarkable investment on available technology. One of the sub-criteria of technology investment was new products. KAS VALVE was observed to assess new products. The result of the assessment revealed the level of investment on generating new technology in the market. This means that the enterprise's investments produced innovative products. However, it should invest to produce smart products for reaching the level of remarkable investment on R&D in the technology market. The last criteria were technology transfer (in and out). Unfortunately, KAS VALVE's technology transfer levels were on shop management. The results indicated that these criteria were not adequately considered for investment. Firstly, the items were evaluated by the enterprise manager.

Then, the result of determination focused on investments to reach the technologically higher level. To sum up, as seen below in Figure 5.4,

$$\boldsymbol{\lambda}_4 = 0.19 * 3 + 0.14 * 4 + 0.12 * 3 + 0.10 * 3 + 0.12 * 3 + 0.13 * 4 + 0.09 * 1 + 0.10 * 1$$

$$\boldsymbol{\lambda}_4 = 2.86$$

Similarly;

$$\text{MR}=\frac{2.86}{5} * 100$$

$$= 57\%$$

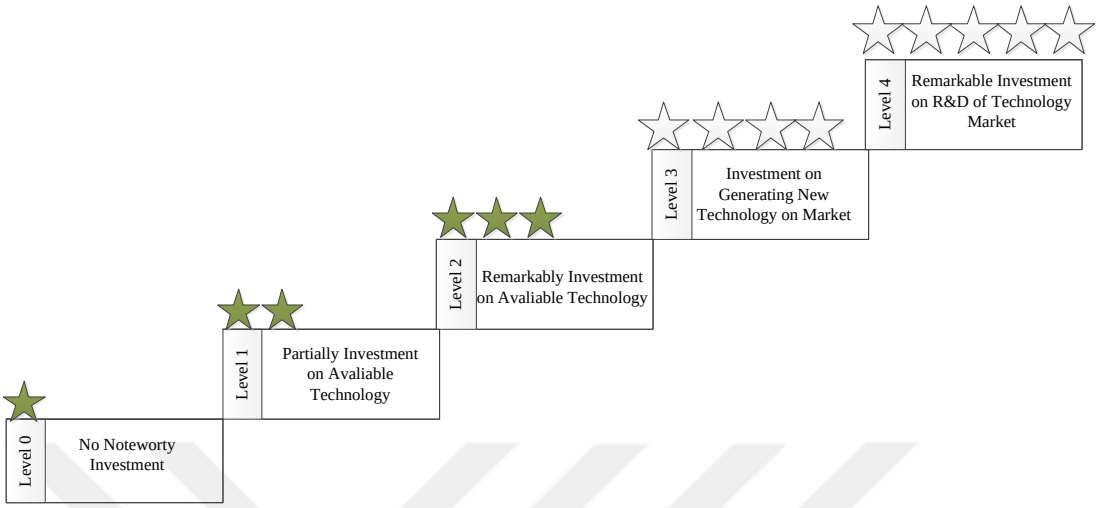

Figure 5.4: KAS VALVE Technology Investment Level

Finally, the main criterion was business results. KAS VALVE was audited to assess technological readiness, and its business result level was product variety and globalization. The rating of 61 percent indicates capability of producing business results. Hence, if the Enterprise needs to get to a higher business result level, it should improve its own sub-criteria. Initially, a market share criterion of KAS VALVE was dominated market, and it had competitive advantages. In other words, the enterprise would like to develop technologically on business results for getting to an upper level; it can be opened to the global market or produce various products ready to use globally. Additionally, it can also target production of multi-functional and cost-effective consumer products. When the number of customers was reviewed to identify the enterprise's business result readiness level, it had an increasing trend generally in each quarter up to the multi-functional and cost-effective products level. The reason for this was the lack or inadequacy of multifunctional outputs. Furthermore, the number of product feature criteria was on a product variety and globalization level. This means that KAS VALVE had a variety of product range, and it could release products to global markets. Besides this, it was important to assess the enterprise growth rate for defining ETRL. During the auditing of the enterprise, it seemed like that the growth rate was continuously increasing until the level of product variety and globalization. KAS VALVE needs to increase the number of executives, number of operators, production capacity, etc. for producing new products and

creating new features for global customers. Another sub-criterion was the number of innovation products. It is significant to define business result TRL because of technology based on innovativeness. When it was reviewed to designate business results TRL, the number of innovation trends was increasing both towards the profitability level and the dominated market and competitive advantages level. However, the enterprise needs to make the number better and it can take on an innovativeness approach on new products to get to the product variety and globalization level. Otherwise, KAS VALVE can produce innovative, cost-effective and multi-functional products to be assigned the highest level for the number of innovation products sub-criterion. Moreover, the number of innovation processes was evaluated to designate a level to business results technological readiness level. As known, KAS VALVE does not have an approach of process-oriented management, while this situation causes it to focus on profitability in its processes. Hence, if the number of innovation processes is desired to get to a higher level, the enterprise can provide a new design process to increase new products for sale to the global market. Additionally, it can carry out innovation-based processes to produce multi-functional and cost-effective products for having a higher degree to business results TRL. Moreover, the other sub-criterion was financial rate, and it was evaluated to make an assignment to view the enterprise's increasing financial performance trend. Then, if the enterprise aims to get to a higher level of financial rate, it can make cost reduction attempts for both producing multi-functional products and creating product variety for globalization. of the final sub-criterion was capacity utilization. The capacity utilization level for KAS VALVE was the dominated market and competitive advantages level.

Hence, the enterprise can plan to make lean production, used the 5S method or Kanban approach for both product variety for globalization and multi-functional production with cost effectiveness.

$$\boldsymbol{\lambda}_5 = 0.12 * 3 + 0.14 * 4 + 0.16 * 2 + 0.18 * 3 + 0.11 * 3 + 0.15 * 2 + 0.07 * 3$$

$$\boldsymbol{\lambda}_5 = 2.62$$

The maturity rating was;

$$MR=\frac{2.62}{5} * 100$$

$$= 52\%$$



Figure. 5.5: The Assessment of KAS VALVE

To sum up, the assessment of KAS VALVE resulted in the following value

$$\alpha_{ETRL_A} = 0.32 * 3.17 \ + 0.2 * \ 3.28 + 0.18 * \ 2.31 + 0.15 * 2.86 \ + 0.16 * 2.62$$

$$\alpha_{ETRL_A} = 2.97$$

KAS Valve's ETRL was `Pre-Mature and Addictive Technology` which indicates a `Follower Enterprise` as bolded highlighted in Table 5.7 by assessing the overall activities.

Table 5.7: KAS Valve ETRL Result

L5	**Most Mature and Moderate Technology**	**Leading Enterprises**
L4	**Mature and Alignment of Moderate Technology**	**Guiding Enterprises**
L3	**Pre-Mature and Addictive Technology (KAS VALVE)**	**Follower Enterprises**
L2	**Unmatured Technology and Well Addictive Technology**	**Classical Enterprises**
L1	**Poor/ Base Technology**	**Exhausted Enterprises**

6. CONCLUDING REMARKS AND RECOMMENDATIONS

6.1 Conclusions and Recommendations

This thesis focused on evaluating technological readiness in manufacturing enterprises by use of the SWARA method. In this study, we proposed a model to define the technological readiness level of an enterprise. Moreover, we also considered the model's applicability at a manufacturing factory, as well as providing a contribution for future academic studies. We selected an enterprise named KAS Valve.

This study presented the SWARA methodology to determine the levels of a manufacturing company by weighting a technological readiness criteria set. In the methodology, we used five experts in the field. The objective of this study was to define all the main criteria that should have an impact on technology readiness assessment decisions.

The reason for choosing the SWARA approach was the aim to solve the shortcomings in lower numbers of comparisons in comparison to other multi-criteria decision-making methods. The SWARA method and the approach here proved to be straight-forward.

This method allows limitation of the ambiguity in human thinking and solving multi-criteria decision-making problems effectively.

Additionally, all criteria were divided into five levels to understand the maturity of each criterion. Furthermore, a technological readiness checklist was built to view all the activities of the enterprise. The list included the main criteria, sub-criteria, technological readiness levels and evidence. This provides simplicity in collecting data and obtaining evidence for determination of ETRL during interviews.

Besides, the determination of the weighting in the criteria set involved calculation by using the interview data. As calculated by the weights, the proposed ETRL model was shown to perform for a manufacturing enterprise. Executing the model on KAS Valve provided an assessment result of 60 percent maturity, which means that the enterprise was on Level 3, namely a "Follower Enterprise". Otherwise, the components of KAS Valve were examined to reveal that;

- The technological infrastructure level completed level 3, but it was not fully mature to get to level 4 completely. As considered by its technological infrastructure, KAS Valve was a member of the automatic systems level,
- The technology culture was on level 2, namely the experimental society and culture level. The enterprise had planned strategies to be able to reach a higher level,
- The management aspect of the technology assessment of the organization revealed level 2, namely the management by objectives level,
- Technology investment was on level 2, namely the remarkable investment on available technology level,
- The business results were assigned level 3, namely the product variety and globalization level.

To sum up, the proposed model proved to provide a common understanding among enterprises. Moreover, as considered, the ETRL model also contributes to conduction of a gap analyses for necessary situations.

6.2 The Future Work

A future study can be carried out for application in different sectors and it may include service, R&D and other as the development criteria set. This is because the model found that settings of different sectors result in very different solutions. Furthermore, the model can be improved to make risk assessment to reach higher technological readiness levels for enterprises. The study can be also improved to apply fuzziness theory to get more real-life results. Furthermore, the research can be coded to automatize an assessment for enterprises.

REFERENCES

Adeoti, J. O., Umar, G. U. N. U., Tsado, E., (2012) Determinants of pension fund investment in nigeria: the critical factors. International Journal of Human Resource Studies, 2(4), 1.

Adler, N. J., C, A., (2008) International Dimensions Of Organizational Behavior, Thomson South-Western, 5th edition, United States.

Altunok, T., Cakmak, T., (2010) A technology readiness levels (TRLs) calculator software for systems engineering and technology management tool. Advances in Engineering Software, 41(5), 769-778.

Apostolopoulos, T. K., Pramataris K. C., (1997) Information technology investment evaluation: investments in telecommunication infrastructure. International Journal of Information Management, 17(4), 287-296.

Apte, M., (1994) Language In Sociocultural Context, The Encyclopedia Of Language And Linguistics, 4, 2000-2010.

Ashraf, F., Khan, M. A. (2014) Does emotional intelligence moderate the relationship between workplace bullying and job performance. Asian Business and Management, 13(2), 171-190.

Austin, M. F., Homberger, C., Ahalt, V., Doolittle, E., Polacek, G. A., York, D. M. (2017) Applying bayesian networks to TRL assessments–innovation in systems engineering. In INCOSE International Symposium, 27(1), 1622-1634.

Avruch, K., (2004) Culture and Conflict Resolution, 4th edition, United State Institute of Peace Press, Washington DC.

Bass, B. M., Avolio, B. J., (1993) Transformational leadership and organizational culture. Public Administration Quarterly, 17(1), 112-121.

Belton, V., Stewart, T., (2002) Multiple Criteria Decision Analysis: An Integrated Approach, 1st edition, Kluwer Academic Publishers, London.

Boulart, C., Connelly, D. P., Mowlem, M. C., (2010) Sensors and technologies for in situ dissolved methane measurements and their evaluation using Technology Readiness Levels. TrAC Trends in Analytical Chemistry, 29(2), 186-195.

Broadbent, M., Weill, P., (1997) Management by maxim: how business and IT managers can create IT infrastructures. MIT Sloan Management Review, 38(3), 77.

Caggese, A., (2012) Entrepreneurial risk, investment, and innovation. Journal of Financial Economics, 106(2), 287-307.

Carmack, W. J., Braase, L. A., Wigeland, R. A., & Todosow, M. (2017). Technology readiness levels for advanced nuclear fuels and materials development. Nuclear Engineering and Design, 313, 177-184.

Conrow, E. H., (2011) Estimating technology readiness level coefficients. Journal of Spacecraft and Rockets, 48(1), 146-152.

De Lange, W. J., (2006) Multi-criteria decision-making for water resource management in the Berg Water Management Area, PhD Thesis, University of Stellenbosch, Stellenbosch, South Africa.

Defense Technical Information Center (DTIC), (2009) Technology Assessment Deskbook,. http://www.dtic.mil/docs/citations/ADA524200, (09.05.2018)

Dehning, B., Richardson, V. J., Stratopoulos, T., (2005) Information technology investments and firm value. Information and Management, 42(7), 989-1008.

Dion-Schwartz, C., (2010) DoD Current State for Software Technology Readiness Assessments, http://www.ieee-stc.org/proceedings/2010/pdfs/cd2694.pdf (04.05.2018).

Dissel, M. C., Phaal, R., Farrukh, C. J., Probert, D. R., (2009) Value road mapping. Research-Technology Management, 52(6), 45-53.

Dixit, A. K., Dixit, R. K., Pindyck, R. S., & Pindyck, R. (1994). Investment under uncertainty. Princeton university press.

Duncan, N.B., (1995) Capturing Flexibility of Information Technology Infrastructure: A Study of Resource Characteristics and their Measure, Journal of Management Information Systems, 12(2), 37-57.

Eckhause, J. M., Hughes, D. R., Gabriel, S. A., (2009) Evaluating real options for mitigating technical risk in public sector R&D acquisitions. International Journal of Project Management, 27(4), 365-377.

El-Khoury, B., Kenley, C. R., (2014) An assumptions-based framework for TRL based cost and schedule models. Journal of Cost Analysis and Parametrics, 7(3), 160-179.

Engle, M., Sarkani, S., Mazzuchi, T., (2009) Technical maturity evaluations for sensor fusion technologies. IEEE In Applied Imagery Pattern Recognition Workshop,1-6.

Fast-Berglund, Å., Blom, E., Ahram, T., Karwowski, W., Marek, T., (2014) Evaluating ICT-tools for knowledge sharing and assembly support. In Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics, 2734-2742.

Fischer, F. M., Martinez, M. C. (2013) Individual features, working conditions and work injuries are associated with work ability among nursing professionals. Work, 45(4), 509-517.

Government Accountability Office (GAO), 2012 Annual Report: Opportunities to Reduce Duplication, Overlap and Fragmentation, Achieve Savings, and Enhance Revenue, https://www.gao.gov/products/GAO-12-342SP, (06.04.2018)

Haeckel, S. H., (1990) Business Strategies in an Information Economy: Commentary, Technical Report, Marketing Science Institute, Chambridge, 90-119.

Héder, Mihály, (2017), From NASA to EU: the evolution of the TRL scale in Public Sector Innovation, The Innovation Journal, 22(2), 1-23.

Henderson, J.C., Thomas, J.B., Venkatraman, N., (1992) Making Sense of IT: Strategic Alignment and Organizational Context, Working Paper No. 3475-92BPS, Massachusetts Institute of Technology, Chambridge.

Hofstede, G., Minkov, M., (2010) Cultures and Organizations: Software of the Mind Intercultural Cooperation and Its Importance for Survival, Mc Graw Hill, London.

Islam, N., Brousseau, E., (2014) Implementing a multi-staged methodology to micro and nanotechnology: Technology maturity assessment and framework. International Journal of Productivity and Performance Management, 63(2), 170-193.

Karabasevic, D., Stanujkic, D., Urosevic, S., Maksimovic, M., (2015) Selection of candidates in the mining industry based on the application of the SWARA and the MULTIMOORA methods. Acta Montanistica Slovaca, 20(2), 116-124.

Katz, D. R., Sarkani, S., Mazzuchi, T., Conrow, E. H., (2015) The relationship of technology and design maturity to DoD weapon system cost change and schedule change during engineering and manufacturing development. Systems Engineering, 18(1), 1-15.

Keen, M. (1991). Corporation tax, foreign direct investment and the single market. European integration: Trade and industry, 1st edition, Chambridge University Press, Australia, ISBN: 0 521 43527 7

Keuschnigg, C., Nielsen, S. B., (2001) Public policy for venture capital. International Tax and Public Finance, 8, 557–572.

Knaggs, M., Ramsey, J., Unione, A., Harkreader, D., Oelfke, J., Keairns, D., Bender, W. (2015) Application of systems readiness level methods in advanced fossil energy applications. Procedia Computer Science, 44, 497-506.

Kochan, F., (2013) Analyzing the relationships between culture and mentoring. Mentoring and Tutoring: Partnership in Learning, 21(4), 412-430.

Lalienė, R., Sakalas, A., (2014) Development of R&D effectiveness assessment system in the research organizations. Procedia-Social and Behavioral Sciences, 156, 340-344.

Leitão, P., Colombo, A. W., Karnouskos, S., (2016) Industrial automation based on cyber-physical systems technologies: Prototype implementations and challenges. Computers in Industry, 81, 11-25.

Magneye, R., Sauser, B, Marquez, J.E.R., (2010) . System development planning using readiness levels in a cost of development minimization model, System Engineering, 13(4).

Malone, P., Wolfarth, L., (2012) System-of-systems: an architectural framework to support development cost strategies. 2002 IEEE In Aerospace Conference, 1-13.

Mankins, J. C., (1995) Technology readiness levels. Advanced Concepts Office of Space Access and Technology, White Paper, NASA.

Moorman, C., Deshpande, R., Zaltman, G., (1993) Factors affecting trust in market research relationships. The Journal of Marketing, 57(1), 81-101.

Morton, M. S. S., Allen, T.J., (1994). The corporation of the 1990s: Information technology and organizational transformation. Oxford University Press, New York.

Murray, G., Belanger, J., Giles, A., Lapointe, P.A., (2002) Work and employment relations in the high-performance workplace, Routledge Taylor and Francis Group, London, 120-150.

O'Brien, B. F., D'Amico, A., Larkin, M. E. (2011, November). Technology transition of network defense visual analytics: Lessons learned from case studies, 2011 IEEE International Conference for Homeland Security (HST),481-486.

Pascale, R. T., Athos, A.J., (1981). Athos., AG (1986), The Art of Japanese Management, Penguin Books Ltd., New York.

Pilch, I., Turska, E., (2015) Relationships between Machiavellianism, organizational culture, and workplace bullying: Emotional abuse from the target's and the perpetrator's perspective. Journal of Business Ethics, 128(1), 83-93.

Probert, D., Farrukh, C., Dissel, M., Phaal, R., (2011) Towards a process framework for assessing the potential value of technologies, 2011 Proceedings of PICMET'11: Technology Management in the Energy Smart World (PICMET), 1-10.

Rybicka, J., Tiwari, A., Leeke, G. A., (2016) Technology readiness level assessment of composites recycling technologies. Journal of Cleaner Production, 112, 1001-1012.

Saaty, T. L., (1979) Optimization by the analytic hierarchy process. Air Force Office of Scientific Researchbolling, Philadelphia.

Sarfaraz, M., Sauser, B. J., Bauer, E. W., (2012) Using system architecture maturity artifacts to improve technology maturity assessment. Procedia Computer Science, 8, 165-170.

Schein, E. H., (2004) Organizational Culture and Leadership, 4th edition, Jossey-Bass business and management series, San Francisco.

Seablom, M. S., Lemmerman, L. A., (2012) Measuring technology maturity and readiness for mission infusion. 2012 IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 5646-5649.

Sharif, A., (2014) A multi goal multi criteria (MGMC) methodology for improving technology transition in defense systems development, PhD Thesis, Southern Methodist University, Dallas, 78-98.

Slócum Jr, J. W., (1971) A comparative study of the satisfaction of American and Mexican operations. Academy of Management Journal, 14(1), 89-97.

Smoker, R. E., Smith, S., (2007) System cost growth associated with technology-readiness level. Journal of Parametrics, 26(1), 8-38.

Solomon, S., (1998) Impact on Business Performance by the Organizational and Technological Infrastructures, Master of Science, Concordia University, Canada.

Spencer-Oatey, H., (2008) Culturally Speaking. Culture, Communication and Politeness Theory, Continuum International Publishing Group, 2nd edition, London.

Straub, Jeremy, (2015) In search of technology readiness level (TRL) 10, Aerospace Science and Technology, 46, 312-320.

Tambur, M., Vadi, M., (2012) Workplace bullying and organizational culture in a post-transitional country. International Journal of Manpower, 33(7), 754-768.

Tapia-Siles, S. C., Coleman, S., Cuschieri, A., (2016) Current state of micro-robots/devices as substitutes for screening colonoscopy: assessment based on technology readiness levels. Surgical endoscopy, 30(2), 404-413.

Teece, D. J., Pisano, G., Shuen, A., (1997) Dynamic capabilities and strategic management. Strategic management journal, 18(7), 509-533.

Terril, R. J., Doumani, F. G., Ho, G. Y., Jackson, B. L., (2015) Calibrating the Technology Readiness Level (TRL) scale using NASA mission data. In Aerospace Conference, 2015, 1-9.

Teubal, M., Foray, D., Justman, M., Zuscovitch, E., (1996) Technological Infrastructure Policy An International Perspective, Springer Science Business Media, ISBN: 978-94-015-8739-6

Watson, T. J., (2006) Organizing and Managing Work: Organisational, Managerial and Strategic Behaviour in Theory and Practice, 2nd edition, Pearson Education, Australia.

Woodrow, C., Guest, D. E., (2014) When good HR gets bad results: Exploring the challenge of HR implementation in the case of workplace bullying. Human Resource Management Journal, 24(1), 38-56.

APPENDIX

APPENDIX 1. Sub-Criteria Weighting of All Experts

Technology Infrastructure Sub-Criteria	A	B	C	D	E
Manual Machining	2	5	4	2	2
Operator Dependency	1	4	3	1	1
Software Dependency	3	3	2	3	3
Maintenance	5	2	5	4	5
Remote Control	4	1	1	5	4

Technology Culture Sub-Criteria	A	B	C	D	E
Technology Training	5	4	4	4	5
Scientific Meeting Attendance	4	5	5	5	3
Technology Learning Organization	3	3	3	2	3
Solution to Problem with Technology	1	2	2	3	1
Market-Related Innovativeness and flexibility	2	1	1	1	4

Management Sub-Criteria	A	B	C	D	E
Single Leader	8	8	8	8	8
Smart Objectives	1	1	1	1	1
KPI	3	5	5	3	3
Automatic Knowledge Processing	5	2	2	5	5
Strategic Alignment	6	3	3	2	2
The Need for Integrated Software	7	4	6	7	7
Performance Assessment	4	6	4	4	4
Periodic Assessment	2	7	7	6	6

Technology Investment Sub-Criteria	A	B	C	D	E
Allocated Budget	2	6	1	7	2
New Machine Creation	3	3	5	5	5
Renewing Machine	4	4	7	6	4
New Method to be Implemented	5	2	6	3	3
Production Speed/ Quality/ Cost Effectiveness	1	7	8	1	1
New Products	6	1	4	4	6
Technology Transfer (in)	8	8	3	2	8
Technology Transfer (out)	7	5	2	8	7

Business Results	A	B	C	D	E
Market Share	4	4	5	1	1
Number of Customer (Portfolio)	1	6	6	6	3
Number of Product Feature	2	7	3	2	2
Enterprise Growth Rate	5	3	4	5	5
Number of Innovation Product	6	1	2	3	6
Number of Innovation Process	3	2	1	4	4
Financial Rate (EBITDA)	7	5	7	7	7

APPENDIX 2. Main Criteria Importance Levels

Main criteria	A	S_j	Main criteria	B	S_j	Main criteria	C	S_j
Technological Infrastructure	1		Technological Infrastructure	1		Technological Infrastructure	1	
Culture	2	0,6	Technology Investment	2	0,5	Culture	2	0,6
Management	3	0,2	Business Results	3	0,4	Business Results	3	0,15
Business Results	4	0,2	Management	4	0,2	Management	4	0,5
Technology Investment	5	0,1	Culture	5	0,15	Technology Investment	5	0,1

Main criteria	D	S_j	Main criteria	E	S_j
Culture	1		Technological Infrastructure	1	
Management	2	0,4	Management	2	0,7
Technological Infrastructure	3	0,2	Business Results	3	0,3
Business Results	4	0,3	Technology Investment	4	0,3
Technology Investment	5	0,1	Culture	5	0,1

RESUME

Süleyman YAMAN was born in 1991in Altındağ, ANKARA. he started his undergraduate studiesin 2009, pursing course in Industrial Engineering at the Anadolu University in Eskişehir.he completed his degree in 2014. He had an internship at Toyota Material Handling in Sweden. He has since then been doing his master degree in Industrial Engineering at Marmara University.