Systems Thinking and Simulation to help IT/Software professionals to visualize knowledge assets evolution according to digital solutions implementation

by

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To my family…

Published and submitted content

Journal Papers

Title: **"Valence Matters in Judgments of Stock Accumulation in Blood Glucose Control and Other Global Problems"**
Authors: Cleotilde Gonzalez, María-Isabel Sánchez-Segura, German-Lenin Dugarte-Peña, Fuensanta Medina-Domínguez
Journal: *Journal of Dynamic Decision Making*
Year: 2018
Vol, Issue: Vol. 4, No. 3, pp 1-18
Impact factor: Unavailable
DOI/URL: https://doi.org/10.11588/jddm.2018.1.49607
Reference: (Gonzalez, Sanchez-Segura, Dugarte-Peña, & Medina-Dominguez, 2018)
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Title: **"Team Formation Using a Systems Thinking Approach"**
Authors: María-Isabel Sánchez-Segura, Mirsad Hadzikadic, German-Lenin Dugarte-Peña, Fuensanta Medina-Domínguez
Journal: *Systems Research and Behavioral Science*
Year: 2018
Vol, Issue: Vol. 35, No. 4, pp 369-385
Impact factor: 2016 JCR- Impact Factor: 1,034 Management, Social Sciences - interdisciplinary, Q2
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Title: **"System dynamics and agent-based modelling to represent intangible process assets characterization"**,
Authors: María-Isabel Sánchez-Segura, German-Lenin Dugarte-Peña, Fuensanta Medina-Domínguez, Cinthya García de Jesús
Journal: *Kybernetes*
Year: 2018
Vol, Issue: Vol. 47, No. 2, pp 289-306

Impact factor: 2017 JCR- Impact Factor: 0,98 Computer Science, Cybernetics, Q3
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Title: **"A Model of Biomimetic Process Assets to Simulate their Impact on Strategic Goals"**
Authors: María-Isabel Sánchez-Segura, German-Lenin Dugarte-Peña, Fuensanta Medina-Domínguez, Alejandro Ruiz-Robles
Journal: *Information Systems Frontiers*
Year: 2017
Vol, Issue: Vol 19, No. 5, pp. 1067-1084
Impact factor: 2017 JCR- Impact Factor: 3,232 Computer Science, Theory & Methods, Q1
DOI/URL: https://doi.org/10.1007/s10796-016-9702-6
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Title: **"Strategic characterization of process assets based on asset quality and business impact"**
Authors: María-Isabel Sánchez-Segura, Alejandro Ruiz-Robles, Fuensanta Medina-Domínguez, German-Lenin Dugarte-Peña
Journal: *Industrial Management & Data Systems*
Year: 2017
Vol, Issue: Vol. 117, No. 8, pp. 1720-1737
Impact factor: 2017 JCR- Impact Factor: 2,948 Computer Science, Interdisciplinary Applications, Q1
DOI/URL: https://doi.org/10.1108/IMDS-10-2016-0422
Reference: (Sanchez-Segura, Ruiz-Robles, Medina-Dominguez, & Dugarte-Peña, 2017)
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Conferences

Title: **"Do professionals on the Digital and Knowledge Era Know Systems Thinking?"**
Authors: Maria-Isabel Sanchez-Segura, German-Lenin Dugarte-Peña, Fuensanta Medina-Dominguez, Antonio de Amescua.
Conference: I Congreso Iberoamericano de Soluciones Sistémicas para la transformación de las Organizaciones (CISSTO)
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Title: **"Inter, Intra, and Multi-Disciplinary Teams That Really Succeed"**
Authors: Maria-Isabel Sanchez-Segura, Mirsad Hadzikadic, Fuensanta Medina-Dominguez, German-Lenin Dugarte-Peña.
Conference: 5th Business Systems Laboratory International Symposium "Cocreating responsible futures in the digital age"
Date: January 21st-23rd, 2018
Location: Naples, Italy.
URL: http://bslab-symposium.net/Napoli-2018/BOA-BSLAB-Symposium-2018.pdf#page=10
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Title: **"Soft Methodology for Systemic and Viable Capitalization of an Organization driven by its Intangible Process Assets"**
Authors: María Isabel Sánchez Segura, German-Lenin Dugarte-Peña, Fuensanta Medina Domínguez
Conference: 4th Business Systems Laboratory International Symposium "Model-based Governance for Smart Organizational Future"
Date: January 23rd-24th, 2017.
Location: Rome, Italy.
URL: http://bslab-symposium.net/BSLab-Sydic-2017/Book-Abstracts-BSLab-Sydic-2017-final.pdf#page=107
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Title: **"System Dynamics and Agents-based simulation as tools for characterizing Intangible Assets in Organizations"**
Authors: María Isabel Sánchez Segura, German-Lenin Dugarte-Peña, Fuensanta Medina Domínguez.

Conference: World Organization of Systems and Cybernetics WOSC 2017
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Title: **"Software Engineers must speak the Systemic Intangible Process Assets Language"**
Authors: María Isabel Sánchez Segura, Fuensanta Medina Domínguez, German-Lenin Dugarte-Peña, Ángel Jordán Goñi.
Conference: SWEBOK Evolution: Virtual Town Hall Meeting, IEEE Computer Society
Date: August. 2016.
Location: Virtual
URL: https://stuff.mit.edu/~richh/SWEBoK-evolution/townhall/submissions/Sanchez-Segura+.pdf
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Talks

Title: **"Systems Thinking and Simulation to Envision Future Scenarios Based on Process Assets Evolution"**
Authors: German Lenin Dugarte Peña. Maria Isabel Sanchez Segura, Fuensanta Medina Dominguez.
Conference: Jornadas Doctorales 2017 – Programa de Doctorado en Ciencia y tecnología Informática de la Universidad Carlos III de Madrid
Date: October 25th, 2018.
Location: Leganes, Madrid, Spain
URL: https://www.inf.uc3m.es/19-articulos-sin-categoria/227-jornadas-doctorales-dpto-informatica-2017
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Title: **"Software Engineering under the prism of System Dynamics"**

Authors: German-Lenin Dugarte-Peña
Conference: XXIII Jornadas Internacionales de Ingeniería de Sistemas
Date: November 2016.
Location: Universidad Católica de Santa María, Arequipa, Perú.
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Title: **"Modeling and simulation of processes in the software industry: strengths, weaknesses and opportunities"**
Authors: German-Lenin Dugarte-Peña
Conference: VIII Escuela Latinoamericana de Pensamiento y Diseño Sistémico - ELAPDIS 2015
Date: November 2015.
Location: Universidad de Ibague. Colombia
Declaration: All material from this source included in the thesis is indicated by typographical means and an explicit reference

Other merits of research

Other related conferences

Title: **"Application of Software Engineering techniques to provide a formal, repeatable methodology to teach programming in the field of statistics and business"**
Authors: Fuensanta Medina-Domínguez, María-Isabel Sánchez-Segura, German-Lenin Dugarte-Peña, Antonio de Amescua Seco.
Conference: EDULEARN16 Proceedings: 8th International Conference on Education and New Learning Technologies
Date: June, 2016
Location: Barcelona, Spain.
URL: https://library.iated.org/view/MEDINADOMINGUEZ2016APP
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Title: **Do professionals of the digital and knowledge era know systems thinking?**
Authors: María-Isabel Sánchez-Segura, German-Lenin Dugarte Peña, Fuensanta Medina-Dominguez, Antonio de Amescua
Conference: I Congreso Iberoamericano de Soluciones Sistémicas para la Transformación de las Organizaciones (CISSTO)
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"Without changing our pattern of thought, we will not be able to solve the problems we created with our current patterns of thought"

Albert Einstein

"Once you have tasted flight, you will forever walk the earth with your eyes turned skyward, for there you have been, and there you will always long to return"

Leonardo da Vinci

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Abstract

This doctoral thesis presents the SIPAC-framework, a methodological proposal created to systemically guide and help software engineers and information technology professionals in the process of proposing a customized technological solution, specifically oriented to propose software or IT solutions that provides business value supported on the status of intangible knowledge assets of organizations, and from this, drive the achievement of the strategic goals that define the organizational operation.

To achieve this, the SIPAC-framework comprises three layers clearly differentiated but intimately interrelated and co-dependent on each other: a methodological layer, a mechanisms layer and a technological layer inclusive of the technological artifacts to be used.

1. The methodological layer comprises the SIPAC methodology itself, inspired by Peter Checkland's soft systems approach, but adapted to, from an engineering point of view, addressing the situation given by the underlying knowledge of an organization, which it is usually unstructured and disordered, and whose understanding fits to be addressed as a complex problem. The SIPAC-framework guides the professional in the process of identifying such knowledge, structuring it in knowledge assets, organizing such assets according to the identity of the organization, characterizing them according to their quality and the impact they have in achieving the strategic objectives, exploiting them to propose an appropriate technological solution and envisaging possible future scenarios based on what can happen to them as a consequence of the decision making about the technological solution to be implemented.
2. The mechanisms layer comprises the constructs necessary to be able to carry out the subjacent activities of the methodological layer, mainly a model of identification and valuation of intangible knowledge assets, a model of characterization of the assets according to their quality and impact, a

Markovian model of prediction of the re-characterization of intangible knowledge assets, and an instance-based learning model implementation of decisions on the implementation of technological solutions.

3. The technological layer constitutes the artifacts to be used during the deployment of the methodology to support its methodological processes. In detail, this layer presents an instrument for collecting information on the knowledge of a company and its structuring into knowledge assets, a web application for the management of such information through a database, an agent-based model that implements both the automatic characterization of the knowledge assets from the information stored in the database, as well as the simulation and prediction of the behavior of said assets as a product of the decisions made regarding technological implementations.

The SIPAC framework has been used in a total of 11 small and medium enterprises, by means of teams of 2-4 software engineers each, who have been in charge of doing the deployment in two different time stages: an initial audit carried out in the pre-project phase and prior to the decision of technological implementation; and an audit carried out after the implementation of the technological solution. The interaction of said professionals with the interested parties by the companies (stakeholders) has been discontinuous, limited to specific audits, interviews and validations on the information and models built.

This work has derived in the methodological proposal that constitutes the SIPAC-framework, with its mechanisms and technological artefacts, and whose impact can be evidenced in several aspects:

- The effective elicitation and characterization of organizational knowledge of the participating companies.
- The success of the goals-aligned digital solution implementation proposals, which is evidenced by the improvement in organizational knowledge assets' state.
- The effective predictive power of the SIPAC-framework's simulation module.
- The satisfaction of software engineers and IT professionals by both the process of deploying the methodology and the results obtained.

- The improvement of the profession of software engineers and professionals of information and communication technologies, by providing them with an innovative approach that leads them to demonstrate to their clients the knowledge they have, in what state they are, how they can improve and what can happen if they decide to improve it.
- The emergence of organizational information that is traditionally hidden and incomprehensible, usually reserved for its management by expensive consultants and the experience of a few; all at a minimum cost, maximizing the visualization of the information and minimizing the complexity of its interpretation.

This thesis is a starting point for the development of the body of knowledge on the valuation of knowledge assets in technological environments as a tool to achieve the strategic goal of an organization. In addition, this work leaves open the way for the future development of decision-making models based on value, as well as the evolution of the presented model, ideally in a single patentable technological device.

Resumen

Esta tesis doctoral presenta SIPAC-framework, una propuesta metodológica creada para sistémicamente guiar y ayudar a los ingenieros de software y profesionales de las tecnologías de la información en el proceso de proponer una solución tecnológica customizada, orientada a proporcionar valor a las organizaciones y soportada en los activos intangibles de conocimiento de las organizaciones, de manera que se pueda, a partir de esto, impulsar la consecución de los objetivos estratégicos que dirigen su funcionamiento.

Para conseguir esto, el SIPAC-framework comprende tres capas claramente diferenciadas, pero íntimamente interrelacionadas y codependientes entre sí: una capa metodológica, una capa de mecanismos y una capa tecnológica o de artefactos tecnológicos de soporte a ser usados.

1. La capa metodológica comprende la metodología SIPAC en sí misma, inspirada en el enfoque de sistemas blandos de Peter Checkland, pero adaptada a, desde un punto de vista ingenieril, abordar la situación dada por el conocimiento subyacente en una organización, el cual usualmente está desestructurado y desordenado, y cuya comprensión debe ser abordada como un problema complejo. SIPAC-framework guía al profesional en el proceso de identificar tal conocimiento, estructurarlo en activos de conocimiento, organizarlos en función de la identidad de la organización, caracterizarlos en función de su calidad y el impacto que estos tienen en la consecución de los objetivos estratégicos, explotarlos para proponer una adecuada solución tecnológica y visualizar posibles escenarios futuros en función de lo que puede pasar con ellos como consecuencia de la toma de decisiones sobre la solución tecnológica a implementar.
2. La capa de mecanismos comprende los constructos conceptuales necesarios para poder llevar a cabo las actividades de la capa metodológica, principalmente un modelo de identificación y valoración de activos intangibles

de conocimiento, un modelo de caracterización de los activos en función de su calidad e impacto, un modelo markoviano de predicción de la re-caracterización de activos intangibles de conocimiento, y una implementación del modelo basado en instancias (IBL-model) sobre las decisiones estratégicas con respecto a la implementación de soluciones tecnológicas.

3. La capa tecnológica se constituye por los artefactos utilizados durante el despliegue de la metodología para soportar sus procesos. En detalle, esta capa presenta un instrumento de recolección de información sobre el conocimiento de una empresa y su estructuración en activos de conocimiento, un aplicativo web para la gestión de dicha información por medio de una base de datos, un modelo basado en agentes que implementa tanto la caracterización automática de los activos de conocimiento a partir de la información almacenada en la base de datos, como la simulación y predicción del comportamiento de dichos activos como producto de las decisiones de implementación tecnológica tomadas.

El SIPAC-framework se ha usado en un total de 11 pequeñas y medianas empresas, por medio de equipos de entre 2 y 4 profesionales de la ingeniería del software cada uno, que han estado a cargo de hacer el despliegue metodológico en dos estadios de tiempo diferentes: una auditoría inicial llevada a cabo en la fase de pre-proyecto y con anterioridad a la decisión de implementación tecnológica; y una auditoría llevada a cabo con posterioridad a la implementación de la solución tecnológica. La interacción de dichos profesionales con los interesados por parte de las empresas ha sido discontinua, limitándose a auditorías concretas, entrevistas y validaciones sobre la información y modelos construidos.

Este trabajo ha derivado en la propuesta metodológica que constituye el SIPAC-framework, con sus mecanismos y artefactos tecnológicos, y cuyo impacto se puede ver en varios aspectos:

- La elicitación y caracterización efectiva del conocimiento organizativo de las empresas participantes.
- El éxito que han tenido las propuestas de implementación de solución tecnológica alineadas con los objetivos, lo que se evidencia por la mejora en el estado de los activos organizativos de conocimiento.

- El efectivo poder predictivo del módulo de simulación del SIPAC-framework.
- La satisfacción de los ingenieros de software y los profesionales de TI, tanto por el proceso de implementación de la metodología como por los resultados obtenidos.
- La mejora de la profesión de los ingenieros de software y profesionales de las tecnologías de la información y la comunicación, al dotarles de un enfoque innovador que les conduce a evidenciar ante sus clientes el conocimiento que tienen, en qué estado se encuentra, cómo lo pueden mejorar y lo que puede ocurrir si deciden mejorarlo.
- La emergencia de información organizativa que tradicionalmente está oculta e incomprensible, usualmente reservada a costosas consultoras y a la experiencia de unos pocos; todo a un coste mínimo, maximizando la visualización de la información y minimizando la complejidad de su interpretación.

Esta tesis es un punto de partida para el desarrollo de la base de conocimiento sobre la valoración de activos de conocimiento en entornos tecnológicos como herramienta para conseguir los objetivos estratégicos de una organización. Además, este trabajo deja abierto el camino para el futuro desarrollo de modelos de toma de decisiones basados en el valor, así como la evolución del modelo presentado, idealmente en un solo artefacto tecnológico patentable.

Abbreviations

CS	Complex System
DDBB	Data Base
IA	Intangible Asset
ISVA	Duque de Santomauro Institute for Vehicle Safety
IKA	Intangible Knowledge Asset
K	Knowledge
KA	Knowledge Asset
KM	Knowledge Management
PA	Process Asset
PM	Project Management
PMBOK	Project Management Body of Knowledge
SE	Software Engineering
SG	Strategic Goal
SIPAC	Systemic Process Assets Characterization
SPEA	Systemic Process Assets Engineering Application
SSM	Soft Systems Methodology
ST	Systems Thinking
SW	Software
SWEBOK	Software Engineering Body of Knowledge
VBSE	Value-based Software Engineering
VSM	Viable System Model

1. Introduction

1.1. Motivation

In the current era, the digitization of organizations is essential to add value to the business. For many years has been recognized the fact that Business-value generation has become one of the main focus of organizational strategists and stakeholders, and one of the key aspects to better keep this focus is the relation between IT governance and decision making processes (J. Ross, 2009), and still in recent times is stated that with a better IT governance in mind, it is feasible to understand that *"Companies are looking to technology to create business value"* (Ransbotham, Gerbert, Reeves, Kiron, & Spira, 2018). An example of actions aligned with strategies to achieve this value-creation focus is the way that *"pioneer organizations are deepening their commitment* ***to technology*** *and focusing on revenue-generating applications over cost savings."* (Ransbotham, Gerbert, Reeves, et al., 2018), however no clear indication about which the appropriate stakeholders are to be aware of decision-making in regard to this. According to (J. Ross, 2009) "*Business executives must own decisions about strategic use of IT*", and this is a clear indication of the need of Business people to speak the software and information technology (SW/IT) language as well as the SW/IT professionals need to speak the business language, if an effective organizational digitalization strategy is desired to be implemented.

In view of the above industry needs, IT/SW professionals are the appropriate professionals to be in charge of providing digital solutions to improve companies' business value with the long-term goal of guaranteeing organizational competitiveness against their competitors, ensuring sustainability along time and envisioning innovation strategies to face the future. The IT/SW professionals are those that may be in charge of both leading the development of digital solutions and such digital solutions (IT) governance, where IT governance may be understood as "*the decision rights and accountability framework for encouraging desirable behaviors in the use* *of IT*" (J. W. Ross, Weill, & Robertson, 2006). IT governance reflects the general corporate governance principles of an organization, and it focuses on "*the management and use of information technologies to achieve corporate performance goals*" (J. W. Ross, Weill, & Robertson, 2006). **Given that digital solutions provision affects most industries, and that such is crucial for digitization, IT/Software professionals must have the capability to create and offer the digital solutions that effectively leverage the specific business goal defined to create business value**. Although there are existing formal attempts for identifying and measuring some specific aspects of these assets using technology, and given that "*the digital economy is not just about using computers and networks; it's about using them well*"(J. Ross, 2009), there is still a remaining gap with respect to how this measured information is shown for seizing a better decision making and how it may affect the business development.

In the current era of simultaneous immediacy and service or product quality, the IT/SW professional must have mechanisms intended to help in making decisions about which is the convenient digital solution that better fits the company needs. It is not enough to have several recognized and brand affiliated tools, but the IT/SW professional must be able to visualize and propose that solution that correctly fits the clients' needs, which it is argued are affected for both trivial (procedures, documents, etc.) and soft and complex aspects (in-culture, external culture, the environmental constraints, etc.). **Until now, no mechanisms have been considered to help the IT/SW professional to identify and propose the best digital solution (whether it is an existent artefact or an ad-hoc development project) having into account something inherent to every company, that is the state of health of organizational knowledge assets**, of their knowhow. To become competitive, software/technology provision companies and their professionals have begun to interest and appreciate the importance of their client's aspects such as:

- Their clients' knowledge and organizational culture,
- What sets apart client companies from their competitors and,
- What their client companies have learned to do from their professional practice, that is, their know-how.

All this knowledge, which is the key asset for company's differentiation, can be used to ascertain how well a client company is faring in the pursuit of its organizational goals. Company knowledge is represented by all the resources that despite being non-tangible still contribute "*to the delivery of a company's value proposition*" (Marr, 2008; Sanchez-Segura, Medina-Dominguez, & Ruiz-Robles, 2016). An enterprise's success may not be guaranteed by just it having the financial (money, credit, funds, etc.) or physical (computers, buildings, etc.) capital to support its operations (Sanchez-Segura, Ruiz-Robles, Medina-Dominguez, et al., 2017). As a matter of fact, enterprises with an intensive operation around using or creating knowledge must indisputably consider the "*vital key resource*" that its intangible side is (the so-called intellectual capital) (Sanchez-Segura, Ruiz-Robles, Medina-Dominguez, et al., 2017). The Intellectual capital of a company is determined mainly by its intangible knowledge assets status (also frequently referenced as process assets, knowledge assets or intangible assets). Therefore, a company with better intangible knowledge assets is expected to have "*better prospects of long-term success*" (Andrews & Serres, 2012; Axtle-Ortiz, 2013; Greco, Cricelli, & Grimaldi, 2013; Khan, 2014; Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2018), which is the first goal of every company pursuing viability and sustainability.

An example of the importance of considering knowledge assets as a key element for developing technological solutions that effectively empowers a company's business goal can be illustrated by listing some of the companies that have positioned themselves at the top in terms of economic and future prospects, i.e., Google, Amazon, Facebook or Apple. All of them, with different market share, have achieved a solid success with the business model they have, but one thing in common to note is that all of them have been recognized for aspects related to knowledge assets empowerment: the innovation capability, human resources effective management, diversification of services, adaptable product development models, or a clear multi-target expansion model, among others. It might be said that the success of such well-known companies is directly related to their capability to digitize, to learn from themselves, to install a continuous improvement intraorganizational culture, and their capability of evolution and adaptation to the environmental requirements and constraints defining the domain among which such companies operate.

If we accept that the success of more and more businesses depends on a technological and/or digital solution, information technology

consultants or software engineers can be regarded as being more responsible than ever for helping companies to achieve their business goals (through the proposal of software and technological solutions and strategies). Assuming that this is what technology consultants, or any provider of software and technological solutions do, how easy is for them to demonstrate their clients that the proposed solutions is the correct one? what tools do they use to demonstrate the potential impact of the proposed solution on business value? Nowadays, backed by their experience, the world of the consultant or software engineer is judged to be enough. Companies use to trust on the proposed solution based on the proposal "brand" or the talent of the consultant. But what if clients could picture their near future and judge for themselves whether it is worthy or not investing in a technological or software solution?

In this thesis work the focus on the creation of a methodological proposal and its related technical mechanisms designed to:

- Meet the need of companies to make decisions regarding which would be the correct business-value-oriented digital solution to implement in a company, based on the state of its knowledge assets present and prospective visualization.
- Satisfy the need that current IT/SW professionals have of doing their work effectively in a world that is dominated by both immediacy and maximum quality of the offered service or product, and in which software and business languages have been considered as divorced but need to be considered in a conjoint way.

Considering the abovementioned needs, it becomes evident the worth of doing research and developing solutions aimed at giving steps in the direction of guiding the SW/IT professional on supporting their clients to identify their needs, their knowledge assets and the digital solutions that will effectively help the company to achieve its goals and to empower based on business-value creation from technology: "*If the expense of the implementing information technology can help you achieve your company's financial goals then the technology is creating value*" (Cequea, 2017), and an appropriate framework for doing so is through the use of a systemic perspective, by engineering systems, which perfectly fits in the software engineering professional practice. From the perspective of the software engineering professional practice, systems engineering has been stated as "*The process of developing a system that must fulfill a certain purpose using the systematic application of engineering techniques, and of which software engineering is a part, provided the system has a software subsystem*" (Burge, Carroll, & Mistrík, n.d.; Chaudron, Groote, Hee, et al., 2004).

The followings subsections of this chapter present the general objectives, hypotheses and other introductory information relevant for the remaining chapters.

1.2. Objectives

As stated before, the main actors being affected by and contributing to the development of this thesis work are the SW/IT professionals, the organizations in need of digitization, and the academicist in charge of developing the methodological strategies for supporting business value generation intervention approaches. With these as the intervenors, the main objective of this thesis is:

> *"To develop a methodological and technological framework to guide IT/SW professionals to identify and use their client's knowhow and its alignment with the client's business goals, as the basis to identify better digital solutions that provide business value to their clients"*

In order to achieve such general objective, and given the wide effect that it may have, the following specific objectives are proposed for a better comprehension of the direction of this research:

- **Objective 1:** To develop a general methodological guide for the SW/IT professionals to be able to do to their clients a knowledge audit comprising the elicitation of intangible knowledge assets, the definition and measurement of such knowledge assets indicators, the proposal of the adequate digital solution for organizational improvement based on their knowhow, and finally the demonstration of how such solutions effect on the state of the knowledge assets and vice versa.
- **Objective 2:** To develop a conceptual framework for the valuation and characterization of knowledge assets based on their quality and the impact on the defined business goal.

- **Objective 3:** To develop a simulated environment that represents the characterization of knowledge assets and how they may change along time depending on decisions made regarding the implementation of the organizational digital and technological solutions.
- **Objective 4:** To develop a conceptual framework able to represent the process of making decisions in regard to implement or not a specific digital solution and how the intangible assets status are affected by this decision and vice versa.

1.3. Hypotheses

The following hypotheses have been proposed for this research work. The first hypothesis refers to the process of identifying and measuring the knowledge assets which will be the basis for proposing the best software solutions to be implemented in an organizational context:

> H1: "*By using the SIPAC-framework, and following all its methodological guidance, IT/SW professionals can effectively elicitate the processes, know-how and knowledge related assets of their clients organizations*".

The second hypothesis refers to the effect that the deployment of the SIPAC-framework, from the perspective of the knowledge assets of the company, i.e., given that knowledge assets can be measured and characterized, by watching at them is a good way to check how good or bad the SIPAC-framework is on suggesting digital a solution strategy.

> H2: *"From the implementation of the strategy or digital solution that the SIPAC-framework helps the IT/SW professional to propose to their clients, the state of organizational knowledge assets can be improved so that the organizational business goal is better pursued"*

The third hypothesis regards the predictive capabilities that the SIPAC-framework gives to the IT/SW professional, i.e., the SIPAC-framework has been prepared to learn from previous cases and be trained to predict knowledge assets evolution for new companies.

> H3: "*The SIPAC-framework is effective at predicting a company's' knowledge assets evolution, based on information about its effectiveness in previous experiences*".

The fourth hypothesis refers how experiencing with the SIPAC-framework has been for the IT/SW professionals in charge of deploying it in organizational context. Important aspect to test with this hypothesis is how they perceived the framework, how hard the concepts management was, how instructive was for them and how promising is in their opinion.

> H4: "*SW/IT professionals are satisfied with the process of deploying and experimenting with the SIPAC-framework in real organizational contexts*"

1.4. Approach to the solution

The SIPAC-framework, the solution proposed in this research thesis comprehends a general framework that the IT/SW professional may use for going from the starting point of understanding the complex problem of a company organizational knowledge to the proposal and demonstration of a digital solution or strategy that from its alignment with the business goals better leverages its achievement.

1.4.1. The SIPAC-framework

The SIPAC-framework comprehends three clearly differentiated layers of application:

- A methodological layer.
- A mechanisms layer.
- A technological layer.

1.4.1.1. Methodological layer

The methodological layer, contentive of all the step by step, although iterative process of eliciting the client organization knowledge, aligning the knowledge asset with the organizational mission and strategic goals, measuring and characterizing knowledge, identifying the correct strategy of digitization (whether this is a single product or a set of components), simulating the effect of such solution and discussing with the client such effect from simulated scenarios.

The general methodological layer is an adaptation of the Soft Systems Methodology (SSM) of Peter Checkland. The SSM is specifically designed to deal with complex problematic unstructured situations in which several elements are co-existing and interacting with a common purpose. Knowledge, which besides being intangible is complex for its distributed form and its dependencies on many other tangible and intangible "things", defines a complex problematic situation perfect to be addressed through a Soft Systems approach. The SIPAC-framework has adapted it and equipped it with some engineering perspective that bases on artefacts, mechanisms and technological construct to guide from the beginning to end the process. In summary, the general stages of the methodological layer may be stated as:

1) Initial approximation to the client company problematic situation.
2) Strategic Organizational Expression.
3) Definition of relevant systems.
4) Systemic assessment and characterization.
5) Knowledge-based Model Adjustment Validation.
6) Smart Decision-Making Module Design.
7) Strategic Discussion.

1.4.1.2. Mechanisms layer

The mechanisms layer comprehends the design of the engineering mechanism to support the methodological transition from one stage to another with the inputs required to do so. In concrete, the mechanisms presented in this layer are:

- A model of knowledge asses valuation, which may be used in stages 1 and 2 of the methodological layer.

- A model of knowledge assets characterization, which may be used in stages 4 and 6 of the methodological layer.
- A proposal of knowledge assets markovian re-characterization, to be used in stage 6 of the methodological layer.
- An implementation of the instances-based learning (IBL) model to represent the decision process based on instances with information about knowledge assets state, the decision of implementation or not, and the reward obtained from good or bad decisions.

1.4.1.3. Technological layer

The technological layer presents specific technological artefacts that catalyze the process defined by the methodological layer. Concretely, this layer presents:

- The description of a spreadsheet for conducting knowledge audit interviews, which is used in stages 1 and 2 of the methodological layer.
- The description of a tool for knowledge audit information upload and reports generation.
- A simulation model of knowledge assets behavior based on their representation as agents. This agents-based model is used in stage 4, for automated characterization of knowledge assets based on the information collected from a company, and also in stage 6 to predict the knowledge assets evolution (change on their characterization state) from the experience of the SIPAC-framework experimentation with previous cases.

1.5. Validity of the solution

The SIPAC-framework and its related artefacts have been designed to be used in the context of companies that are interested in improving its competitiveness in the digital and knowledge era from:

- Digitization of its processes.
- Exploiting its intangible side (its knowhow) and its related components (its knowledge assets),

- Implementing digital solutions that correctly drive the organization to a better performance from its alignment with strategic goals achievement.
- Improving the effect of important decisions regarding its intangible side exploitation and the digital solutions to use for it.

This methodological and technological proposal has been tested in 11 small and medium enterprises. It has been required the collaboration of specific stakeholders that provide the information to correctly elicitate organizational knowledge, since a general strategic vision is needed to correctly transform unstructured information into concrete structured pieces of knowledge, which leads to the knowhow and specific knowledge assets specification. Besides the experimentation while collecting information, the IT/SW professional clients allowed the validation after the SIPAC initial immersion, so that the knowledge assets identification, characterization, and its effect was tested with the client perspective.

1.6. Structure of the Document

This thesis document has been structured so that the reader can easily identify the important aspects: the introduction, the state of the art, the proposal, the experimentation with a specific real case, the general analysis of results and experimentation with all cases and the conclusions and future work.

Chapter 1 contains the introduction to the general context of this research, defined by the motivation, hypotheses, general and specific objectives and the followed methodology for research.

Chapter 2 describes the conceptual framework introducing systems thinking, knowledge management, modeling and simulation approaches for management in technological companies, and a brief summary of relevant contributions integrating some of these research fields.

Chapter 3 presents the SIPAC-framework and its three layers: the methodological layer, the mechanisms layer and the technological layer. This chapter was structured so that each of the layers contains a subsection with its corresponding sub-pieces. The methodological layer describes the seven stages methodology. The mechanisms layer contains each of the constructs developed to support the methodological layer, mainly the knowledge assets valuation model, the knowledge assets characterization model, the re-characterization model and the agents-based implementation of the IBL-model for the decision regarding technological selection. The technological layer contains the technological artefacts supporting the methodological layer: the description of a spreadsheet for data collection, the description of a web application for data management and storage, and finally the description of the agents-based model of knowledge assets and the processes of characterization and re-characterization as a markovian process.

Chapter 4 presents a step by step demonstration on the deployment of the SIPAC-framework in a real case, for which the case of the ISVA (Duque de Santomauro Institute for Vehicle Safety) was selected.

Chapter 5 presents the validation of this thesis through a set of experiences using the SIPAC-framework in eleven real cases. Specifically, the general SIPAC-framework deployment was summarized in a table where every case study is presented. This chapter also presents the discussion of results from the perspective of: domain in which this methodology is valid, limitations for future deployments and potential research lines for the future. A special emphasis is given by considering the breakthrough that this work represents for the IT industry.

Chapter 6 presents the conclusions of this thesis in which the emphasis is on the achievement of the proposed objectives, the difficulties from both the methodological or the practical validation sides, and in the feedback obtained from the IT/SW professional, the company's stakeholders and the academic reviewers of related publications in which advances of this work were presented.

2. State of the Art

From the main goal and hypotheses of this thesis, several knowledge areas must be considered for appropriately framing the solution that will then be presented. We have mentioned that the SIPAC-framework is aimed at being used for IT/SW professionals, for which it is necessary to review which are the current trends that such professional follow for addressing the problem of digitizing organizations and whether or not its client's organizational knowledge is considered in such endeavor. Also, we will look at how knowledge has been previously measured and exploited, be it in technological context or not, for which a general exploration about works in the fields of intellectual capital, knowledge management and software engineering is performed. Regarding how analytical or holistic the approaches for measuring an organization knowledge for digital improvement have been, we briefly explore the validity of systemic approaches and methodologies for addressing complex problems as the one being faced here. And finally, we explore the use that has been made of the smart approach used to mimic a smart behavior: the instance-based learning model of cognition in context beyond psychological or merely mind-functioning descriptive attempts. Following are described de subsections in which this review was structured and the main contents of each.

Subsection 2.1 of this chapter presents a brief introduction to systems thinking, focusing on how it has been used, the main trends and the kind of problems that may be addressed with it.

Subsection 2.2 contains an introduction to existing works that have tried to provide smart approaches in the field of information technology. Specifically, this subsection contains the "smart" perspective that will be used in the following chapter, and relates the relevant works that following this, or a very similar perspective, have provided a concept of smartness from a theoretical or practical point of view.

Subsection 2.3 has an initial approximation to works that have considered the use of simulation for supporting strategic decisions, specifically focusing on decisions based on organizational knowledge or know-how.

Subsection 2.4 presents the state of the art on the value of intangible assets in the software industry, specifically trying to identify works within the fields of Intellectual Capital and Knowledge Management that have tried to measure a company's intangible side and use it for improving from any perspective the digital business related to software service supply.

Subsection 2.5 goes deeper and explores how in the IT/SW industry the intangible side, mainly processes and documents, have been considered as important for better technology and software process management.

Subsection 2.6 presents the latest approaches for measuring the digital maturity of organizations, trying to identify whether these approaches have explicitly considered how organizational knowhow directly affects organizational performance, and whether organizational performance is measured in terms of technology recency or also considering the effectiveness and the use made of them.

Subsection 2.7 explores the approaches of decision-making that have been considered in the software industry. Mainly some specific decision-making models' applications and experiments are presented.

Subsection 2.8 introduces the works focused on implementing the process of learning from a practical perspective, of special interest in this thesis for the learning that a smart system must be able to achieve.

Subsection 2.9 introduces the works justifying the use of cybernetics in modern management, such as management in the software industry.

2.1. Brief Introduction to Systems Thinking

Systems thinking has been widely used for many years with the aim to solve problems that cannot be correctly expressed from an analytical point of view. i.e. separating the problem in parts and studying and comprehending the parts to conclude about the whole. Facing such inability, systems thinking's *moto* is that instead of looking at the parts, the set of elements and its relations must be understood from a wider inclusive perspective. Such (systemic) inclusive approach is expected to be more emergency-propitious and is expected to generate the conditions under which complex problems can better find proper solutions.

Most of systems science practitioners have been using for years the systemic approaches specifically designed for methodologically facing soft (unstructured) and hard (structured) complex problems (P. Checkland, 1993, 1999, 2000; Winter & Checkland, 2003). Some have used the systems approach to get closer to management sciences by exploring how organizations can be improved by the systemic regulation of its elements and by guaranteeing the existence of all necessary subsystems for viability (Beer, 1984; Espejo, 1994; Espejo & Gill, 1997; Espejo & Kuropatwa, 2011; Perez Rios, 2010). Some other authors have targeted their efforts to the practical application of systems thinking in current organizational settings, which is why more recently emerged works like *The Fifth Discipline* (Senge, 1990) or the interactive planning and idealized approach of (Ackoff, 2001), to mention some.

One important distinction between the type of problems that may be faced through systemic approaches is the nature of the situations that such approaches shall face. Some of the most widely known systemic approaches have been adopted in traditional managerial settings of both the academia and the industry. Examples of such approaches are the cited works of Russel Ackoff with his "Mess management" proposals, and clear indications of the advantages to take from the co-existence of many organizational elements, the importance of feedback with either negative or positive inputs, the value of discussion and questioning over immediate and preestablished agreement, or the disadvantages of adopting only analytical processes to manage complexity.

This thesis has considered several aspects of systems thinking, some relative to the application of the soft approaches and some relative to the application of the hard approaches. Essentially, this thesis has taken learnt lessons from systems thinking and has merged them into the complete software engineering process of providing digital solutions to digitizing companies, focusing on the organization's knowhow alignment with strategic and business goals. Such merging of systems thinking with the SE professional practice nurtures and prepares from a management perspective the information of knowledge to be processed and considers the multiple perspectives, stakeholders and interacting elements that may coexist around the mentioned problem, while the engineering process is finally better carried out by considering the inherent complexity in the problematic situation around the state of the knowledge of an organization.

2.2. IT and Smartness: finding connections

There are several approaches that may be considered appropriate for embracing the concept of smart decision making. However, in this work we aim to focus on those approaches specifically considering the emergence of a learning, collective or individual, that enables an entity of a kind of intelligence to choose among alternatives. The concept of smartness being considered here approaches the one proposed by (Alter, 2019; Medina-Borja, 2015), in which a smart service system is a system with the capacity to learn, dynamically adapt, and make decisions based upon data, and finally to improve its response to future situations. This smartness also considers properties that have been usually attributed to adaptable systems such as: self-detection, self-organization, self-monitoring, self-replication or self-control, which are normally seen in smart systems of nature, like ants and honey-bees colonies, fish swarms or birds. Despite the previous definition of "Smartness" has been thought for the Internet of Things domain, we have framed our research considering that we want to provide a smartness property to the general SIPAC-framework by both the presented mechanisms and models representing how to make decisions and learn from them, as well as the technological artefacts developed representing the complex processes of valuation, assessment, comparing choices, making decisions, or learning from obtained outcomes.

Another concept of smartness, interesting to us from a theoretical perspective, is the one provided by Swarm Intelligence (SI), which refers to intelligent behaviors of individuals based on biological swarms like those of fishes, ants, honey bees or termites. Following this, according to Ebubekir (2010), SI is the direct result of self-organization in which the interactions of lower-level components create a global-level dynamic structure that may be regarded as intelligence. As presented in (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2017), these lower-level interactions are guided by a simple set of rules that individuals of the colony follow without any knowledge of their global effects, and this kind of behavior can be mimicked by technological developments so that abstract implemented products learn from this intelligence.

Individuals in a nature's colony only have local-level information the variables and elements surrounding them, but no universal information can be interpreted by them. Using direct and/or indirect methods of communication, the local-level interactions of the members of a colony affect the smart global organization and behavior of the whole colony, which leads to a collective responsible by-nature behavior, in which with no norms there is a clear intrinsic objective always that all of the member contribute to pursue.

Swarms in nature show that this synergetic capability is a crucial feature that shields them with very effective techniques for survival, evolution and for the achievement of not just individual but also collective goals. Specific clear examples are illustrated through a simulated tool in (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2017).

Other approach is the one of Resnick (1994), who presents a set of experiments related to Swarm Intelligence as the representation of biologically cooperative complex behaviors. In such a work, a simulation project presents how a colony of ants forages for food. Although there is present a set of simple rules that every ant follows, the colony (as a system) shows a complex behavior of action in a sophisticated (smart) way. This model is an implementation of the Netlogo software, demonstrating not just its usefulness but also its power to implement complex relations and emerging behavior in several fields.

Another example of a computer model of systems based on Swarm Intelligence is presented by Guo & Wilensky (2014) in which is shown a colony of honey-bees during their hive-finding process. In this model, a swarm of tens of thousands of honey bees can "*accurately pick the best new hive site available from dozens of potential choices through self-organizing behavior*". As theoretical foundation, the internal mechanism that defines this model's agents behavior is based on the Honeybee Democracy (Seeley 2010) in a simplified way. One of the simplifications is that it only shows scout bees, which account for from 3% to 5% of the population of the whole colony, in which there are other bees and roles actively involved in the real decision-making process. The other bees were left out because their behavior is defined by simply following the scout bees to the new hives they find when a decision is made. As stated by the authors, leaving out the non-scouts reduces the computational load and makes this model visually clearer. Other studies of social animals and social insects have resulted in a number of computational models of SI, where "*The collective behaviour of a swarm of social organisms emerges from the behaviour of the individuals of that swarm*" (Yuce et al. 2013).

As an example of the honey-bees strategy, in big fields a colony of honey-bees can exploit a large number of food sources, and they can fly up to 11 km to exploit food sources. The foraging process begins with scout bees searching out promising flower patches (which is a smart behavior of exploration). The colony keeps a percentage of the scout bees during the harvesting season, and when the scout bees have found a flower patch, they will look further in the hope of finding an even better one. This is the type of behavior that can strategically be mimicked in other domains, like ours, taking lessons of honey-bees self-organization, resources management, strategic vision, conscious cooperativeness, goals orientation, etc.

The scout bees are explorers in the sense that they **randomly** look for the best patches and **inform** their peers, who are waiting in the hive as to the quality of the food source, based, among other things, on sugar levels. The scout bees deposit their nectar and go to the dance floor in front of the hive to **communicate** the other bees through their performance of what is known as the *waggle dance*. (Yuce et al. 2013). These smart behaviors of patches exploration and communication may be perfectly mimicked in other domains, not only from honey-bees but form any functional system in nature.

Smart approaches, as the Swarm Intelligence, have been used since the late 1980s in several fields (Zhang, Agarwal, Bhatnagar, Balochian, & Yan, 2013). Besides in some applications to conventional optimization problems, Swarm Intelligence has been also used in ambits like "*communications, dynamic control, heating system planning, materials* *acquisition, medical dataset classification, moving-objects tracking, and prediction*". Although applied to a variety of fields in research, engineering, industry, and even social sciences, no research has been carried out on applying Swarm Intelligence to improving business from their capability to mimic smart behaviors and apply it for a systemic improvement strategy. This is the motivation behind the conception reported in this thesis, in which Knowledge Assets are conceived as agents that may be managed in a smart way.

The approach of computational intelligence has been widely used for "*studying, understanding and solving problems in several fields of study with excellent results*"(Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2017). Specifically, some previous work on swarm intelligence has encompassed "*the development and testing of evolving and effective algorithms for solving academic and industry-related problems*". Among the several examples that have used this mentioned logic, it can be mentioned the applications on the well-known fuzzy logic, neural networks and other evolutionary computation approaches. In spite of that, not very much has been done aiming to approach the strategic management improvement, which is why in this thesis all these concepts are brought to be used.

The information on Knowledge Assets of a company, its strategic goals and the relations that may exist among these, intelligent or not, are usually only obtained by specialist that besides being expensive to pay, restrict their knowledge for themselves, which is not very useful for the companies. This thesis will present an appropriate approach to help the IT/SW professional to make tangible such knowledge and relations so that, besides available, it will be reusable and exploitable at different levels and for different actors of an organization, but more importantly to be used as a driver for a smart digitization implementation. Some studies already consider the importance of knowledge assets recognition (Aboody & Lev, 1998; Blackler, 1995; Hall, 1993; Kogut & Zander, 1992; Martín de Castro, Delgado-verde, Amores-Salvadó, & Navas-López, 2013; P.M.I., 2013a; Seleim, Ashour, & Bontis, 2007; Software Engineering Institute, 2010; T. Stewart & Ruckdeschel, 1998; Verdun, Paguas, & Alberti, 2011), and the need to connect such knowledge assets with the corresponding company's objectives (April & Laporte, 2009; Nathan Baddoo & Hall, 2002). However, this theses is the compendium of advances initially presented in (Sanchez-Segura, Medina-Dominguez, & Ruiz-Robles, 2016) and evolved through the use of technologies and technological artefacts in the works of

(Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2018, 2017) in which the linking of knowledge assets and strategic goals is used in simulation models, under several simulation paradigms, finally aimed to predict and support real decision making, which is in accordance to this thesis objectives and hypothesis.

2.3. Approaching simulation to strategy.

As mentioned in the introductory section, and in accordance to (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2018), "*knowledge-intensive organizations are companies that are conscious of the importance of their knowledge for survival in the changing environment of the 21st century*", which is why a common and very accepted in modern times fact emerges: that such companies "*need to pursue and achieve their business goals with the aim of surviving, adapting and, at best, evolving with the environmental requirements*". Aiming to do so, these companies must focus their attention in the really important resource that they own, i.e., in the organizational knowhow. The knowhow is a matter that has widely been studied in deep by a wide set of academic branches of knowledge related to the well-known fields: intellectual capital, strategic management or process improvement. Nonetheless, research works focusing on studying this but from the point of view of how useful it is or how effective might be once incorporated in the industry seems to be "*scant*" (Demartini & Paoloni, 2013).

By strategically managing a company, organizational stakeholders can point towards the company success, but in this endeavor they must consider both the tangible and the intangible (González & Dopico, 2017; Greco, Cricelli, & Grimaldi, 2013; Pike, Roos, & Marr, 2005; Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2018), however, the intangible side is not always properly considered, leading to ineffective strategies or misunderstood results. The mission of a company is defined by its strategic goals, which are "*the essence of organizations and define the target towards which all activities and policies should be aimed*"(Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2018), and as stated by these authors, the strategic actions that drive organizations towards the achievement of business goals, which are supposed to be clear, are no longer sufficient for doing so, and even if understood as complex systems, the complexity of such system of business, knowledge and people interacting around a specific goal, is usually misunderstood leading to an "*obscured the understanding of how an organization can function effectively*".

The intangible assets of a company can be "*used as levers to achieve business goals if they are considered under the systems thinking paradigm*" (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2018), and form the many branches of the systems thinking paradigm, of specific interest to this research is the possible use of it to represent and understand through simulation modelling the inherent complexity that is present in an organization with the intangible assets' system identified, mainly represented by the organizational knowledge assets. A clear example of works taking advantage of simulation to support form a strategic perspective is the work of (Iandolo, Barile, Armenia, & Carrubbo, 2018), in which system dynamics is used to represent the what the authors called sustainable value, and how it may be affected by the complexity of the environment, taking into account all the complexity management guidelines provided by the viable systems approach.

A common trend in modern organizations is to develop organizational studies with the basis mainly on information about economics or very generalist chunks of information. This approximation fails mainly because it does not to take into account the organization's intangible side and how knowledge related assets may change in their state among time. It is frequent to find professionals and business people mentioning the direct impact that intangible assets have on the operation of an organization and in performance reports, however, such intangible assets are not considered explicitly as frequent. This thesis is a contribution in the search to find a usable and practical solution, supported by simulated features enabling the measurement and characterization of knowledge assets based on the quality and impact these have on the organization's strategic objectives.

Part of the aim of this thesis is to illustrate how useful a specific modelling and simulation tools is for characterizing the intangible knowledge assets of organizations according to the SIPAC framework, which will be extensively explained in chapter 3. Specific advances have been presented in (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2018, 2017; Sanchez-Segura, Ruiz-Robles, Medina-Dominguez, et al., 2017). Regarding these works, until now, three specific models have been published in advance.

The first one is an agent-based simulation model in which the behavior of knowledge assets if represented as smart biomimetic constructs is presented (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2017). This NetLogo representation considers the dynamic of biomimetic knowledge assets and the collective smart properties that the system as a whole may have.

The second model is a system dynamics simulation model representing the knowledge assets dynamics (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2018). In this, the dynamics of the knowledge assets is presented, specifically emphasizing in the changes of state of the knowledge assets according to their parameters evolution.

The third model is an agent-based simulation model in NetLogo also presented in (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2018), that focuses on the visual power that Netlogo has for representing the characterization of assets as a product of such assets' impact and quality assessments. This representation is made through the distribution of patches of the simulation window in as many spaces as characterization states exist, so that the agents (the knowledge assets) locate in one of the characterization spaces. The manipulation of sliders and setters that this model allows is powerful for from a strategic perspective stimulate the discussion on possible scenarios for the knowledge assets, which may be dynamically observed through the simulation window.

This thesis goes ahead with the work previously presented in the third model, by incorporating several aspects to the state of research, such as:

- The assessment mechanism has been evolved to consider that not all the knowledge assets of the company are equally important for achieving a business goal, and not all the indicators of a knowledge asset are equally important for such knowledge asset.
- The state of the indicators can change according to decisions made, so a decisions simulation module has been added and the connection among those reflects the effect of decisions in knowledge assets state.

- The representation of the decisions using the Instance Based Learning Theory has been added, which is explained ahead.

2.4. IC and KM for IT-based organizational improvement.

Software engineering services are driven by two currents of thought: a formal body of knowledge (Bourque & Fairley, 2014) and complex and dynamic professional practice. Irrespective of the current of thought, the service provided by a software engineer should be aimed at satisfying the client's needs and specific requirements. This section gives a brief summary of previous research focused on developing technology- and software-supported businesses based on the value of intangible assets, followed by a brief history of approaches focused on understanding decision making in the software business context, and, finally, a summary of research aimed at using experience-based decisions to study real contexts. The main compendium is presented at (Sanchez-Segura, Medina-Dominguez, & Ruiz-Robles, 2016), however the main contributions relevant to this thesis are mentioned next.

Strategically, "*a cornerstone of the long-term survival and sustainability of any organization is the status of its intellectual capital*" (Khan, 2014; M.-I. Sanchez-Segura, Medina-Dominguez, & Ruiz-Robles, 2016; Tsai, Lu, & Yen, 2012), which is widely known by businesspeople but not as well-known by IT/SW professionals. World level data correlations confirm the explicit relationship existent between a country's intellectual capital and its related gross domestic product (Ståhle & Ståhle, 2012), which is indeed an increasingly recognized factor of production (Abhayawansa & Guthrie, 2014) at all levels of nations. Whereas, while the role played by intellectual capital in value creation is well established in academia, it is still to be explored in the industry or corporate world (Demartini & Paoloni, 2013) nor technological developments.

The intellectual capital targets the valuation of intangible assets, which are all the non-tangible resources contributing to the delivery of a company's value proposition (Marr, 2008; T. Stewart & Ruckdeschel, 1998). Axtle-Ortiz (Axtle-Ortiz, 2013) offers an excellent compendium of intellectual capital definitions from 1971 to the present, and suggest that both the concepts of "intellectual capital" and "intangible assets" should be equivalent, which are also related to the process assets in the software engineering world. Another author, (Edvinsson, 1997), defines the intellectual capital as "*the knowledge that resides in people, organizations, technology, procedures, customer relationships and professional skills that give a competitive advantage*" (M.-I. Sanchez-Segura, Medina-Dominguez, & Ruiz-Robles, 2016), and (Edvinsson, 1997; Roos, Roos, Dragonetti, & Edvinsson, 1998) also defined intellectual capital as "*the processes and assets that do not usually appear in the balance sheet, on which they do, however, have an indirect effect*".

Considering the previously mentioned definitions for "intellectual capital" and the points of view that they might represent, it is possible to identify the existent connections between the terms: "intellectual capital", "intangible assets", "knowledge assets" and "process assets". It is necessary then to manage knowledge or process assets, which are essentially knowledge sourced from different parts of any organization. This, aiming to address and take advantage of the intellectual capital of an organization for its own improvement and evolution.

No matter how much knowledge a company it may have, it will be unable to capitalize upon it unless it makes such knowledge become accessible to the company members in the form of knowledge assets that might be used by the organization, and on this ground, it is very important to identify which knowledge assets must be used and in which most of the attention should be paid in order to keep or drive the company to a good shape, as well as which ones are putting the company into risks so that should be watched carefully. Knowledge assets describe, implement and improve a company's processes, so some examples of these may be the policies, the defined processes, checklists, lessons learned, documents, templates, standards, procedures, plans and/or training materials of a company. As stated by (M.-I. Sanchez-Segura, Medina-Dominguez, & Ruiz-Robles, 2016) citing (Software Engineering Institute, 2010), "*These assets are developed or acquired by organizations in order to meet their business goals and represent investments that definitely provide business value*". The knowledge assets of a company "*allow the deployment or improvement of its processes, and their performance determines how well the processes work and projects are executed*" (P.M.I., 2013a; Software Engineering Institute, 2010)

The strategic need to manage knowledge assets, and more specifically to manage how they are stored or reused, has previously been presented in the relevant literature (Aurum, Daneshgar, & Ward, 2008; Buco, Jamjoom, Parsons, & Schorno, 2010; Caralli, Allen, Curtis, White, & Young, 2016; García, Amescua, Sánchez, & Bermón, 2011; Heredia, Garcia-Guzman, Amescua, & Sanchez-Segura, 2013; Sanchez-Segura, Dugarte-Peña, & Medina-Dominguez, 2016; Software Engineering Institute, 2010b), however the industry has not properly advanced in regard to their practical implementation aiming to identify and classify what are the knowledge assets or how they may be measured so that such information may boost the business value of a company (Demartini & Paoloni, 2013). In spite of that, this need was explicitly recognized by (Dutta, 2007) in 2007.

Unfolding knowledge assets is of critical importance for industries with intensive and dynamic knowledge, such as the software and information technology fields, with knowledge being recognized as "a key intangible process asset" (Kaltio, 2001; Leon, 2011; OECD, 2011; Pagnozzi, Davis, Raco, & Ma, 2018; M.-I. Sanchez-Segura, Medina-Dominguez, & Ruiz-Robles, 2016; Verdun, Paguas, & Alberti, 2011). At this point, it is important to differentiate between software assets management (SAM) and what is of interest in this thesis: the knowledge assets identification and classification, which is clearly a bigger and softer approach. For such specific field (SAM), some of the specific developed applications include: Microsoft SAM®, Flexera Software®, Spiceworks IT Desktop®, InvGate Assets®, etc. However, it is a fact that such applications have their focus on software assets understanding them as "*programs running on the organization's systems, which represent only a few of the intangible assets possibly influencing an IT organization's intellectual capital*"(M.-I. Sanchez-Segura, Medina-Dominguez, & Ruiz-Robles, 2016). One reflection from this is that the kind of assets of our interest, the knowledge assets, may include a wider set of elements (which may be more complex as well), justifying our wider and systemic approach presented in chapter 3.

Although in the literature several classifications have been proposed, some are specifically focused on any of the branches of intellectual capital (Blackler, 1995; Hall, 1993; Housel & Nelson, 2005; Kogut & Zander, 1992; Marr, 2008; Nonaka, Toyama, & Konno, 2000; T. Stewart & Ruckdeschel, 1998), while others adopt a different type of classification of intangible assets characterized for being more dynamic throughout their life cycle (Li & Tsai, 2009; Li, Tsai, & Lin, 2010). (Aboody

& Lev, 1998) focuses on the importance that intangible assets have in the software and IT field, like the example assessing the impact of intangible assets in Egyptian software companies (Seleim, Ashour, & Bontis, 2007) and the one that specifically highlights intangible assets governance in the IT industry and how they might be classified taking into consideration the culture (Verdun, Paguas, & Alberti, 2011).

Even though any of the previously mentioned approaches could be used, the problem is that most of them have not yet been deployed in real contexts, which conducts to many doubts about its effectiveness in the knowledge economy. Among other objectives, this thesis seeks to methodologically identify, assess and measure knowledge assets by classifying them and using technological artefacts that allows its practical monitoring and audit, especially useful in the information technology (IT) based transformation industry.

The IT industry is knowledge-based, and as such is extremely sensitive to the value of its knowledge assets, but not much has been made on increasing the awareness of their value. Understanding such knowledge assets will make the organization capable to improve its management and increase its intellectual capital, which means that companies under this focus will take a first step in the direction of making better and well informed strategic decisions.

Although there are many intellectual capital models, there is a handicap in their related process of identification and classification of intangible assets, becoming more likely to theoretical approaches. According to (Li, Tsai, & Lin, 2010), the perceptions of the intangible assets of worldwide organizations vary according to the related context (Axtle-Ortiz, 2013), which is why we argue that knowledge assets must be specifically identified and classified for every company in a customized but practical way. Not doing so leaves organizations the risks of not benefiting enough from the improvement of processes based on their knowledge or the inability to see the full picture regarding all the assets that could help to implement and improve the company's processes, and so meet their business goals.

2.5. The value of intangible assets in IT related context

The most widely known approach for managing the intangible side of technological organizations is given by the advances of the Project Management Institute and its special chapter dedicated to software, as well as the formal body of knowledge on the theme, in which most of the aspects regarding processes, process knowledge, ontologies and process management is considered (Bourque & Fairley, 2014; P.M.I., 2013b). However, a relatively new field has emerged on knowledge focused on research into the value of intangible assets in technology companies. The starting point was the development of a taxonomy for identifying organizational intangible process assets with experimentation at two small software services enterprises (Ruiz-Robles, 2017; Sanchez-Segura, Medina-Dominguez, & Ruiz-Robles, 2016). This research evolved into a methodology for helping stakeholders assess an organization based on the state of health of its organizational process assets. For this purpose, measurement indicators and a process asset characterization based on asset impact and quality in regard to business goals were proposed (Sanchez-Segura, Ruiz-Robles, Medina-Dominguez, et al., 2017). Also, some agent-based and system dynamics simulations were carried out to implement this methodological characterization (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, & García de Jesús, 2018; Sanchez-Segura, Dugarte-Peña, & Medina-Dominguez, 2018). To help evolve the process assets, other research mentioned in section 2.3 proposed a biomimetic design of process assets based on lessons learned from natural intelligence and survivability, borrowing aspects from swarm intelligence (intelligence of ant and honey-bee colonies) and identifying the desired features that both a *colony* of process assets and individual process assets should have in order to behave intelligently and resiliently. This was represented as a simulation modelling application in (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2017).

This thesis takes this field forward, since it evolves existing research by adopting the first decision-making model based on knowledge asset characterization using simulation, thus leading to a paradigm shift. We are now evolving the simulation model for use by software engineers as a decision-making tool for clients from any field in which technological solutions are required. The technological solution is based on the knowledge assets at the disposal of the client company in order to achieve its business goal.

Other related work has explicitly considered three aspects related with the focus under which this thesis has been developed, and this was previously published by the research team in (Sanchez-Segura, Ruiz-Robles, Medina-Dominguez, et al., 2017). These aspects are:

- The task of identification and classification of knowledge assets,
- The linkage of knowledge assets with business goals.
- Knowledge assets assessment.

Several approaches for knowledge assets identification and classification have been previously proposed in the literature (Aboody and Lev, 1998; Blackler, 1995; Hall, 1993; Housel and Nelson, 2005; Kogut and Zander, 1992; Li and Tsai, 2009; Li et al., 2010; Marr, 2008; Nonaka et al., 2000; Seleim et al., 2007; Stewart and Ruckdeschel, 1998; Verdun et al., 2011). They face the problem of classifying knowledge assets from different perspectives that directly fit the needs that IT companies of the 21st century are having. Despite that, not many of the previous approaches have been tested in real cases and many of them rely on mere theoretical proposals. An initial attempt to tackle this was the process asset identification and classification method proposed by (Sanchez-Segura et al., 2016), which is based on the intellectual capital models of (Edvinsson, 1997; Marr, 2008; Stewart and Ruckdeschel, 1998), that have been adapted and applied to the reality of information technology companies, proving to be valuable for identifying and classifying intangible knowledge assets in IT companies.

In regard to the connection between knowledge assets and the business goals of a company, other traditional models for implementing and using specific processes make special emphasis on the need to verify what the knowledge assets of a company are and how to assess or evaluate them to measure their quality (April and Laporte, 2009; Baddoo, 2003; Scacchi, 2002; Software Engineering Institute, 2010; von Wangenheim et al., 2010). Importantly, in the IT industry there have been suggestions about the importance of correctly linking the processes, the related assets, and the improvement of such aspects for strategic or business goals achievement (Basili, Caldiera, & Rombach, 1994; Basili, Lindvall, Regardie, et al., 2010; García Guzmán, Mitre, Amescua, & Velasco, 2010; Plösch, Pomberger, & Stallinger, 2011; Sun & Liu, 2010). Specifically, some of the mentioned advances proposed:

- The proposal of the deployment of corporate strategies, the lower division strategies and also the functional or operative strategies. Functional strategies specifically refer to areas like those in charge of software development or production. Their proposal focuses on the alignment between the strategic goals and the software development for which a breaking down of strategic goals into division goals, and iteratively of division goals into functional or operative goals of software development areas (Plösch et al., 2011).

- In the context of process improvement, there is a suggestion that any of these models must consider the requirements fostering process improvement, explicitly including business or strategic goals. These proposals have used the quality function deployment (QFD) technique (Akao and Mazur, 2003) to connect the requirements of a company to the CMMI areas and activities (Software Engineering Institute, 2010), opening for companies the possibility to understand how CMMI contributes to its business goals achievement (Sun and Liu, 2010).

- Another proposal of this research group is the balanced objective-quantifiers methodology proposed by (García Guzmán et al., 2010), in which they propose a methodology for the design and implementation of a strategy to the measurement and management of aspects like the competitiveness of software engineering companies through the use of specific indicators that must be aligned with strategic goals in a balanced scorecard (Kaplan and Norton, 1993).

The previous advances have in common their effort in facing the problem of how professionals can define a strategy of improvement or a digital solution correctly aligned with a company's business goals. However, there are still insufficient efforts in focusing on the effect of knowledge assets as levers in an organization functioning and its related strategy of improvement from a digital transformation perspective.

Another work proposes an enhanced way to identify the value of intangible assets in software companies (Qian, 2010), nonetheless, this proposal is clearly made under the perspective of an accounting approach which leads to an insufficient explanation on how the value should be determined, which would be tackled from an engineering viewpoint. Other work, valuates and relates intangible assets to company product innovation (Martín de Castro, Delgado-verde, Amores-Salvadó, et al., 2013), however such advance determines asset quality generally with no clear link to strategic goals. One more work, (Saunders and Brynjolfsson, 2015), face the problem of understanding the value of intangibles by relating the company market value and the value related to the company's IT infrastructure, leaving no advance on the direction of connecting intangible assets with the strategy.

As stated in the introduction chapter, software and technology are important factors for value creation in modern organization.

The work of (Ghobakhloo, Azar, & Tang, 2019) focuses on how the implementation of an Enterprise Resource Planning (ERP) contributes to business value creation in terms of higher organizational performance from higher ERP spending. Although interesting from the perspective of finance, it does not consider the value that organizational knowledge (know-how) would provide, since the ERP is associated to standard, although generic, software implementations existing in market.

Unclearly the mentioned advances had simultaneously the purposes of classifying the knowledge assets, establishing links between knowledge assets and organizational business goals, and characterizing such knowledge assets. As stated by (Sanchez-Segura, Ruiz-Robles, Medina-Dominguez, et al., 2017) "*although the value of knowledge assets is evident from their proposals, it is impossible to make strategic decisions without such a linkage* [with business goals]".

In regard to the three mentioned interconnected aspects, the most suitable approach is the one presented in this thesis, which advances have been published in (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2018; Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2017; Sanchez-Segura, Medina-Dominguez, & Ruiz-Robles, 2016; Sanchez-Segura, Ruiz-Robles, Medina-Dominguez, et al., 2017). Besides that, we have not found any all-round methodologies addressing all the three aspects mentioned: the task of identification and classification of knowledge assets, the linkage of knowledge assets with business goals, and the knowledge assets explicit assessment.

2.6. Digital maturity of organizations

In modern IT management, a common term used to refer to organizations capability to survive from the use of technology and disrupting is that of "digital maturity" (also "maturity" in studies where the digital context is assumed). In a recent study, (Kane, Palmer, Phillips, Kiron, & Buckley, 2019) use a three stages scale for characterizing digital maturity: early, developing an maturing, and declare clear differences between those companies approaching maturity and those that are not, which may be explained by the innovation capacity that the first have.

Another recent work is presented by (Plekhanov & Netland, 2019) presents a conceptual proposal for representing the digitalization stages of a company, from the fact that the increasing volume of data and the availability of digital technologies is not being properly used. The stages (or digitalization states) are presented as analogue, coordinated transition, digitally fragmented and full-fledged digital enterprise; which are directly dependent on organizational aspects such as the size and type of the company, the technology push or the market pull that characterizes it. Important for our research was the authors declaration: "*A transition to more advanced stages of digitalisation is mainly driven by organisational reforms that unleash a full potential of digital technologies and align them with business needs, in-house capabilities and external environment*". Although real and very interesting, no direct mention or focus is done regarding the organizational knowledge (or knowhow) and how it might influence the digital maturity of a company or the achievement of a digitization goal, but the focus is on diagnosing the digitization state of a company according to how intense is the use of technologies and how coordinated the digitalization initiatives are. See this typology in Figure 2.1.

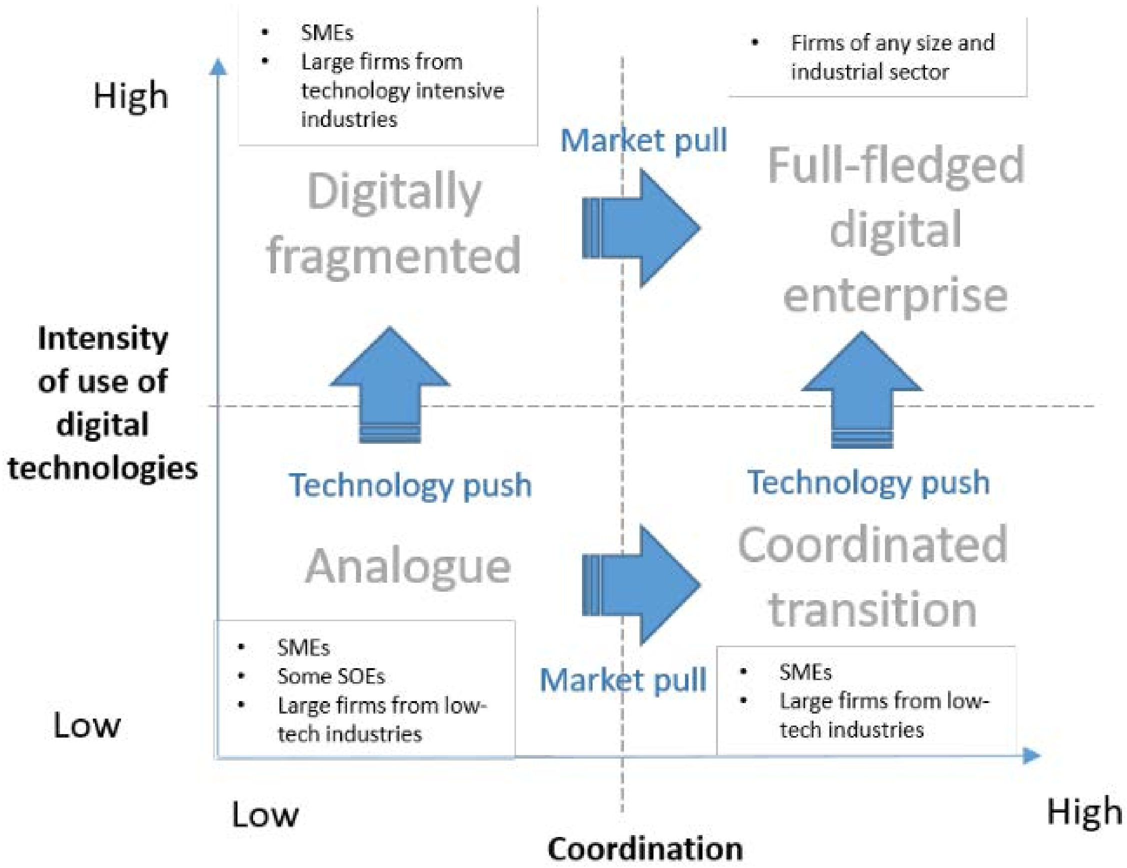

Figure 2.1 A topology of digitalization of firms [Taken from (Plekhanov & Netland, 2019)**].**

From the perspective of this thesis research, it is our interest to point towards leveraging the digital maturity of organizations from the fact that an appropriate knowledge use is essential to empower business, end the alignment between knowledge assets and the business goal (closely related to digital maturity achievement) is determinant on giving companies the capability to sustain from they have (the knowhow) instead of focusing on merely investing in technologies. However, it is not the main focus of this research to establish maturity levels or states, but a continuous digitalization improvement characterized by its capacity of using and exploiting organizational knowledge to improve general performance, i.e., the digitalization strategy we want to implement MUST be aligned with the organizational knowhow, so that the implementation of a digitalization strategy is viable not only by the features of the technological tools but for how people in the organization is able to use it and incorporate it in daily processes, which will be reflected in all performance measurements.

2.7. Decision making in software services contexts

Software engineering practice is mainly based on guidelines from the Software Engineering Body of Knowledge(SWEBOK) and Project Management (PMBOK) Bodies of Knowledge (Bourque & Fairley, 2014; P.M.I., 2013b). In this thesis, we pay special attention to the sections of SWEBOK and PMBOK regarding the decision-making process with respect to the services that engineers offer their clients. However, decision making is not a major focus of software engineering research (Burge, Carroll, McCall, & Mistrik, 2008).

SWEBOK is the default reference with respect to the featured topics: software requirements, design, construction, testing, maintenance, configuration management, management, engineering process, models and methods, quality, professional practice, economics, computing foundations, mathematical foundations and engineering foundations. The software economics section of this body of knowledge explicitly states that it "covers the foundations, key terminology, basic concepts, and common practices of software engineering economics to indicate how decision-making in software engineering includes, or should include, a business perspective". However, most of the research refers to value-based decisions from the viewpoint of software process costs, effort, and estimation, and none of the papers delve deeply into a systemic understanding of the complexity of decision making. Decisions depend on human beings and must be addressed as a complex problem (Sanchez-Segura, Jordan, Medina-Dominguez, & Dugarte-Peña, 2016).

From the perspective of software engineering rationale, Burge et al. (Burge, Carroll, McCall, et al., 2008) focused on comprehending the decisions that software engineers are involved in making as part of software engineering practice. They address naturalistic decision making by humans (and software engineers) and how they can learn from considering the rationale as an output resource in human decision making. However, an important point that they make is that the rationale has tended to be merely documented and not used effectively as a decision-making aid.

From the perspective of value-based software engineering (VBSE), (Mendes, Rodriguez, Freitas, Baker, & Atoui, 2018) proposed the VALUE framework, which accounts for a mixed-methods approach aiming to elicitate key stakeholders' knowledge, and to manage the knowledge through a web application employed to support decision-making. Regarding the technique used to measure and estimate the value of knowledge, the researchers used the Expert-based Knowledge Engineering of Bayesian Network process (EKEBN) and the weighted sum algorithm (WSA). Although this work bases on the traditional framework of knowledge creation of (Nonaka, Toyama, & Konno, 2000), their main interest is on exploiting the identified value factors to support general decision making through giving a value to decisions , this thesis goes beyond that point by focusing on the alignment the knowledge assets must have with the strategic or business goals, which are who essentially define the mission and mission of a company. The pilot experience of this work showed promising results, and the authors suggest the evolution of their measurement and conceptual models, for which it may be said that this thesis complements such work by incorporating the systemic domain-independent approach, with the mathematical and technological artefacts to help the IT/SW professional to go beyond eliciting a client's knowledge and demonstrating through simulations the effect of decisions, in which the value is included and graphically represented.

Another work has focused on the characteristics of digital solution alternatives (electronic medical records software packages) and their valuation based on multi-criteria decision-making (Zaidan, Zaidan, Al-Haiqi, et al., 2015). As stated, the focus in this work is in the alternatives themselves and in a specific domain (health), whilst no consideration is given to how these alternatives fit the companies' business or strategic goals, neither considering the knowhow of the companies. Although very interesting for the decision-making field, this work does not center the focus on the strategic effect that the alternatives may have for business, which is one of the issues addressed by this thesis work.

Also using multicriteria decision-making, (Wang, Huang, & Wang, 2018) propose an approach for selecting among web services based on their reliability, and defining the problem of selection as an optimization of non-functional requirements problem. The interesting results regard the higher precision on the solutions performance, however these results are partial and did not consider the organizational knowledge nor the strategic and business goals.

In this thesis, we focus on taking advantage of the alignment between knowledge and business goals to make the decision about digitization strategies in organizations. Specifically, we modeled the process of decision so that the expensive task of experimentation is made through a simulated environment, in which both exploration (trying the alternative), valuation (measuring the outcome), and selection of the solution is represented. Additionally, this work integrates the process of learning that guarantees that good decisions tend to repeat and bad decisions tend to be unused.

2.8. Learning from experience: practical approaches

Learning from experience can be understood as an accumulation process of experiences with an associated feedback loop in which a valuation of each experience is performed, so that by observing previous experiences the future experiences are conditioned. One important thing to mention is that such learning by experiencing is present in everyone's natural behavior. According to experiential learning theory, "*we learn through a learning cycle. Our experience serves a basis for reflection. From reflections, we develop ideas about the world. We then test the ideas to see if they are true, and finally we have a new experience. The learning cycle does not necessarily begin with experience. For example, we may have an idea that we want to test, and so on*" (Moesgaard, 2014).

In this thesis, it is of interest to identify practical works that have modeled the process of learning from experience, whether it has been for developing the theory itself or aiming to represent and simulate specific learning processes in general or specific contexts. Of specific interest for this research were the Instance-based learning theory (IBLT), a complete theory representing the process of learning as a dynamic interaction of instances of memory that store information about the experiences; and the Management Flight Simulators (MFS), an approach using simulators to help managers to learn by experiencing with simulated management contexts.

2.8.1. Works on applications of the IBLT

Existing research has presented implementations of the instance-based learning theory (IBLT) (Gonzalez, 2017; Gonzalez & Dutt, 2011; Gonzalez, Lerch, & Lebiere, 2003) to improve explicitness, transparency and preciseness (Gonzalez, 2017; Gonzalez, Lerch, & Lebiere, 2003). Cog-IBLT was the first computational model based on IBLT. It focused on demonstrating diverse mechanisms, as well as the learning process, in a resource allocation problem (Gonzalez, Lerch, & Lebiere, 2003). This paper drew on the wider experimental cognitive architecture ACT-R (Anderson & Lebiere, 1998) to model the following concepts: activation (defined as a value that defines how potentially useful an instance is based on memory, experience and its relevance to the current context and environmental constraints); partial matching (which is the representation of the similarity between instances), and retrieval probability (defined as the probability of retrieving an instance as a function of the above activation and partial matching concepts). Likewise, (Lebiere, 1998) presented the concept of blending (an aggregate of the values of multiple instances available in memory).

Once IBLT had been established as a formal theory of cognition, a number of models were created for several instance-based problems, focusing on highly complex dynamic tasks (i.e. training, the effect of fatigue, etc.) (Gonzalez, Ben-Asher, Martin, & Dutt, 2015; Gonzalez, Best, Healy, Kole, & Bourne, 2011; Gonzalez & Dutt, 2010), tasks related to skill acquisition through simple stimulus-response practice, and repeated binary-choice tasks (Lejarraga, Dutt, & Gonzalez, 2012). Although a descendent of ACT-R (Lebiere, 1998), the IBL model is representative mainly of ACT-R declarative memory and was successfully tested in modelling competitions (Erev, Ert, Roth, et al., 2010; Gonzalez, Dutt, & Lebiere, 2013; Gonzalez, Dutt, & Lejarraga, 2011).

More recent implementations and uses of the IBL model and experience-based decisions have primarily addressed distributed domains, ranging from decision-making models in energy-relevant interaction with buildings (J. von Grabe & González, 2016; Jörn von Grabe, 2017), behavioral sciences studies on the effect of switch rate or optional stopping on how people decide between options based on expected rewards (Soo & Rottman, 2018), or implementations considering human decision making in autonomous vehicles (Govindarajan & Bajcsy, 2017).

This thesis integrates an application of the IBL-model since it was appropriate for representing the difficult task of exploring alternatives and comparing them based in their outcomes. Additionally, the whole learning process of the IBL-model was used since it represents the way that cognitive memory works, providing this thesis with an approach for representing smart decision making, as will be shown in chapter 3.

2.8.2. Works on the use of MFS

Management Flight Simulators (MFS) are simulators that provide managers simulated environments intended to help them to learn from experiencing with such environments. The name comes from the initial inspiring system for these: the simulators used to train pilots before they can securely flight planes by themselves in an autonomous way.

MFS's can be created from scratch, so that they can be adjusted to diverse contexts in which managers, the initial target audience, can operate. As stated by (Daniel, 2018), the MFS's are systemic tools "*particularly useful for getting away from the details of day-to-day operations and focusing on the long-term dynamics of managerial decisions*".

The general process of design of an MFS consists of four sequential stages: Select Issue Focus, Conceptual Model, Computer Model, Flight Simulator (See Figure 2.2).

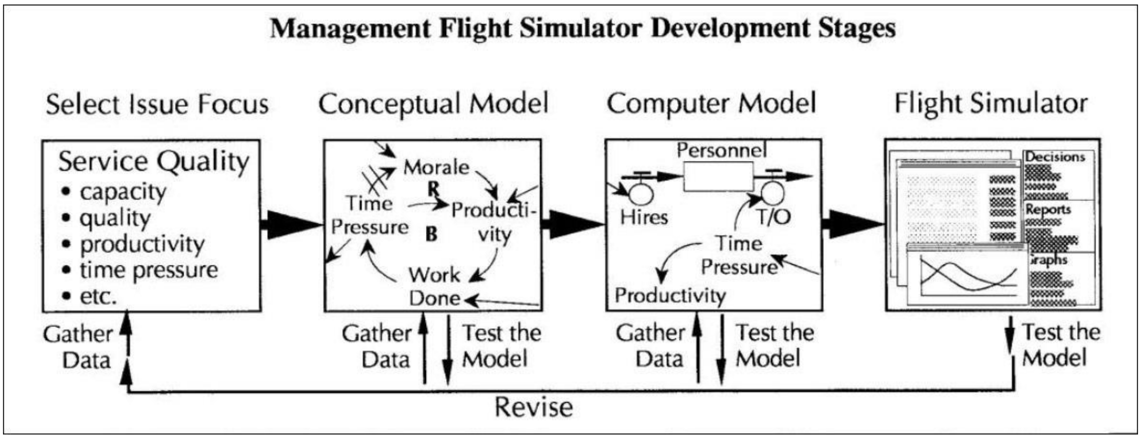

Figure 2.2 Management Flight Simulators Development Stages [taken from (Daniel, 2018)].

As it may be seen, from a strategy perspective the use of MFS is very attractive and powerful, since it considers information usually managed at a strategic level such as: productivity, service quality, relations among work done, capacities, time constraints or cultural settings. This information is used to build models of the real organization and explore their dynamics to teach managers how these operate by manipulating the model.

Although very interesting and with proved effectiveness, the most attractive future for this research was the exploitation of the graphical power that the models have for making strategic (although simulated) decisions. This thesis similarly will exploit graphical particularities of the developed artefacts to support decision making and to represent the strategic context of analyzing the state of the knowledge of a company.

2.9. Relevancy of managerial cybernetics in modern organizations

Regarding the use of cybernetics in modern organizations, a recent diagnostic is presented by (Vahidi, Aliahmadi, & Teimoury, 2019), who reviewed the main recent journals, authors and research trends, focusing on applications in the field of IT in large-scale organizations, finding the VSM as the more attractive cybernetics operational construct at the current times. Such exhaustive work suggests that although introduced as far as in 1946, management cybernetics has evolved enough to remain attractive in current times, mainly for the need to sustain of organizations, which may be addressed by the Stafford Beer's viable-system-model, the concept of control, the human-machine interaction and the feedback loop beneficial properties of all these interrelated concepts. This optimistic affirmation contrast with the also extensive and more critic state of the art presented by (Werner, 2017), where with no focus on a specific domain, the main principles of cybernetics are presented through a series of contributions.

As stated by (Werner, 2017), cybernetics has been used in western academy in a reductionist way according to the discipline in which it fits. In most cases, engineers have considered only the feedback property, humanities have focused on its his historical importance by the time computers were created. On the other hand, European academics have kept it alive as clustered researches, but with an always proven efficiency and efficacy. This work is an interesting asset that brings back the cybernetic concepts to recent research about both theoretical and applied managerial problem solving within the context of the current era, specifically within what systems scientist have called the evolution of the era of the Anthropocene.

In all cases, the main contributions to management cybernetics are clear. It stands out that the cornerstone of this field is given by (Ashby, 1956; Beer, 1964, 1972, 1984, 1985), with important inputs given by (Espejo, 2003; Espejo & Gill, 1997; Espejo & Reyes, 2011; Espejo, Schuhmann, Schwaninger, & Bilello, 1996; Perez Rios, 2010; Pérez Rios, 2008; Schwaninger, 2009).

Although being of great importance, the contributions of cybernetics have been framed in domains as general governance, public policy, public administration reorganization, organizations theory, management and planning. Explicitly, (Vahidi, Aliahmadi, & Teimoury, 2019) affirms that cybernetics has vast implications for practice in the fields of:

- Information Technology.
- Policy-Making.
- Production.
- Social Issues.
- Organizational Architecture.
- Knowledge Management.
- Software Development.
- Business Processes.
- Project Management.

Since this thesis is relevant to Knowledge Management, Software Engineering, Information Technology, Business Processes and Project Management, we have reviewed the cybernetics contributions compendiums and taken some relevant concepts to the epistemological principles guiding this research: mainly the contribution of the CATWOE construct and the incorporation of feedback and continuous environment-aware improvement, which is considered within all the methodological framework of the proposal of chapter 3. The incorporation of such cybernetics lessons is justified in alignment with the affirmation that managerial cybernetics (such as the VSM) are "*not just the substance of philosophical debate nor a* *simple management tool, but a coherent means for organizing thought and action*" (Espejo & Harnden, 1990), which is one of the goals of this research but aimed at organizing thought and action regarding organizational knowledge and its use for organizational improvement from a technological view.

2.10. Summary of reviewed works

Annex I contains a table listing the reviewed works and relating such works with the specific aspect of interest for this research. The specific aspects that have been considered are:

- Systems Thinking.
- Cybernetics
- Simulation
- SW/IT Profession
- Dynamic Decision Making
- Knowledge Management
- Management
- Smart Approaches
- Digital Maturity
- Business value creation
- Intellectual Capital

Considering the holistic approach of these research, the more aspect related to a work, the more relevant to this work it will be. As expected, no works correlated with all of the aspects were found, however, it is clearly identifiable that some works are more relevant than others.

3. The SIPAC Framework: A systemic methodological proposal

Considering the important role that IT/SW professionals [1] have on current organizations functioning and dynamics; and considering also the importance of the need they have to design innovative solutions for effectively taking advantage of intrinsic organizational knowledge (i.e. the knowhow), this thesis presents the SIPAC-Framework (Systemic Intangible Process Assets Characterization Framework), a methodological framework that comprises three main structural layers, which as a whole represent the general guide for these professionals to provide their clients the specialized service of:

- Analyzing their organizational state of health from the perspective of their knowledge assets.
- Identifying, analyzing and characterizing their knowledge assets regarding their quality and the impact these have on strategic goals achievement.
- Simulating possible scenarios of the impact that strategic technology-based decision-making have on these assets and so in the organizational goal achievement.

In the first layer, the methodological guide of the SIPAC-Framework is presented, which constitutes a general roadmap inspired on Peter Checkland's Soft Systems Methodology (SSM) (P. Checkland, 1993, 2000), with certain variations that make of it something more like a methodological matrix of engineered solutions that although soft in its application form, hard in the sense of being conductive to the

[1] Those who will directly use the methodological proposal of this thesis

generation of appropriate technological solutions able to unfold an organization knowledge, i.e. to make knowledge clear and explicit to the main stakeholders, which serves as basis for enhancing the organizations' performance from the perspective of the impact that knowledge in general, and specifically that knowledge assets have on the organizational business goal achievement.

In the second layer, the SIPAC-Framework presents a set of abstract models of structures needed to correctly deploy this methodological framework. Specifically, this layer presents:

- A model of valuation and characterization of knowledge assets based on their quality and the impact they have on organizational goals achievement.
- A model of dynamic decision making for representing the problem the SIPAC-framework's digital solution, which represent the decision that strategist make to improve their organization performance from the basis of the implementation of digital solutions. Given that this expensive decision cannot easily be "tested" due to the high cost that involves, this model tackles this problem using a model of these decisions.

At the third layer, this framework comprehends the use of a set of artifacts designed to support the general deployment of the methodology mentioned in the first layer and the practical implementation of the abstract models presented in the second layer. In detail, this third layer comprehends the use of the following artifacts:

- A spreadsheet-based tool to collect specific information from the client company, with the aim to filter and prepare the data needed to proceed with the general methodological framework. Importantly, the data collected is related to the general objectives of the company, the organizational processes involved in the achievement of such strategic goals, the business requirements, the knowledge assets the company has that may be affecting these processes, and the definition of indicators of such assets, as well as related indicators.
- A web application to manage the collected information of companies in a private database. Such application allows the software engineer and IT professional to appropriately store and retrieve information of companies, to generate reports, to show analysis and export specific information in specific

formats to be used in other analysis and studies. Importantly, this tool allows the exportation of information of a company in csv format so that the simulation model presented next can read it.

- An agents-based simulation model with the following main functionalities:
  - The importation and load of an organization or company's information.
  - The load of a new case, step by step, in case the information is not available in the csv format.
  - The visual representation of the valuation and characterization of an organization's knowledge assets based on the real information that has been previously collected from a company. This characterization is shown through *agents* representative of knowledge assets moving or relocating in areas that represent the possible characterization states presented in layer two, meaning their "state of health", depending on how well their quality or impact is in regard to the general goal.
  - The dynamic manipulation of ad-hoc variables directly determining the characterization of knowledge assets, such as the quality and impact thresholds that a company can establish.
  - The visual representation of the instance-based learning model presented in layer two, representing the process of dynamic decision making regarding the implementation or not of the digital solution that the SIPAC-framework proposes. This module illustrates the effect that the SIPAC-Framework's suggested solution may have on an organizational knowledge asset and how these will be affected and recharacterized, from experiencing with the decisions made.

In addition, we give general guidelines to take advantage of this framework to improve real decision making in regard to organizational improvement from the perspective of the IT/SW professional. To do so, we illustrate how to exploit the information that the three previous layers of the solution provide.

In the following lines, all the previously mentioned parts are presented as a whole methodological framework to be followed by an IT/SW professional in the role of providing companies the services of:

- Knowledge assets identification, measurement and monitoring.

- Knowledge addressed technological solution proposal.
- Technological solutions effect prediction and demonstration from a simulated environment.

3.1. Methodological layer: The SIPAC Methodological framework

From this point and on, several stages constituent of the methodological approach will be described. Peter Checkland proposed a seven-stages methodology (the Soft Systems Methodology (P. Checkland, 1993, 2000)) to tackle complex problems involving several elements and connections. According to Checkland, these problematic situations require a soft approach that instead of framing the complex situation in a one and only one exclusive-perspective, allows the identification of different perspectives and several complex interactions among these perspective's elements. The purpose of this original methodology is the identification of the Human Activities Systems present in the complex situation and of the related perspectives.

In this work, given that knowledge related issues are wicked problems, it is needed a soft approach, so we have taken some of Checkland's work lessons because they provides us with a more fitted and general panorama of the wicked situation given by the knowledge of a company, which would be a better kick-off point for using technologies and designing solutions to the complex problems that may be identified, whose complexity doesn´t clearly state the human activities systems. Each of the methodological stages defined is involved in the process of helping a company to identify their knowledge and take advantage of it for pursuing a general improvement by implementing the correct digital solution.

Regarding the "place" in which each stage is allocated, some of the stages belong to the "real-world", which means that actions taken on it are directly over the company's functioning and on their real dynamics, i.e. directly in the organizational context. Other stages belong to the "Systems and Design Thinking world", which means that the stages are part of the engineering work in which both actions to interpret information of the "real world" and actions to generate solutions are taken.

The following diagram of Figure 3.1 shows the general methodology, with clear differentiation of where every stage takes place, and of the sequential logic that in the best case the IT/SW professional must follow. What this mean is that although there is a sequence, the methodology is flexible enough and encourages the IT/SW professional to iterate in stages as needed to guarantee the proper advance to the subsequent stages.

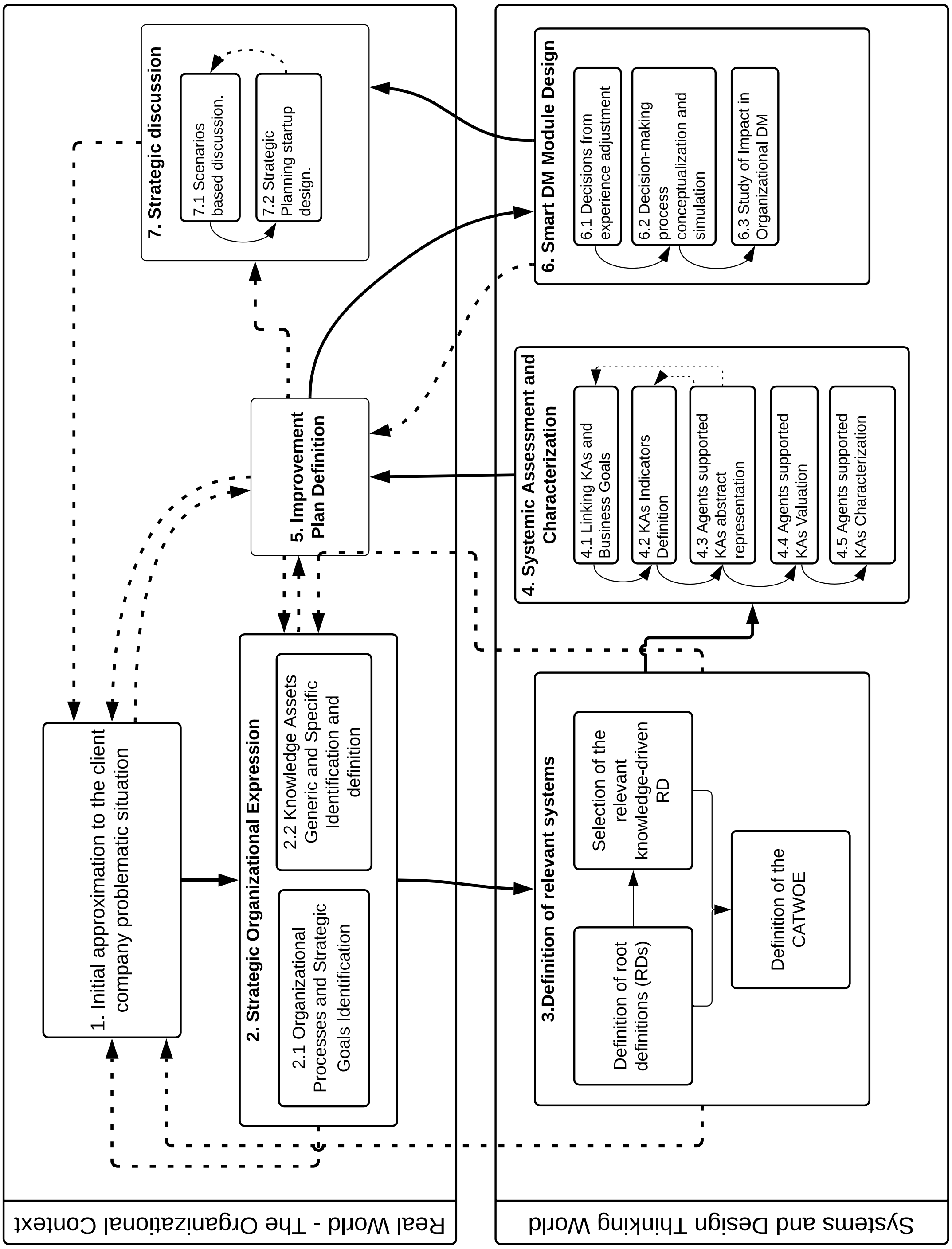

Figure 3.1 The general Strategic Intangible Knowledge Assets Decision Making Framework

3.1.1. Stage 1 – Initial approximation to the client company problematic situation

A company constitutes a mix of people, technology, infrastructure, talent, and knowledge. From the more general concept of complex system, it could be said that a company constitutes a complex system: "a system made up of a large number of parts, that interact in a non-simple way"(Simon & Cilliers, 2005). Having this into account, the stage of organizational immersion comprises the first approach to the systemic intervention to be carried out in which the complex system constituting the company will be approached.

In this initial phase, the IT/SW professional must do an attempt to comprehend in an extensive and unrestricted way the client organization's functioning, its meaning, the elements involved in its operation and the relationships existing between those elements. At this early stage, the role of the IT/SW professional is similar to that of the anthropologist when he wants to understand a particular culture: he needs to situate himself "in" and "between" the reality that surrounds him, and he has to try to bring up all this information into a flexible mean, such as a rich picture or a very descriptive narrative.

The IT/SW professional should put aside, as much as possible, the preconceptions and mental maps that govern his way of thinking and understanding reality. Alternatively, he must situate himself in the reality desired to be understood and begin by observing, without intervening or distorting, the usual and natural way the organization works. The organization must at this stage be the source of information to get a broad description of its operation and general dynamics. Peter Checkland suggests depicting these complex situations through rich pictorial illustrations, in which any situation, relationship, interaction, etc., can be represented with the least possible bias (S. Bell & Morse, 2010; P. Checkland, 2000). However, broad narratives and descriptions as well as complex diagrams can be used if they do not burden the richness of this initial representation.

In general, this first stage can be understood as a set of actions where the complexity of the company must be represented by the IT/SW professional that will lead the knowledge-driven technological audit and solution design. As shown in Figure 3.2, this organizational immersion takes place in the "real world", i.e. in the organizational context that the company represents, and it differentiates of the non-real-world in the fact that real-world problems are those in "*which we find ourselves facing, rather than bounded problems which we ourselves can define and tackle under laboratory conditions*"(Smyth & Checkland, 1976).

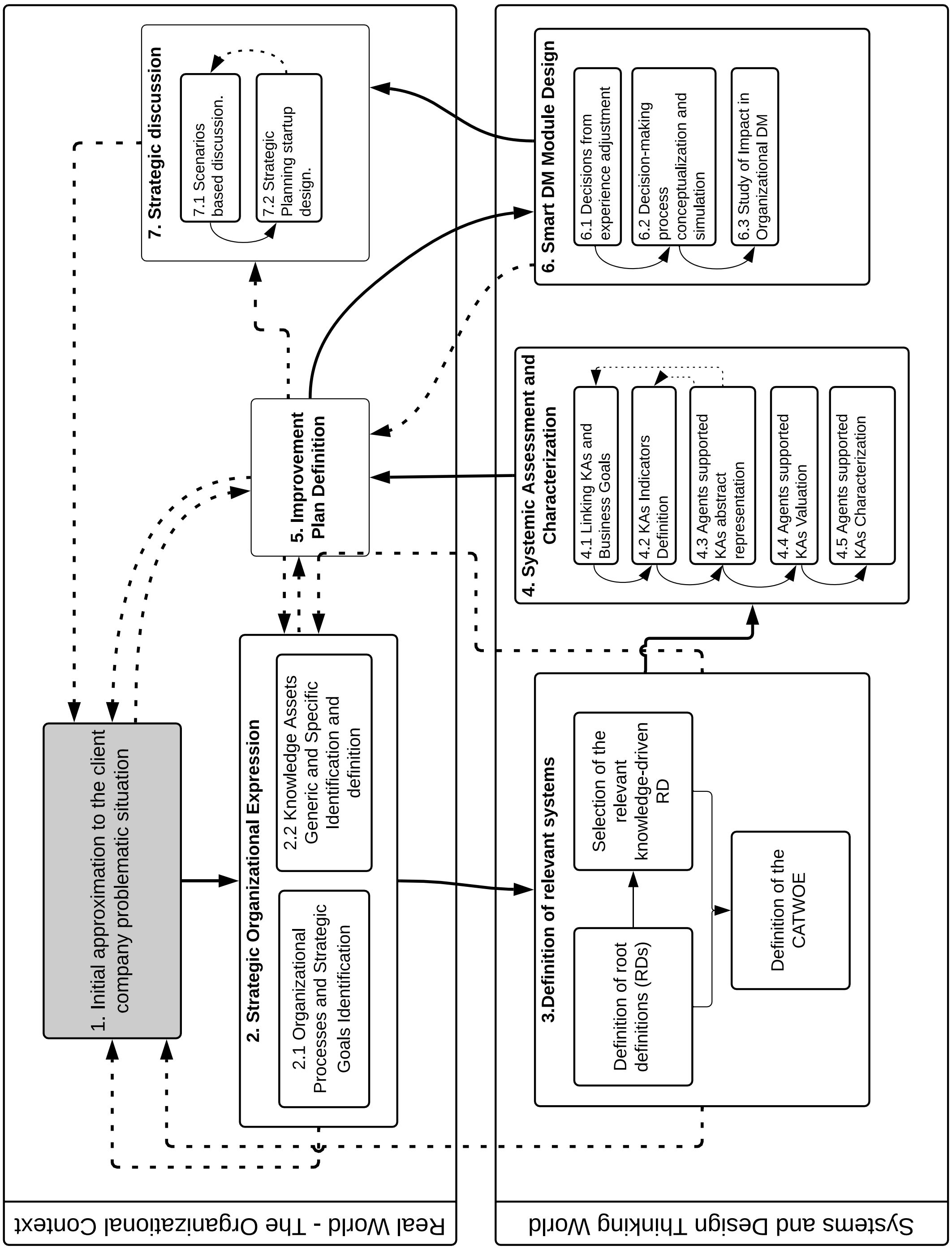

Figure 3.2 Stage 1 - The Initial approximation to the client company problematic situation

correctly capture the "real-world" problem, there is one explicit recommended tool that may be used: the rich picture creation.

Through the process of building a rich picture, the IT/SW professional will have the opportunity to directly interact with the main stakeholders of the client company, who are the main source of information but also of variability, which in this case is not bad but enriching.

The process of a rich picture creation has demonstrated to be productive in several domains, from educational institutions problematic situations (Patel, 1995) to the context of a software development process (G. A. Bell, Cooper, & Qureshi, 2002), just to mention some.

Be a company in need to transform form its basement, be a company wanting to empower from its know-how or a company in need to audit its knowledge for better understanding what is capable or not to do in order to reinvent itself; the rich picture seems to be appropriate for a wide representation of a problematic situation, since it is soft enough to capture several actors (company owners, CEOs, CIOs, directors, strategists, consultants, advisors, etc.), relations (with competitors, with employees, with suppliers, etc.), environmental factors (the market, the burse, social networks effect, etc.) and structures (bureaucratic institutions, laws, government restrictions, etc.), with no preconceived designs or masters to follow, but enabled from a desirable iterative nature that would encourage the IT/SW professional to identify all these elements, their evident relations, and other emerging relations that could affect the problematic situation.

As an outcome of stage 1, there must be a wide rich picture that in the future will guide the IT/SW professional and the company stakeholders to look back and refresh what is their situation, how the problem emerges as complex and what are the elements involved in it, which will be explicitly identified in the following stage.

3.1.2. Stage 2 – Strategic Organizational Expression

In this second stage of the methodology, a first structuring of all the information obtained in the initial immersion should be carried out. Desirably, multiple perspectives on the status of intangible assets of organizations must emerge.

Different people, descriptors and roles can generate different angles of understanding of the functioning of the system relative to intangible knowledge assets, and how their state of health is enhancing or not the performance of the organization. At this stage, the different perspectives at different levels of organization should be identified.

For example, on the one hand, it will be possible to identify the vision of an organization's board about how knowledge and the different ways in which it is structured, is enhancing, increasing or decreasing the organizational performance. On the other hand, one could also identify the perspective of the operating group of the organization, who without having a macro or superior view of the role of intangible assets, can identify that these structures of knowledge, despite being documented and available, could result little practical, so in reality they end up performing their jobs without relying on or making use of the intangible assets that are at their disposal.

The existence of multiple perspectives has been widely studied in systems thinking, specifically for those authors interested in exposing the perspectivism as an alternative (reaction) to the well-known unifying perspective of classic science related to reductionism (Andrade Sosa, Isaac, Espinosa, López-Garay, & Sotaquirá, 2007a).

In the original Soft Systems Methodology(P. Checkland, 1993, 1999), Peter Checkland proposes a general structuring of the situation contained in the rich picture obtained in the previous stage. In our methodology, since the focus is on the identification of the strategic identity and the intangible knowledge assets that may contribute to pursuing it, two fundamental tasks must be specifically done:

- Organizational Processes and Strategic Goals Identification
- Knowledge Assets Identification and definition

As shown in Figure 3.3, the stage 2 and its two related sub-stages are sequential to the stage 1. However, the practice has shown that hardly ever a first attempt clearly derives in a perfect rich picture, for which an iterative switching between these two phases is not only allowed but encouraged, until the organizational goals, processes, and intangible assets are correctly identified and can be considered acceptably representative of the companies.

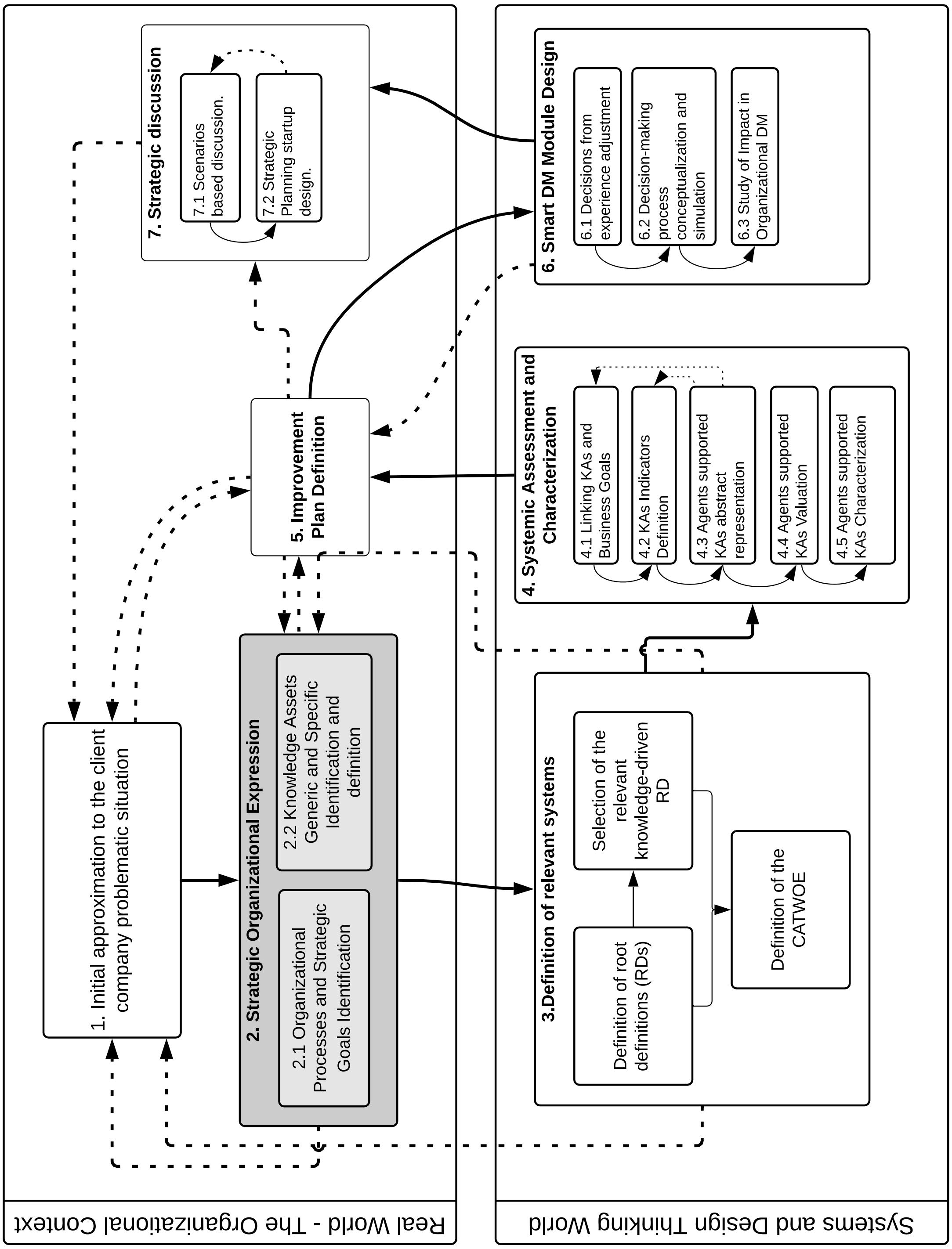

Figure 3.3 Stage 2 - Strategic Organizational Expression

As shown in Figure 3.3, stage 2 takes place in the "real-world" since it comprises a process of continuous validation in which the problematic situation of the rich picture is represented from the perspective of its intangible side, i.e. through the identification and delimitation of strategic goals, processes and intangible knowledge assets.

3.1.2.1. Organizational Processes Identification

In this sub-stage the objective is to identify the organizational processes of the software company, the main objectives it pursues and the priority and weighting of those objectives. To do so, the IT/SW professional must base on the identified identity of the company and extract from an interview with the most representative stakeholder what are the processes conducting the company to perform as it does.

To identify the organizational processes, the IT/SW professional must guide the main stakeholder of the organization to search in totally documented processes already identified and specified in internal whitepapers, reports, balances and other internal documents with relevant information. The IT/SW professional must write a list of the identified processes and their respective description.

In case there are no clear documented processes, or the information given by the organizational stakeholder is insufficient, an alternative is to define them as simple transformations from the information in the rich picture. From the more general concept of process, and for effective use in this stage, there must be identified some inputs, a black-box transformation, and some outputs. (At this moment we should no focus on possible feedbacks but in the more general transformation processes). Figure 3.4 shows an illustration of how a general process may be initially conceived and some specific examples (production, learning, maturity, etc.).

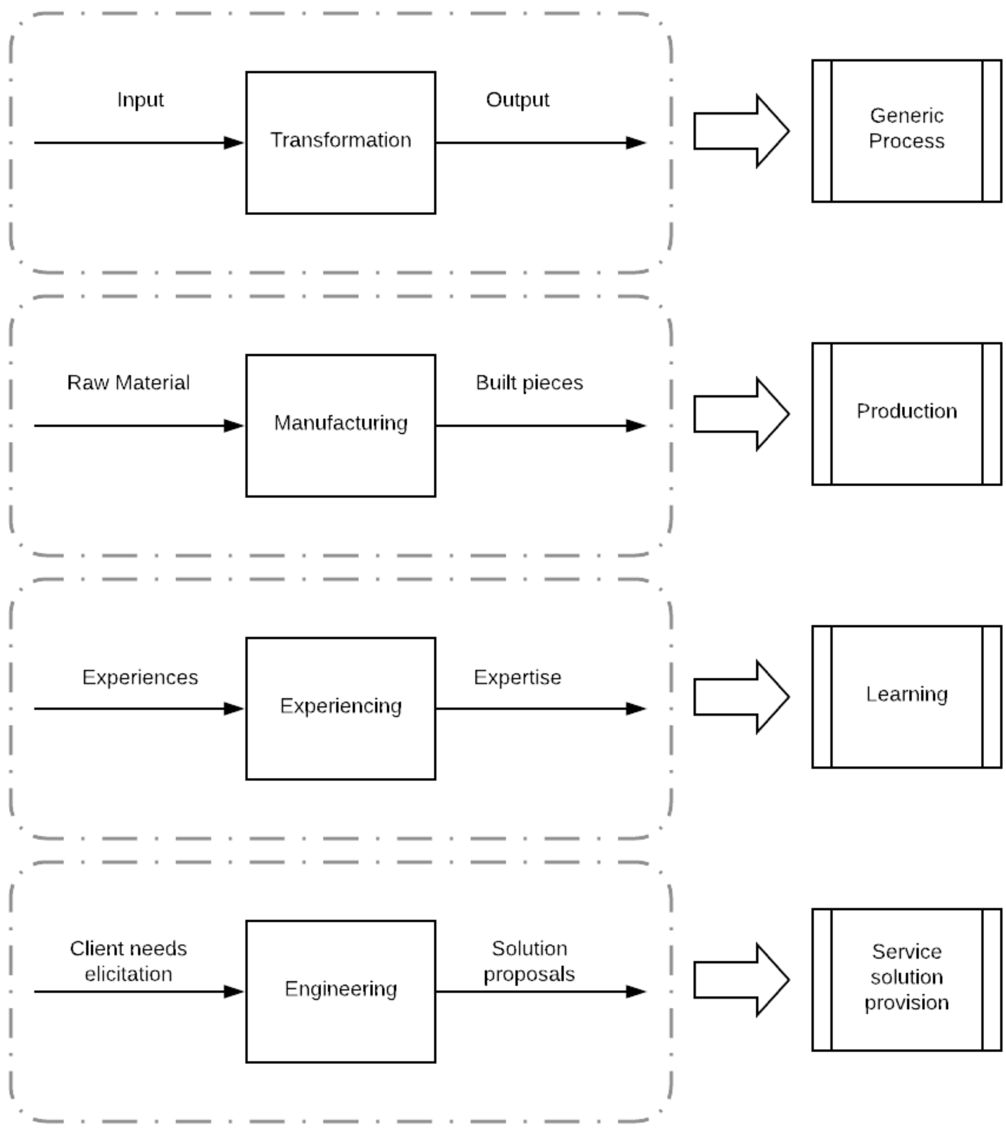

Figure 3.4 Organizational Processes Identification Illustration

3.1.2.2. Knowledge Assets Identification and definition

In this step, the existing knowledge assets of the client company must be identified and classified. The concept of knowledge assets to be used here is wide enough to comprise the "*elements of organizational knowledge that affect and define good or poor organizational operation*"(Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2017), trying to capture the range of perspectives conceptualizing the intangibility of assets in the domains of software (referring process assets), strategic management (referring strategic intangible assets), knowledge management (referring knowledge assets) and intellectual capital studies (referring intangible assets); and the importance that these knowledge assets have for the success of businesses in domains as diverse as technology and software development (Allison & Merali, 2007; Amescua, Bermón, García, & Sánchez-Segura, 2010; Harter, Kemerer, & Society, 2012; Kuhrmann, Konopka, Nellemann, Diebold, & Münch, 2015; Lavallee & Robillard, 2012; Saunders & Brynjolfsson, 2015; Software Engineering Institute, 2010), management and process improvement(García Guzmán, Mitre, Amescua, et al., 2010; Plösch, Pomberger, & Stallinger, 2011; Sun & Liu, 2010), strategic management(Dess, Lumpkin, & Taylor, 2004; Thompson & Martin, 2010), or knowledge management(Alavi & Leidner, 2001; Nonaka, 1994; Zack, 1999).

The procedure of identifying knowledge assets comprises two steps: the general knowledge assets identification and the specific knowledge assets identification.

3.1.2.3. General knowledge assets identification

This first general knowledge assets identification model is a guide to identify intangible assets that may be present in any organization. In accordance to a company's size, some of them may be present whilst others not. Additionally, given that this is a first general identification level, there could be more specific knowledge assets that will be identified in the following subsection, the specific knowledge assets identification.

- GKA1: Productive model / Model of Service Execution
- GKA2: Commercial or customers model
- GKA3: Supply and diversification of services model / Innovation
- GKA4: Model of International Geographic Expansion
- GKA5: Model of HHRR / Professional Development / Principles and Values
- GKA6: Retributive and Property Model
- GKA7: Model of Brand development
- GKA8: Model of Institutional Relations and High-Level Networking / Stakeholders
- GKA9: Model of Organization and Processes
- GKA10: Model of Organizational Strategy / Mission and Vision
- GKA11: Model of Organizational Knowledge Management

Each of these generic knowledge assets may be categorized as Human, Structural or Relational Capital, in accordance to the Intellectual Capital classification of knowledge assets.

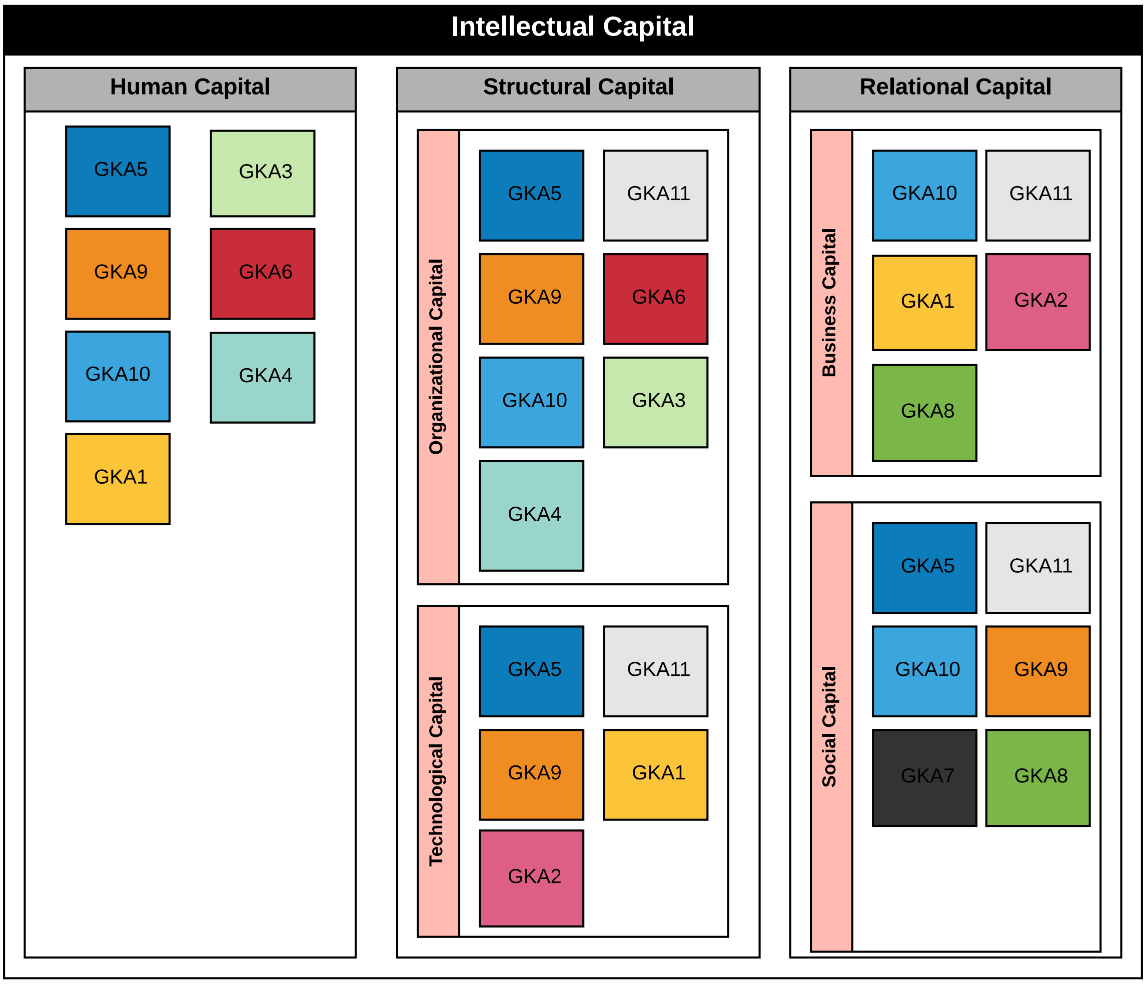

Figure 3.5 Classification of Knowledge Assets according to Intellectual Capital type.

3.1.2.4. Specific knowledge assets identification

This will be done by the use of a mechanism known as "Taxonomy of Process Assets", which was originally proposed by (Sanchez-Segura, Medina-Dominguez, & Ruiz-Robles, 2016). This taxonomy, besides allowing to identify process assets of different types, allows to differentiate between the types of knowledge related to each asset. In the following Table 1, this taxonomy is presented.

Table 1: Process Assets Taxonomy

Process Asset Taxonomy
Description: *This is the taxonomy proposed in* (Sanchez-Segura, Medina-Dominguez, & Ruiz-Robles, 2016)*, which is based on Intellectual Capital and its three differentiated components: Structural, Human and Relational capital.*
Structural assets category: *They are those process assets that belong to the software company and are part of it permanently.*
Knowledge documents (KWD)
These assets represent any kind of knowledge that is found in documents in any format. Examples of these documents are process guides, tutorials, meeting reports, and documented lessons and processes.
Tools (TOO)
These assets represent technological tools, programs, software licenses and any other type of tool that is used to manage or support some process in the accomplishment of tasks and processes of the software company. For example, databases, document repositories, intranets, management systems, project management systems, collaborative wikis, intraorganizational forums, etc. are considered here.
Knowledge management culture (KMC)
In this category the way the software company manages its knowledge. It is considered under this category how knowledge is developed, distributed and used. Examples of assets in this category are learning processes, knowledge reproducibility or processes to stimulate organizational learning and enhance the evolution of staff capabilities.
Human Assets category: *It is the process assets related to the living part of the software company. They are the process assets directly related to and dependent on the human being in the organization. If the company loses people related to active stocks, it also loses those process assets, which is not the case with the structural process assets.*
Knowledge (KNW)
It represents the knowledge that people have about tasks and processes that are carried out in the software company, and with respect to the process assets of the structural and relational categories.
Experience (EXP)
It represents the experience and expertise that people have with respect to the performance of tasks and with respect to the use and interaction with the assets of structural or relational category.
Competences and skills (CAS)
The skills and abilities that people need to carry out their tasks and create or use any of the structural or relational process assets. These activities must, for example, have the capacity of self-learning to adopt a new technology, communication skills that people must transmit information, etc.
Relational assets category: *This category represents the relationships between the organization and any person or organization external to it.*
Relationships with clients and users (CLI)
They are assets that relate formal and informal relationships with customers and users of the software company. Included are, for example, the processes used to communicate with users, or informal meetings held with customers.
Relationships with suppliers (SUP)
They are assets that represent formal and informal relationships with suppliers. They include, for example, processes for requesting services from a provider, informal channels used to improve communication with suppliers, etc.

3.1.3. Stage 3 – Definition of relevant systems

This stage comprises the definition of the "root definitions of relevant systems" that give meaning to the strategic objectives mentioned before. A root definition is initially defined as "*a concise verbal description of a system believed by the analyst to be relevant to the problem situation within which he is working*"(Smyth & Checkland, 1976).

In the context of this work, the specification of the root definitions comprises the formal root definition and from them the definition of the strategic organizational objectives towards which the organization should point to. These definitions should follow the general "system naming" guidelines suggested by Peter Checkland in (P. Checkland, 1993; P. B. Checkland, 1972; Collins, 1976), which specifies the root definitions as purposeful and means-based systems. To carry out these tasks, all the information organized in the previous stage will be the source for the work in this stage.

3.1.3.1. Root definition of relevant systems

In order to define the relevant systems of the software company, it is necessary and useful to define their root definition by "naming systems". The root definition involves "*selecting some viewpoints which seem potentially relevant to bringing about some improvement in the problem situation*"(Smyth & Checkland, 1976), so bringing this to our context, the root definition of interest is desirably that one making sense for improving the company's performance from the identified knowledge assets. As suggested by (Smyth & Checkland, 1976), the systems named *"do not have to, and, on our experience so far, usually should not correspond to organizational groupings such as departments or sections*".

To this point it is important to mention that there could be several viewpoints for the IT/SW professional building the root definitions, and each of these could have implicit and be coherent with one *weltanschauung* (the world-view, the way in which people perceives and comprehends the environment, "*a global paradigmatic worldview*"(François, 2004)), however, the SW/IT professional must select the root definition that coheres with his aim to provide the client company with a methodological and digital solution supported on the basis of its knowledge.

The generic proposed structure of a root definition is formed by the words:

"A" + a very descriptive and representative words-game phrase + "system".

As an example, let us suppose that we are working for an average IT company that provides both software development and technological consultancy. There could be the following root definitions obtained from different stakeholders and perspectives:

Table 2 Examples of root definitions from different weltanschauungs

Number	Root definition	Stakeholders	Weltanschauung
1	*A technology-development-service system.*	Developers	The company provides a service of developing software in accordance to the client's needs
2	*A digital-solutions-generator system.*	Project Managers	The company designs digital solutions to satisfy the client requirements using technology and with the optimal resource's consumption
3	*A technological-services-provider system.*	Analysts	The company develops software from eliciting specific needs or problems from the client.
4	*An ad-hoc-self-improvement-from-technology system.*	Product Owners	The company develops technology using existent software and artefacts and adapting them to design a solution that helps the company to improve its productiveness.
5	*An ad-hoc-self-improvement-from-knowledge-and-technology system.*	Director/CEO	The company has a long trajectory of functioning and takes advantage of its know-how to design and propose the adequate technology that supports the strategic goals achievement from leveraging organizational performance based on its knowledge assets.

An alternative way to represent root definitions is presented by (Andrade Sosa, Isaac, Espinosa, López-Garay, & Sotaquirá, 2007b), who suggest to write it like: "a system that takes E and transforms it into E *", where E is the input entity and E* is the same but transformed entity.

In the previous table there have been shown 5 possible root definitions for an average company, just with the objective to illustrate that there are always several perspectives that may be considered, however, in accordance with this work objective, the aim is to encourage the IT/SW professional to focus on defining a root definition that wraps up aspects related to: intrinsic knowledge, explicit knowhow, organizational functioning and the strategic identity of the company.

As seen in Figure 3.6, the stage 3 takes place in the "systems-thinking" world, since it comprehends an effort of the IT/SW professional to thinking and designing the root definitions, as well as the identity of the company, with no direct intervention of the stakeholders but only occurring from the systemic conception of the IT/SW professional.

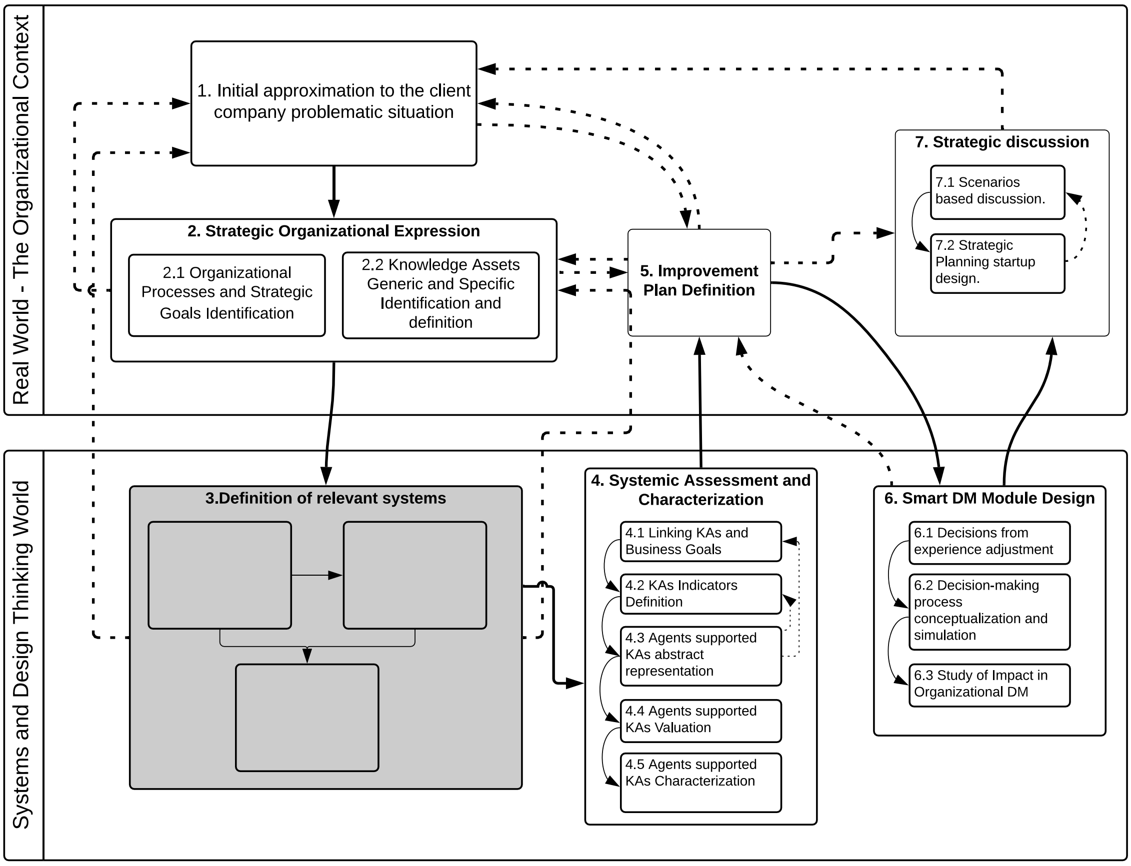

Figure 3.6 Stage 3 - Definition of relevant systems

It is true that several stakeholders and perspectives (or worldviews) are present in the company's expression and the IT/SW should be aware of them, but he must focus on explicitly identifying the one root definition driving the knowledge-based proceeding intervention.

After knowing the root definition to work with, the IT/SW professional must proceed to think on building "models" from them(Smyth & Checkland, 1976), which is suggested to be started inspired by the way that Peter Checkland (P. Checkland, 1999) originally proposed it. Checkland proposes the construction of *holons* that are represented in the conceptual constructs from now and on named as *Human Activities Systems (HAS)*. This methodology proposes the construction of a variant of them, the Knowledge-Dependent Human Activity Systems (KHAS) to bias the universe of human activities to those relevant to the dynamics of knowledge assets in the company and in accordance with the selected root definition.

A Knowledge-Dependent Human Activity System (KHAS) is a conceptual model that interweaves a set of activities oriented towards the development of a purpose implicit in the root definition selected. Its essence is then, the explicit statement of its purpose in a concise an understandable way.

A root definition that only states the transformation process, would usually be insufficient to derive the activities that will be part of the respective KHAS, so it is needed to clarify some aspects that for each KHAS represent valuable information to consider. From Checkland works, it is useful a set of specific aspects to correctly complement a root definition. For this purpose, the elements represented by the mnemonic CATWOE must be explicitly expressed, where each of these letters represent:

- C: customers.
- A: Actors.
- T: Transformation.
- W: Weltanschauung.
- O: Owners
- E: Environmental constraints.

At this point it is possible to realize that a root definition may already contemplate the nucleus of the CATWOE, which is the pair composed by the transformation T and the Weltanschauung or point of view W, under which such transformation has meaning. The other elements of the CATWOE correspond to ideas about who can assume the role of executors of the transformation T (A, actors); who the role of the one who totally controls that transformation (O, "owners"); those affected or beneficiaries of the transformation (C, customers) and the elements perceived to be out of control the KHAS but which, however, must be taken into account since they affect their performance (E, environment).

Table 3 shows the formal definitions for each of the specified terms of the CATWOE according to (Smyth & Checkland, 1976):

Table 3 CATWOE elements definitions accordin to Peter Checkland works (Smyth & Checkland, 1976)**.**

	Consideration	Amplification
O	Ownership	Ownership of the system, control, concern or sponsorship; a wider system which may discourse about the system.
A	Actor(s)	The agents who carry out, or cause to be carried out, the transformation process(es) or activities of the system.
T	Transformation	The core of the root definition. A transformation process carried out by the system. Assumed to include the direct object of the main activity verb(s).
C	Customer	Client, beneficiary, or victim, the subsystem affected by the main activities. The indirect object of the main activity verb.
E	Environmental and Wider System Constraints	Environmental impositions. Perhaps interactions with the wider systems other than that included in "Owners" above, these wider systems being taken as given
W	Weltanschauung	The outlook or taken-for-granted framework which makes this particular RD a meaningful one

The product of this stage of the methodology is the definition of the relevant systems in systemic terms. The subprocess of defining the CATWOE should be partially validated by going back to the organizational expression and the rich picture, and by checking coherence between the constructed systemic representation and the real-world problematic situation, as shown in Figure 3.7.

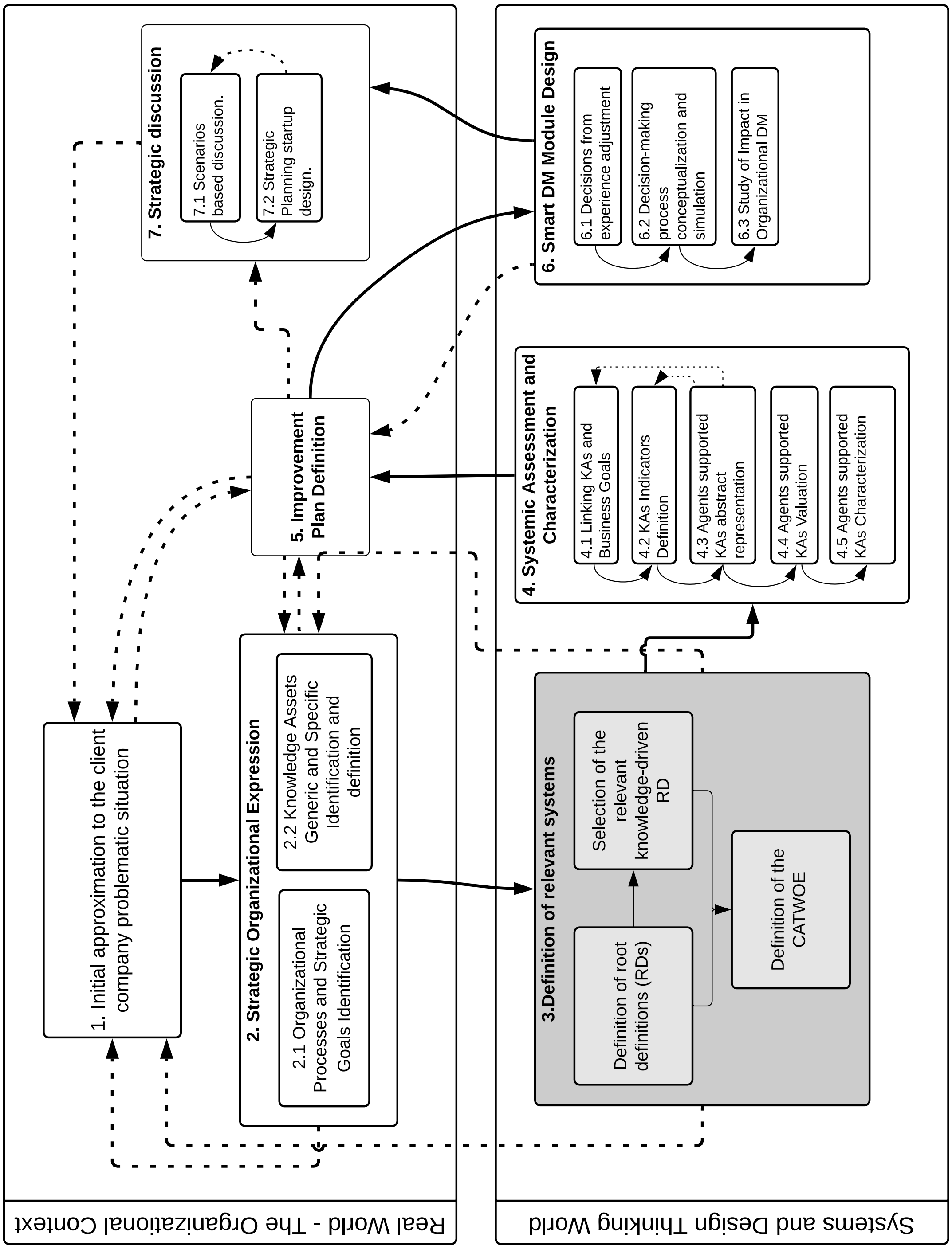

Figure 3.7 Stage 3 - Definition of relevant systems - detailed

With the CATWOE defined, the identity of the company expressed as a system will be clear, so useful to be used in the following stage, which will also be part of the Systems Thinking and Design World of the methodology.

3.1.4. Stage 4 – Systemic assessment and characterization

With the root definition clear and the CATWOE defined for the client company, the IT/SW professional can now start mixing some specific systems thinking, modeling, and knowledge-management abilities to represent the state of the company and its know-how from a perspective in which the strategic goals must be achieved from the support of a systemic design approach. This initial systemic design comprises five steps:

- Linking Knowledge Assets and Business Goals.
- Knowledge Assets Indicators definition.
- Agents-supported Knowledge Assets abstract representation.
- Agents-supported Knowledge Assets Valuation.
- Agents-supported Knowledge Assets Characterization.

The appearance of these steps contained in the conceptual modeling are described next and shown in Figure 3.8.

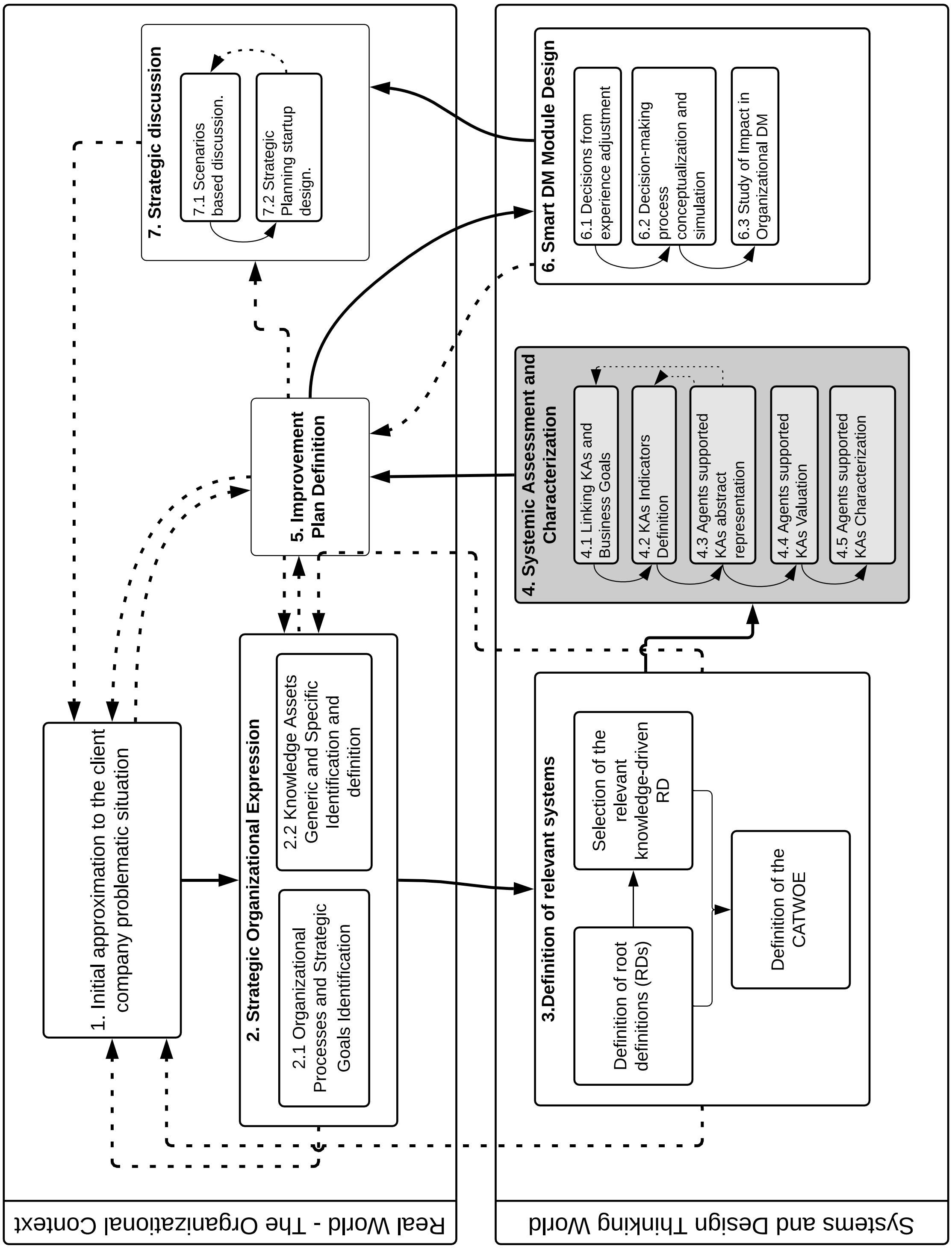

Figure 3.8 Stage 4 - Conceptual Modeling

3.1.4.1. Linking Knowledge Assets and Business Goals

The first step inside this stage is to connect the identified knowledge assets with the organizational business goal identified. To do so, first, the correct business goal must be expressed. It is possible that at this moment of the intervention the business goal has perfectly emerged, been identified or at least it can be "suspected" from the available information. However, all information obtained from stage 3 belong to the systems-thinking-world, so it is necessary now to express it in a way that will be easily understandable by stakeholders interacting in the following stages. In other words, the root definition may be enough to represent the organizational business goal, but a simpler classic-alike expression is needed in order to be used by non-systemic stakeholders interested in the results of this intervention.

With a clear root definition and/or strategic goal statement, the IT/SW engineer must perform the task of linking the knowledge assets with the strategic goal. The objective is to define the relationships between the knowledge assets previously identified for the client company and this company's business objectives (i.e. there must be a direct alignment with the company identity defined in stage 3). The client company must rely on its knowledge assets to pursue its business objectives, for which the relationships between these elements are crucial: if the relationship exist and is functional, there is alignment and so the strategic objective will be pursued, otherwise it will go on detriment.

This subprocess consists of three complementary phases: the "initial approximation" between organizational processes and business objectives, the identification of relationships based on key performance questions ("Expanded KPQ-based linking"), and finally the formal statement of relationships ("Explicit links"). Figure 3.9 shows how the flow of this thread should be to finally identify the relationships between business objectives and process assets.

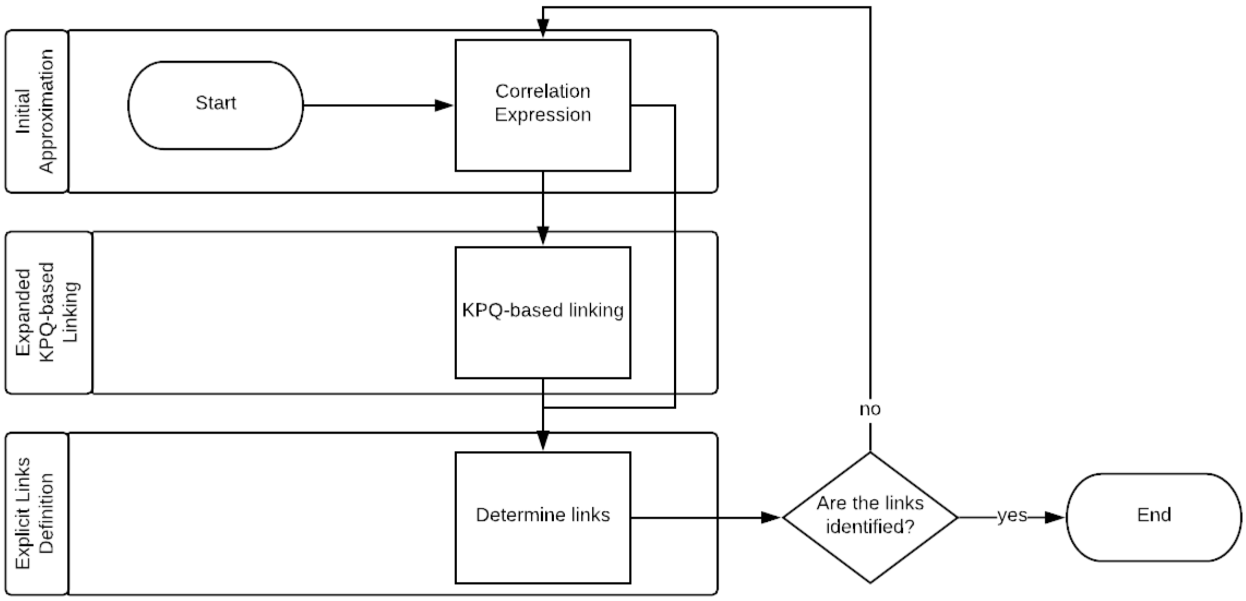

Figure 3.9 Process of linking knowledge assets and the strategic goal

The "Initial approximation" phase.

In this initial internal phase of stage 4 the goal is to do a first approximation to possible relationships between organizational processes identified in stage 2 and the objectives of business. By not being rigorous, it depends largely on the stakeholder who provided the information, although it lacks mathematical rigor, it is very useful as a mental exercise for subsequent steps in the methodology.

To carry out this phase it is suggested to use the artifact "Correlation matrix Strategic Goals – Organizational Processes", see Table 4.

Table 4 Correlation Matrix Strategic Goals - Organizational Processes

Correlation matrix Strategic Goals – Organizational Processes								
Instructions: *Fill with a 0 or a 1 whether an organizational business goal seems to be related to an organizational process, where 0 means no-correlation and 1 means correlated.*								
		Organizational Business Goals						
		BG1	**BG2**	**BG3**	**…**	**…**	**…**	**BGn**
Organizational processes	**OP1**							
	OP2							
	…							
	…							
	OPn-1							
	OPn							

This artefact is an initial support that intends to discuss for the first time, albeit superficially, the possible relationships between organizational processes and the business objectives of the organization. It is important to note that being an introductory strategy, it may not be definitive and by continuing with the methodology, relationships that were not evident in this initial phase may emerge.

The "Extended KPQ-based linking" phase.

This internal phase of stage 4 comprises a deeper attempt to identify relationships between knowledge assets and objectives, based on the Marr's mechanism. This mechanism is based on the use of Key Performance Questions (KPQs), which are a set of questions that a company must design in order to relate its knowledge assets to its organizational processes.

KPQs are generic and can be used for any type of intangible asset. (Ruiz-Robles, 2017) proposes to structure the construction of KPQs in order to limit its reach to the process assets and its relation with the organizational processes, thus guiding its creation and avoiding the possibility of errors or bad approaches.

The structure of a KPQ must always follow a predetermined structure like the one shown in Figure 3.10:

How… *What extent…*	*…does the …*	**KA** *"X"*	*…helps…* *…support…* *…leverages,* *…contributes…*	*…to the description…* *…to the deployment…* *…to the improvement…*	*… of the organizational process…*	*"…Y….."*

Figure 3.10 Generic Structure of a Key Performance Question

Previously, (Ruiz-Robles, 2017) has established two basic rules that KPQ must follow:

- A KPQ may be associated with one or more process assets. A process asset may be associated with different business objectives through different KPQ.

- A KPQ should be established as an open question. A "yes or no" answer should not be enough to answer this question. Dialogue and reflection on the question is expected.

To support the construction of correct KPQs, the following artefact may be used:

KPQs builder

Instructions: *Go to section 1 of this device. In order to carry out the task of identifying relationships, the following matrices that relate business objectives, organizational processes and process assets may be useful.*

Optional auxiliary correlation matrixes.

Knowledge Assets Vs Business Goals

		1	2	3	4	5	6	…	m
		BG1	BG2	BG3	BG…	BG…	BG…	…	BGm
A	KA1								
B	KA2								
C	KA3								
D	KA4								
F	KA5								
G	KA6								
H	KA7								
I	KA8								
	…								
n	KAn								

Organizational Processes Vs Business Goals

		1	2	3	4	5	6	…	m
		BG1	BG2	BG3	BG…	BG…	BG…	BG…	BGn
A	OP1								
B	OP2								
C	OP3								
D	OP4								
F	OP5								
G	OP6								
H	OP7								
I	OP8								
-	…								
n	OPn								

1. Relevant relations between business goals and organizational processes

Instructions: *Analyse the organizational processes identified and the business objectives of the company, and decide based on which process assets are valued, depending on the contribution they make to specific business objectives.*

Organizational Process	Business Goal	Category of BG	Justification:

2. Relevant links between process assets and business goals through KPQs

Instructions: *Formulate the KPQs depending on whether you want to value the process assets with respect to their contribution in the description of processes, in the implementation of processes and in the improvement of processes.*

Category of BG	Business Goal		KPQ		Linked PA
		→		←	
		→		←	
		→		←	
		→		←	
		→		←	

Figure 3.11 KPQs building support template

The “Explicit links” phase

This internal phase of stage 4 consists on simply summarizing and expressing the relationships between business objectives and process assets. There is no strict format for this, but one recommended option would be to use a correlation matrix like the artifact of Figure 3.12, useful as institutional documentation and for validation of the effect of this methodology in future audits.

<table>
<tr><th colspan="9">General Correlation Matrix Business Goals – Knowledge Assets</th></tr>
<tr><td colspan="9">Instructions: Fill with a 0 or a 1 whether an organizational business goal seems to be related to a process asset, where 0 means no-correlation and 1 means correlated.</td></tr>
<tr><td colspan="2" rowspan="2"></td><th colspan="7">Organizational Business Goals</th></tr>
<tr><th>BG1</th><th>BG2</th><th>BG3</th><th>…</th><th>…</th><th>…</th><th>BGn</th></tr>
<tr><th rowspan="6">Process Assets</th><th>PA1</th><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><th>PA2</th><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><th>…</th><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><th>…</th><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><th>PAn-1</th><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><th>PAn</th><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Figure 3.12 General Correlation Matrix Business Goal-Knowledge Assets (BG-KA Matrix)

3.1.4.2. Knowledge Assets Indicators Definition

The second step of stage 4 consist on defining and measuring the indicators to use to assess how the knowledge assets are contributing to meet the business goals from its effect on describing, implementing improving organizational processes.

This methodology encourages the IT/SW professional to propose indicators of all the three following types: efficiency, efficacy and effectivity. Indicators of efficiency should help measuring how good or bad in terms of resources consumption the knowledge assets contribute to meeting the business goal. Indicators of efficacy measure whether the knowledge assets support business goal achievement or not. And effectiveness indicators are strict to measure that the knowledge assets correctly contribute to the business goal achievement the way they are supposed to, so being as useful as expected.

Along with the previous three types of indicators, there must also be desirably indicators representing both:

- The quality of the knowledge asset in their function in organizational performance.
- The impact on the strategic goals achievement.

The Impact indicators are needed since they are useful to assess to what extent the knowledge assets contribute to the business goal achievement, while the Quality indicators are useful to assess knowledge assets characteristics or features.

There could be more than one indicator of quality or impact, and desirably at least one of each, so that in junction by type it is possible to have a general valuation for the impact, for the quality, and using both for what is later termed as the characterization of the knowledge assets.

3.1.4.3. Agents-supported Knowledge Assets abstract representation

This step of stage 4 proposes the use of an agents-based model of knowledge assets that supports this methodology deployment. The model was built using the Netlogo modeling and simulation tool, comprehending:

- A "simulation world" representing the space where the knowledge assets exist. This world is represented on the patches of the Netlogo interface.
- An agent structure constituting the knowledge assets abstract representation.
- A control panel with buttons that implement functions to make the simulation model work.

At this stage of the methodology, the IT/SW professional must use this simulation tool to:

Import CSV information containing organizational audit information such as strategic goals, organizational processes, knowledge assets, indicators of knowledge assets, and the specific values of indicators: minimum range value, maximum range value, sense, type of indicator, actual value and goal value (Specific explanation of these data is on the previous steps of stage 4). In Figure 3.13, there is a diagram showing how the model operates.

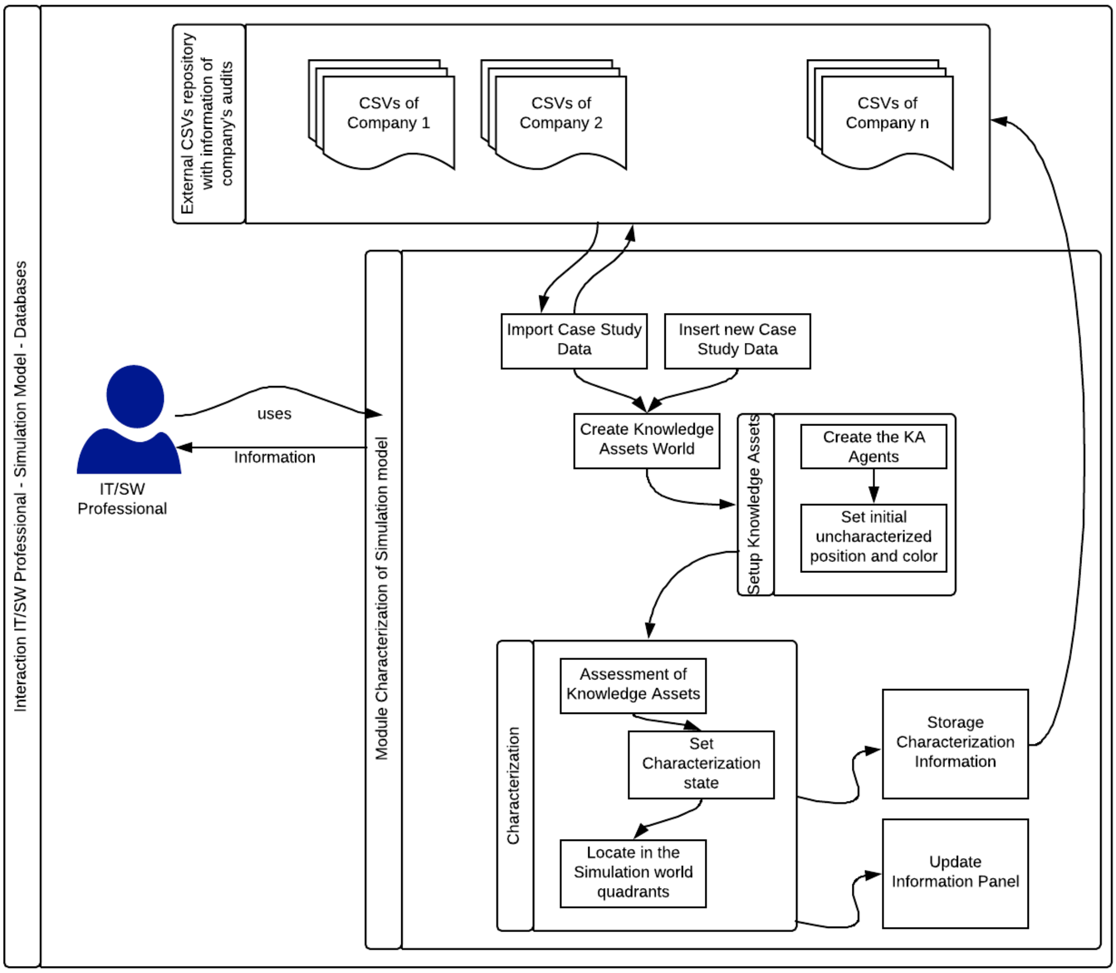

Figure 3.13 IT/SW Professional - Simulation Model - Databases Interaction Diagram

The specification of how to use this simulation tool is given in the section of this chapter corresponding to the third layer of the proposal, since the purpose of such a section is to present the artifacts and technological tools to use.

3.1.4.4. Knowledge Assets Valuation

This step comprehends the valuation of knowledge assets in terms of their indicator's measures. Through the simulation tool described in section 3.3.3, this valuation is made in an automated form, however specific information on how this valuation is made is presented in section 3.2.1.

3.1.4.5. Knowledge Assets Characterization

This methodological step comprehends the characterization ok the knowledge assets in terms of their quality and the impact on the organizational business goal. This characterization is made through the simulation tool presented in section 3.3.3, and specific information about the characterization conceptual proposal is given in 3.2.2.

3.1.5. Stage 5 – Knowledge-based Model Adjustment Validation

This stage comprises a partial validation with the client. It represents an interactive communication with the client company's main stakeholder who is desirably going to give the IT/SW professional a nurture feedback about how the built conceptual and agents-based model has been adjusted to the real-world of the company. See Figure 3.14.

As shown in Figure 3.14, if the model has no correctly adjusted the real problematic situation of the knowledge assets, or if the model is not a correct abstraction of the existent knowledge assets, the SIPAC-framework allows the iteration and return to the stages 2, 3 or 4, so that when the client has finally validated the structures, the SIPAC-framework, through its professional team expertise is able to propose the most suitable digital solution to correctly pursue the strategic goal from the fact that instead of a generic predesigned or fashion solution, the proposal is going to be specifically oriented to the alignment with the strategic goal achievement.

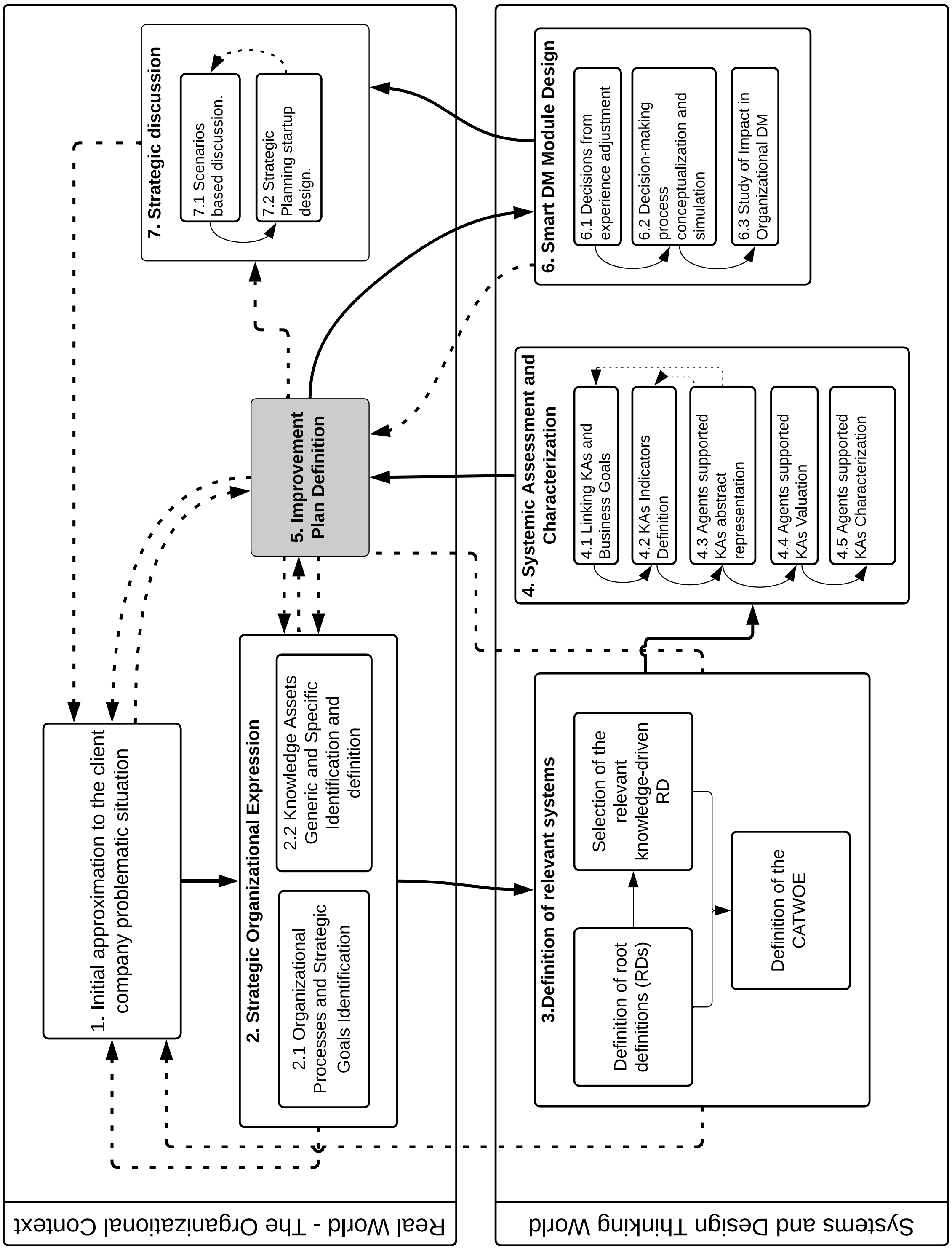

Figure 3.14 Stage 5 - Knowledge-based Model Adjustment Validation

The goal is to let the client company know and validate what the built structure of the model is, as the proposal of the IT/SW professional, containing:

- The identification of processes.

- The identification of business goals.
- The list of knowledge assets identified.
- The list of indicators defined for each knowledge asset.
- The results of the valuation and characterization performed.

Also, as part of this stage, there must be a feedback loop from the client opinions, so that any adjustments over the model can be made at this stage and by going back to stage 4, 3 or two. Again, here it appears the soft property of the general soft systems methodology which encourages the intervenor (in this case the IT/SW professional) to maintain an iterative approach in which going back to better adjustment to reality is a good thing, since it reduces bias and increases the fit of the model.

3.1.6. Stage 6 – Smart Decision-Making Module Design

In the context of decisions to be made by technology consultants, software engineers or any other stakeholder interested in strategically having a wide view of the panorama of a client company and what should be done to satisfy this clients' technological needs in pursuit of its business goals, one very important and frequently biased decision is related to choosing one among several alternatives. To be precise, IT/SW professionals have to offer their clients several alternatives that meet their needs and specific requirements. In the IT industry, before a technological solution is deployed, the service provider company has to be awarded a contract as part of a previous business negotiation or bidding process.

3.1.6.1. Decisions from experience adjustment

In this methodology, the simulation model initially used in stage 4 is complemented with a decision-making module, described in section 3.3.3.2. We have developed a simulation model as an asset to be used by the IT/SW professional to show the client information leading to commit to their software solution proposal. The aim of this model is to generate simulated scenarios to represent the client company's state of health, that in the knowledge economy is based on the state of its knowledge assets and their potential behavior in response to decisions made regarding the implementation of a technological solution.

At this moment, the client company's state of health has already been measured in stage 4, by using the intellectual capital-based approach presented in (Sanchez-

Segura, Dugarte-Peña, Medina-Dominguez, et al., 2018; Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2017; Sanchez-Segura, Medina-Dominguez, & Ruiz-Robles, 2016; Sanchez-Segura, Ruiz-Robles, Medina-Dominguez, et al., 2017). According to this approach, company intangible knowledge assets are measured and characterized to assess how good or bad its performance is. The company intangible assets were identified and categorized according to (Sanchez-Segura, Medina-Dominguez, & Ruiz-Robles, 2016), measured and characterized as suggested by (Sanchez-Segura, Ruiz-Robles, Medina-Dominguez, et al., 2017), and modelled and simulated using technological simulation software (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2018; Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2017). However, this representation of the intangible knowledge-based side of the company is the reflect of the company in an instant of time in which the indicators of the knowledge assets were measured. It is useful to show what could happen by modifying and playing with the agents-based model, but little useful to predict what may happen in the future.

To address this need regarding the decision-making process improvement from a simulation model we use the following approach, which is represented as the Stage 6 of the methodology in the following Figure 3.15.

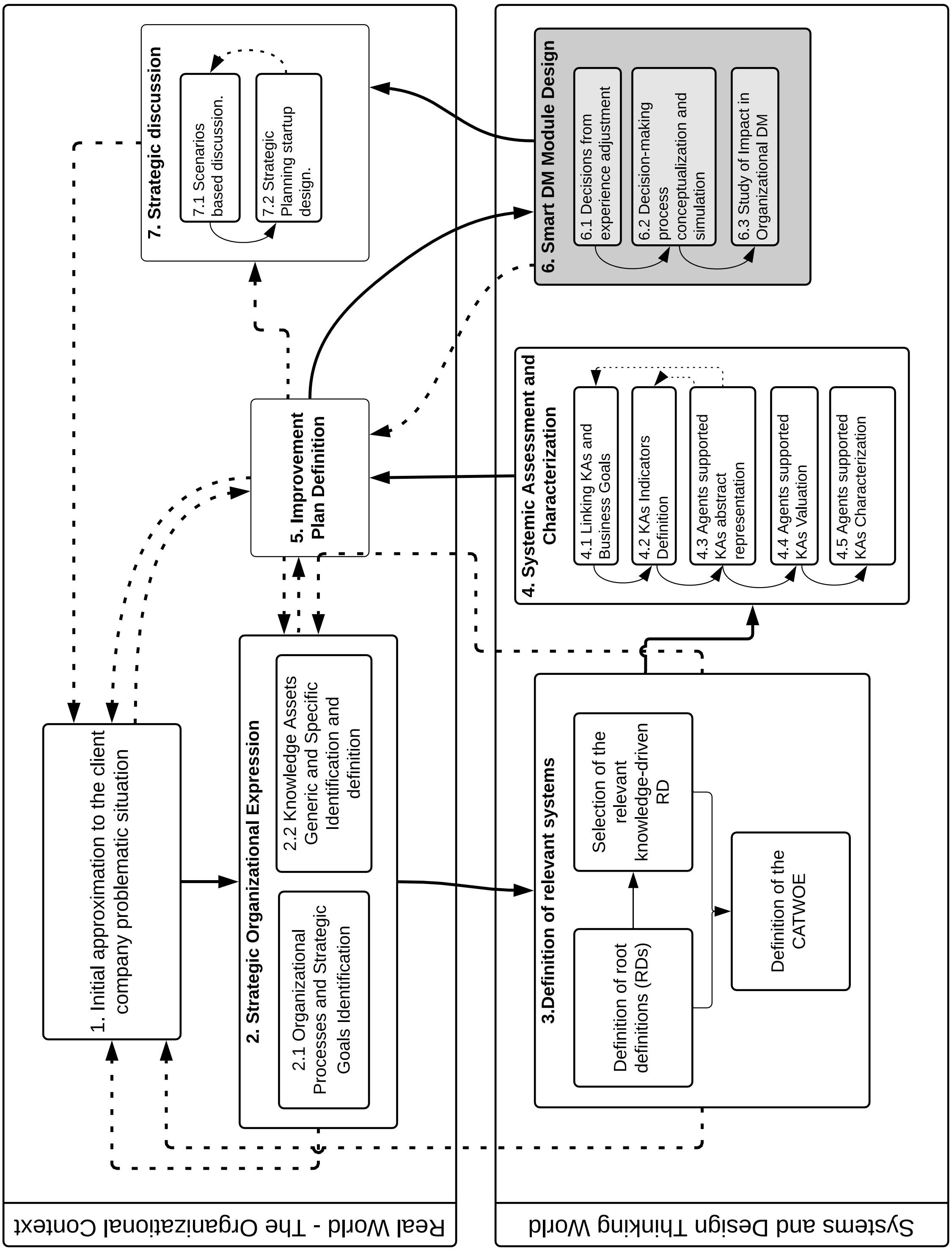

Figure 3.15 Smart Decision-making Module Design

To represent decisions and the dynamics surrounding them, we used the cognitive modelling approach (Anderson & Lebiere, 1998; Gonzalez, Lerch, & Lebiere, 2003), and specifically the related instance-based learning model (IBL model) (Gonzalez, 2013; Gonzalez, Lerch, & Lebiere, 2003; Lejarraga, Dutt, & Gonzalez, 2012; Jörn von Grabe, 2017), to represent how humans make dynamic decisions. This module of the simulation model was also implemented through the NetLogo (Wilenski, 1999; Wilensky, 2012) modelling and simulation tool, and as a complement to the already implemented module of stage 4.

3.1.6.2. Decision making process conceptualization and simulation modeling

All decisions are based on both contextual or environmental conditions and memories or past experience. Decision makers base their decisions on a multitude of information partly received from the environment, partly recalled from memory and partly generated by deduction (J. von Grabe & González, 2016). In experience-based decisions, people discover outcomes and probabilities by exploring the problems at hand (Gonzalez, 2013). To describe the decision-making process in the technological solution selection problem, instance-based learning theory (Gonzalez, Lerch, & Lebiere, 2003; Lejarraga, Dutt, & Gonzalez, 2012) and the general cognitive modelling decision-making approach (Gonzalez, 2017) are taken as a reference and conceptual framework. This framework implemented as part of the already presented Agents-based model, which is shown in Figure 3.16.

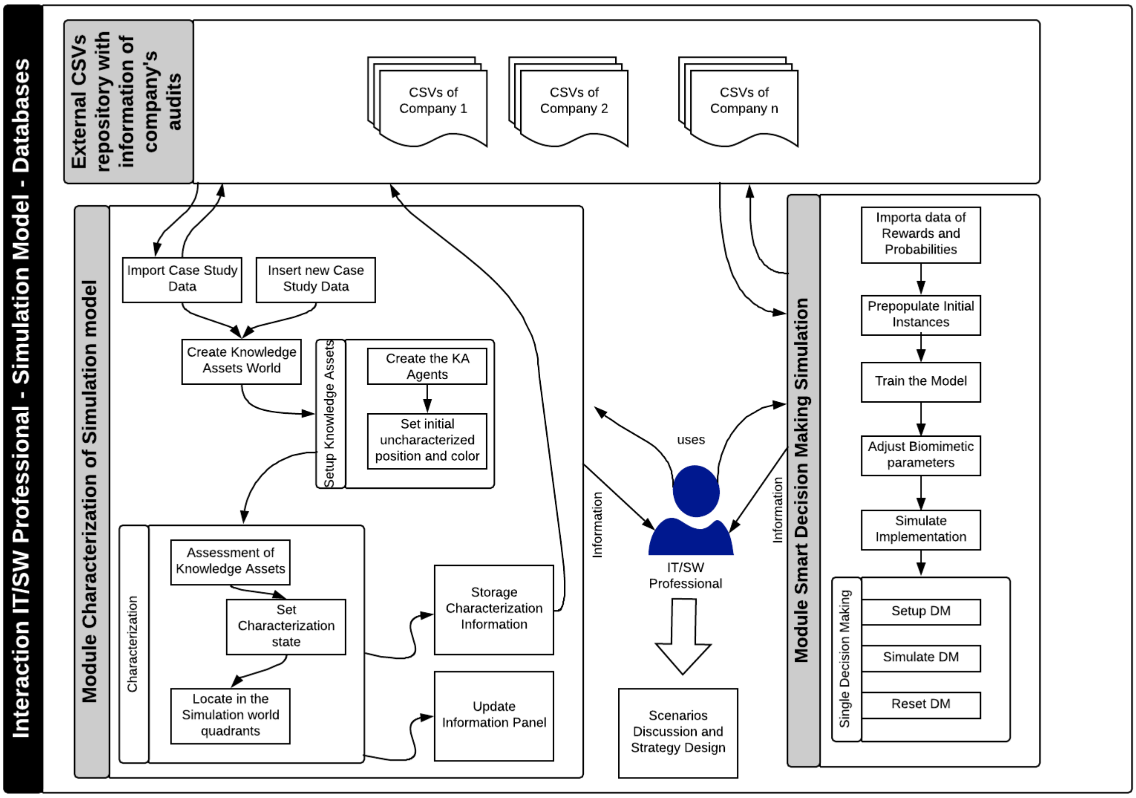

Figure 3.16 Diagram: Simulation Tool - IT/SW Pro - Databases

3.1.6.3. Study of impact in organizational decision making.

The purpose of this substage is to make use of two conceptual designs that allow the simulation of decision making regarding the digital solution implementation. To do so, the simulation model presented ahead in section 3.3.3, implements the conceptual model of decisions in the context of the digital solution selection presented in section 3.2.4 in which the SIPAC-framework has its line of action.

In this step we perform a study on the impact that the proposed solution has on the client company's business. This study uses experience-based decisions and information obtained from its dynamics with knowledge assets and the effect on the business goal

As mentioned before, a knowledge asset may be characterized as warning, replaceable, evolving, stable, unacceptable or acceptable of only impact, and unacceptable or acceptable of only quality (Sanchez-Segura, Ruiz-Robles, Medina-Dominguez, et al., 2017). This will be shown in the simulation world by both the set of colors (red, orange, blue or green, light and dark purple, and light and dark yellow) or the location of the sectors, (center-bottom-left for warning, center-bottom-right for evolving, center-top-left for replaceable and center-top-right for stable), also left-top for acceptable Quality Asset, left-bottom for unacceptable Quality Asset, bottom-left for unacceptable Impact Asset and bottom-right for acceptable Impact Asset.

The interesting thing about the agents-based decision-making model is that it shows how the knowledge assets of a company may be re-characterized as a consequence of decisions made, specifically, as consequence of the decision on whether implement or not the SIPAC-framework proposed solution (which is the output of stage 5, as mentioned in section 3.1.5). Figure 3.17 shows the corresponding sectors, with an example of the recharacterization illustration.

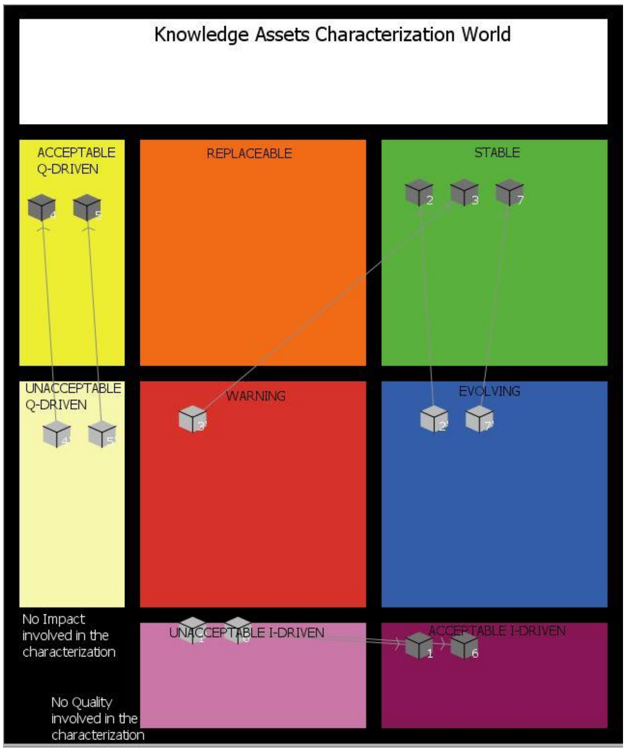

Figure 3.17 Characterization sectors in the agents-based model.

This illustration shows seven knowledge assets recharacterization, as an example. From this it can be observed the following transitions shown in Table 5:

Table 5 Prediction of re-characterization example

Knowledge Asset	Previous Characterization	Expected Re-characterization	Delta
1	Unacceptable Impact Asset	Acceptable Impact Asset	Improvement
2	Evolving	Stable	Improvement
3	Warning	Stable	Improvement
4	Unacceptable Quality Asset	Acceptable Quality Asset	Improvement
5	Unacceptable Quality Asset	Acceptable Quality Asset	Improvement
6	Unacceptable Impact Asset	Acceptable Impact Asset	Improvement
7	Evolving	Stable	Improvement

As it can be seen, besides noticing the potential changes on the characterization states, it is possible to open the discussion on whether there is an improvement, a deterioration or a same result in regard to the characterization state of knowledge assets. In this specific illustration, all transitions show an improvement, however, when correctly deployed, the SIPAC-framework should lead to improvements only when as a result of training it is robust enough as to do so, and in the case that training contains several deterioration cases the SIPAC-framework should lead (guided by probabilities) to indicate that deterioration is the more likely case to occur for the cases in case the same decision is made.

On the right side of the simulation window (Figure 3.18), there are two sections. One shows a man representing the decision maker, and the other shows a space in which the instance agents will interact.

The simulation model is first set from initial information using real data about the client's knowledge assets. From stored information about other cases that have deployed the SIPAC-framework, it is possible to estimate what may happens with the real case under interest. To do so, a first "training" must be performed, which will allow the generation of:

- A matrix of transitional probabilities for the re-characterization.
- A matrix of expected utilities from what has been learnt from other cases.

The simulation model starts to explore all the possible instances and make decisions about the two possible options: implementing or no the proposed digital solution. The model runs for a specified (calibrated) time and shows the dynamics of instances, whereby instances with a greater activation are more likely to be retrieved (i.e. instances that have produced better outcomes have greater probabilities of occurring again and are displayed closer to the decision maker in the simulation window).

For each trial, the left-hand side of the simulation window shows the recharacterization as a result of decision making. For decisions that occur repeatedly (same situation, decision and utility), activation is updated for each occurrence. For unexplored utilities, new instances are created and initialized.

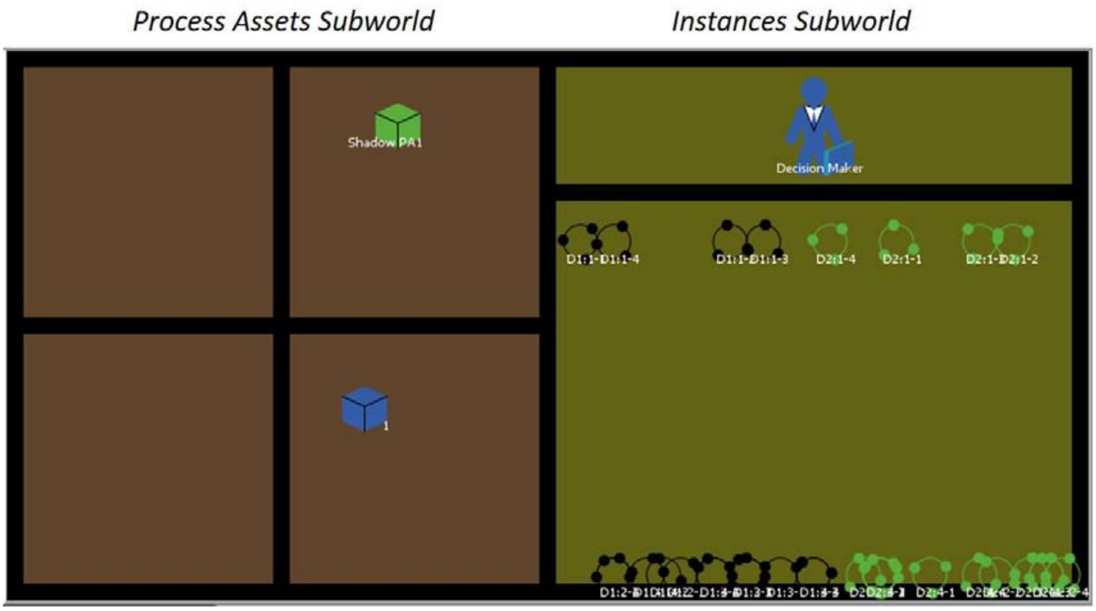

Figure 3.18 Simulation window: instance characterization and visualization

While the simulation is running, the blended values are constantly updated, showing the alternative that is more likely to succeed in achieving the organization's goal through the best management of the knowledge assets.

Knowledge assets had already been characterized based on impact and quality indicators according to the proposal of (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2018). However, the probability of a knowledge asset being recharacterized as any of the other states depends on decisions made by the company's decision maker in regard to its technological solutions, and that is what this specific model tackles.

In summary, the model starts by showing the characterization based on real data collected from the knowledge assets assessment carried in previous steps according to [2]. Simulation modelling explores what would happen if one or other decision is made. In this manner, it forecasts the results of the recharacterization of assets, and thus the effect of decision making on strategic goal achievement in terms of the impact and quality of the knowledge assets.

The simulation model visualizes information about the knowledge assets affecting business goal achievement, the functioning of instances representing memories of the human mind, the way an expert would learn from experience, and the exploration of possibilities for facilitating learning to achieve better outcomes. This provides for better and grounded decision making with respect to the evaluation and selection of a technological solution. This is very valuable and useful for both the software engineer in charge of illustrating the impact of the offered product and the client who needs to envisage what the best decision would be and how it would affect organizational performance based on the study of its intangibles.

This model has paved the way for exploring business dynamics from the perspective of the impact of technology on company know-how. It generates important inputs for discussion and graphical information useful for the purpose not only of illustration but also for documentation and for driving real decision making.

Experience-based decisions are part of what is known as cognitive modelling. Cognitive modelling focuses on representing how decisions are made based on experience rather than from an explicit description of options. It provides a better understanding of cognitive processes, such as information search, recognition and similarity processes, integration and accumulation of information, feedback, and learning (Gonzalez, 2013).

This model represents experiences by simulating experimentation with all the possible instances. All the instances are created as described above and are all accounted for by the simulation model. However, the instances with greater retrieval probabilities will perform better and will account for higher activation values. This will also be reflected in the blended values calculated for each of the choices or possible decisions.

More specific details on the functioning of this decision-making module of the simulation model is given in section 3.3.3.2 in which the simulation model itself is presented.

3.1.6.4. Smart Decision Making

The goal with this is to test through the simulation model the effect in decision making of the decision-maker behavior. To do so, we modelled as part of the simulation model a panel that allows to generate scenarios in which the psychological traits of the Interpersonal Circumplex Model is represented so that in a certain way the psychological behavior of the decision maker is simulated. The control panel for simulating decision-making is presented in Figure 3.19.

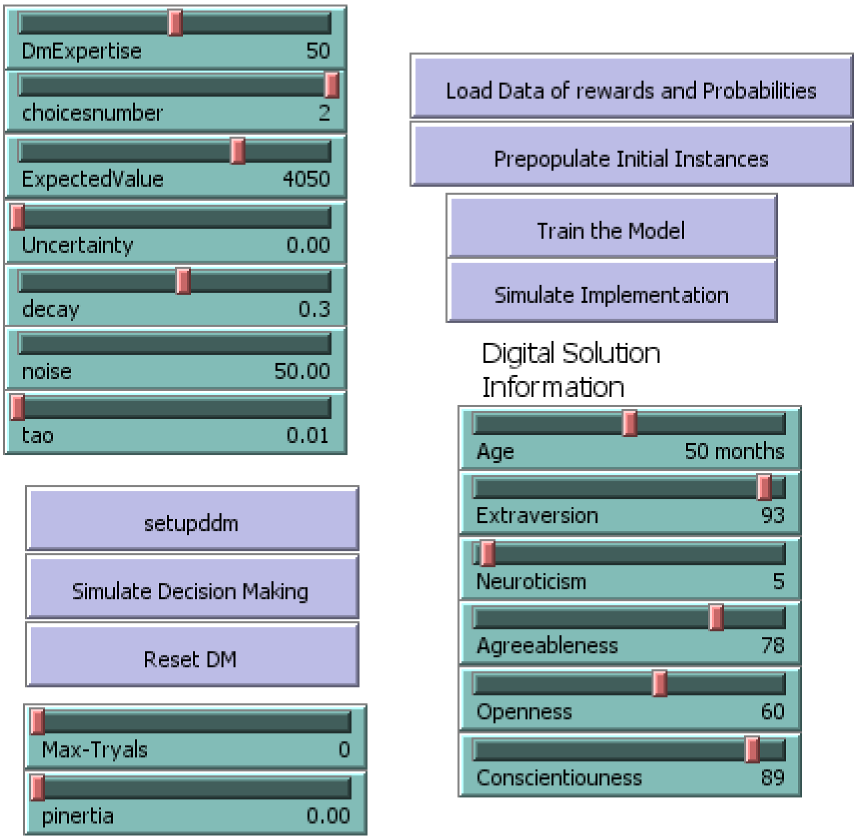

Figure 3.19 Simulation panel for decision making

As mentioned before, the "Prepopulate Initial Instances" button creates the Instance agents from all the combinations of "situations" and "choices" according to the instance-based learning model. In our case, given that there are $4^2+2^2+2^2=24$ possible situations, and 2 possible choices, there are going to be 48 initial instances.

The "train the model" button simulates decisions and storages the obtained simulated results, which is directly dependent on historical information that have been previously of other audits and client companies.

The "DMExpertise" button allows to fix the decision maker expertise in making decisions as the responsible of comparing among choices and deciding to implement or not the solutions. This is also data that must be obtained in stages 1 and 2 but that must be calibrated for the IT/SW professional.

The other sliders (choicesnumber, ExpectedValue, Uncertainty, decay, noise, tao, Max-tryals, and pinertia) are own for the operation of the IBL model as the basis of this decision-making simulation model. The buttons "setupddm", "Simulate Decision Making" and "Reset DM" allow the desired experimentation.

The "setupddm" button creates the shadow KAs that will represent the re-characterization of KAs as product of simulated decisions. These shadow KAs will be in the same simulated than the original KAs but will count on a different label and in case of different characterization state on different colour and locations.

The "Simulate Decision Making" button will put the simulation engine on and the continuous recharacterization from fixed simulation parameters and historical data will be displayed.

The Reset-DM button resets the parameters and deletes any created information from the present experiment.

In summary, the smart decision-making model allows the exploration of decisions can be affected from the personality traits that characterize the decision maker. It is an important input to discussion since it allows to play with the seniority or expertise of the decision makers and brings up to the discussion of leaving important decisions to people with enough experience. Specific research on how these personality traits represent a decision maker expertise and decision is under progress and will lead to a research project posterior to this thesis work.

3.1.7. Stage 7 – Strategic Discussion

A shown in Figure 3.20, stage 7 of the methodological layer is performed again in the real world, i.e., interacting with the client by supporting in strategic planning and other implementation support tasks.

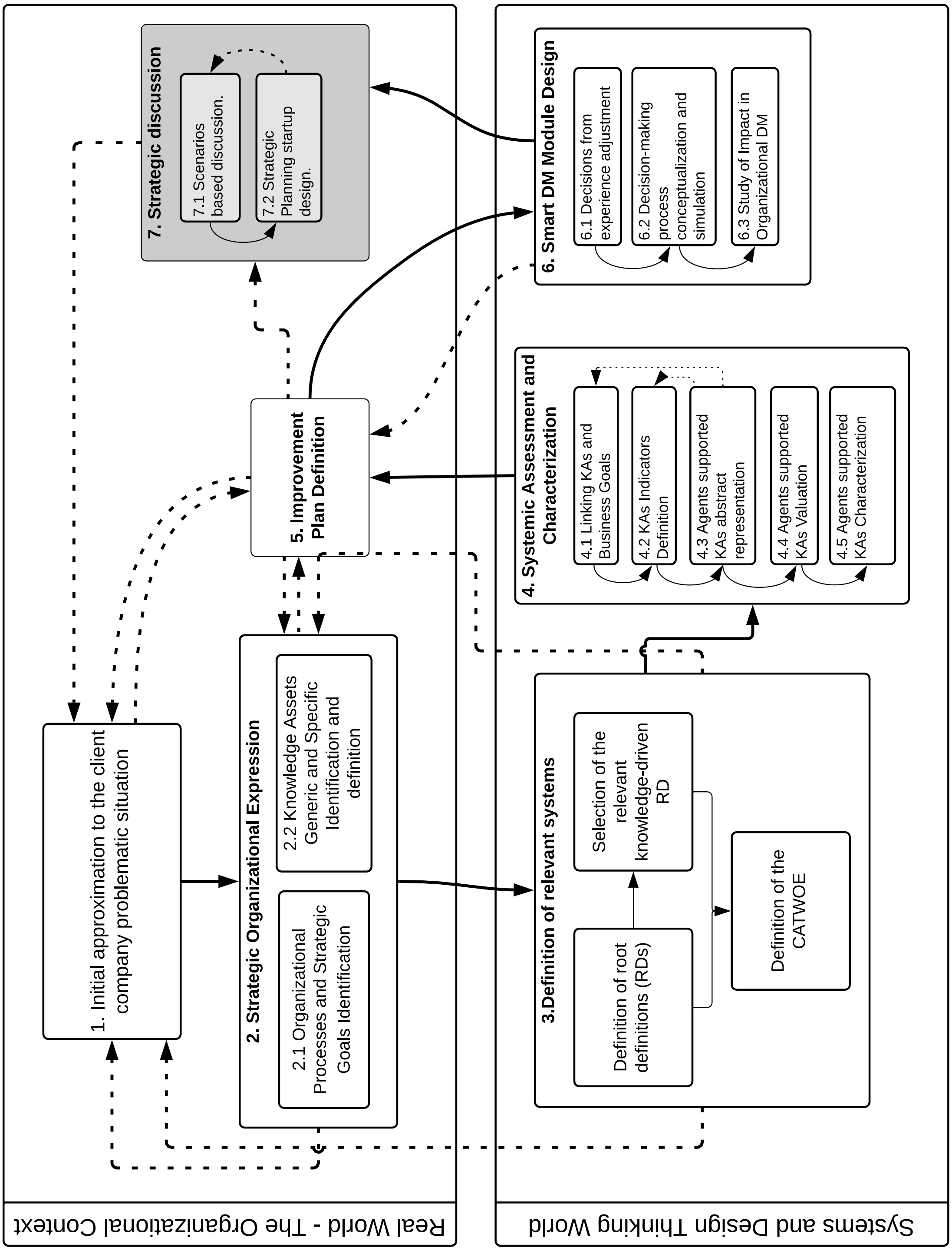

Figure 3.20 Stage 7 - Strategic Discussion

3.1.7.1. Scenarios based discussion

The use of the simulation model described before is useful if future scenarios are to be generated for strategic decision making. To do so, fundamentally the process is:

- Selection of parameters to vary.
- Simulation
- Capture of relevant information.
- Modification of the selected parameters.
- Test of robustness of the scenario.

3.1.7.2. Strategic Planning Startup design

This step is a proposal for the client company to use the generation information in directory board discussions and meetings so that for future and strategy design the intangible side become one of the key factors, enabling the possibility of the company to empower from the alignment between knowledge assets and the strategic goals, which will redound in better revenues and general organizational improvements in general.

3.2. Mechanisms layer

Inn this subsection, the models of some specific constructs will be presented. In this context, a model is understood as "*a formal representation of an aspect of a system*" (Chaudron, Groote, Hee, et al., 2004), so that the formal representations are:

- A conceptual model for characterizing knowledge classification and valuation.
- A conceptual model for knowledge assets characterization.
- A conceptual model for the definition of knowledge assets evolution from experience.
- A conceptual model of decisions from experience in the domain of digital solutions implementation and its effect on knowledge assets.

3.2.1. Model of Knowledge Assets Valuation and Characterization

The SIPAC-framework comprehends the general assessment and characterization of:

- The achievement of the identified strategic goal.
- The knowledge assets identified for a company.

The general strategic goal achievement is given by the assessment that all related knowledge assets have and the importance they have on such goal achievement, while the assessment of these knowledge assets is given by the state that their indicators may have and whether they are related to the quality of the assets or the impact that these assets have on strategic goals achievement.

Each knowledge asset may have one or several indicators, which as a whole provide an overall of the state of the knowledge asset. Similarly, a strategic goal may be assessed from the perspective of the several knowledge assets that may affect its achievement.

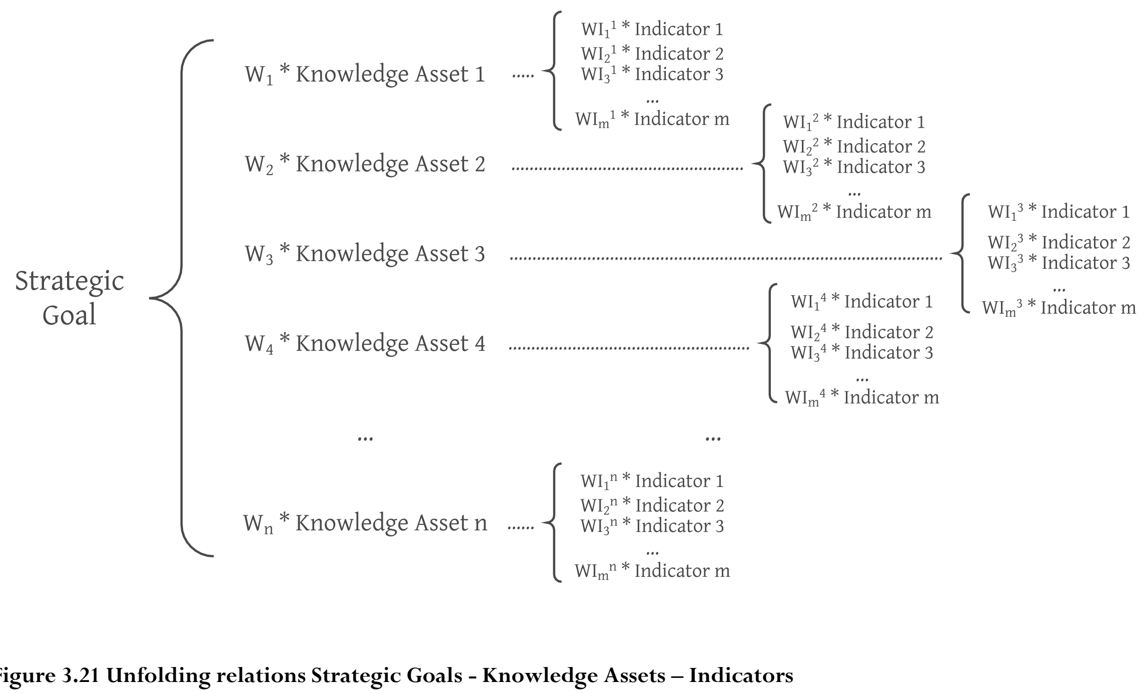

Figure 3.21 Unfolding relations Strategic Goals - Knowledge Assets – Indicators

In summary, the process consists on:

1. Normalize and standardize indicators.
2. Assess Indicators individually.

3. Assess knowledge assets from their related indicator's performance
4. Assess strategic goals achievement

For this model to make sense, some information of the knowledge assets and its related indicators must be previously known. The SIPAC-framework proposes the use of the audit spreadsheet presented in section 3.3.1 for direct on-site data collection, and the web tool described in section 3.3.2, which allows the collection, storage and retrieval of information of a company's goals, the related knowledge assets and its corresponding indicators.

Regarding the knowledge assets of a company, the information that must be previously known refers to the name of the knowledge asset, its corresponding type of intellectual capital, the type of intangible that it is according to the cataloging given in section 3.1.2.3, the number of indicators that it has, and the weight of the intangible in strategic goals achievement. Since all the Knowledge assets affecting a strategic goal do not have the same importance, they are assigned such a weight (W_n) representative of the importance that the knowledge asset "n" has on the achievement of the strategic goal (See Figure 3.21).

Table 6 Information of Knowledge Assets used in the assessment model

Short-ID	Extended-ID	Description
KA-Name	The name of the Knowledge Asset.	This should be a short and representative name of the knowledge asset identified.
IC-type	Type of Intellectual Capital.	This type of intellectual capital must correspond to the classification of (Marr, 2008).
KA-type	Type of knowledge Asset.	This type of generic knowledge asset corresponds to the classification presented in section 3.1.2.3.
N-Ind	Number of indicators	This is the number of indicators that a specific knowledge asset has.
KA-weight	Weight of the knowledge asset	This is the weight that the knowledge asset has for the strategic goal achievement.

The same concept of importance used with knowledge assets applies to the contribution that indicators have on the assessment of a knowledge asset. For every indicator, a weight (WI_m^n) is assigned, representative of the contribution that the corresponding indicator "n" has on the performance of the knowledge asset "m". The Table 7 lists the elements to be observed and measured for each of the indicators that a knowledge asset has. In general, aspects to be measured over the indicators describe the measurement criteria, differentiate an indicator from another, define whether they are representative of quality or impact, represent the importance that these have regarding the knowledge asset, and fits the boundaries among which the indicator may range.

Table 7 Elements of a Knowledge Assets Indicator

Short-ID	Extended-ID	Description
Name	The name of the indicator.	This should be a short and representative name
Type	The type of indicator	It must take two possible values: 1 when the indicator is of the type Quality, and 2 when the indicator is of the type Impact.
Min_Val	Minimum possible value	This is the lowest value that the indicator could take. In other words, it is the lower limit of the interval of possible values.
Max_Val	Maximum possible value	This is the highest value that the indicator could take. In other words, it is the higher limit of the interval of possible values.
Sense	Sense of goodness	It is a value that represents the sense of the desirable direction of the indicator. If higher values are better, it takes a value of 1, and if lower values are better it takes a value of -1.
Act-Val	Actual value of the indicator	This is a value representative of the current state of health of the indicator, i.e. it is a value higher or equal than Min_Val and lower or equal than Max_Val. In other words, it is the measure of the indicator in the present time.
Goal_Val	Goal value of the indicator	This is a value representative of the desired state of health of the indicator, i.e. it is a value higher or equal than Min_Val and lower or equal than Max_Val, but representative of a better state (if possible) than the given by Act_Val. In other words, it is the desired measure of the indicator for the future time.
Ind-Weight	The weight (importance) for the knowledge asset.	This is a value representative of the importance that the indicator has regarding the knowledge asset. The higher this value it is, the more important it is. (Note: the importance is distributed among all the indicators of the asset, so all weights of indicators of a same knowledge asset must sum up 1)

3.2.1.1. Knowledge Assets Indicators normalization

With the information indicated in Table 7 for every indicator, this methodology proposes that a double transformation on the indicator's values must be performed in order to better combine the information and assess the indicators general behavior:

1) A standardization of actual and goal values that comprises the transformation of the original actual and desired values to a scale [0,1] independently of the real range values.

2) A normalization of every indicator that from the standardized values generates a unique value representative of the state of health of the indicator.

3.2.1.1.1. Standardization of indicators

The standardization of actual and goal values is given by the following equations and rules:

- If Sense of the indicator equals 1, i.e. the higher the value, the best performance the indicator has, then the **standardized** value of the indicator is given as:

$$X' = \frac{X - X_{MIN}}{X_{MAX} - X_{MIN}}$$

Equation 3-1 Standardization of indicators values – sense 1

Where X represents the actual or goal value measured for the indicator, and X_{MIN} and X_{MAX} represent the minimum and maximum possible values for this indicator respectively, i.e. the range among which the indicator may be.

- If Sense of the indicator equals -1, i.e. the lower the value, the best performance the indicator has, then the **standardized** value of the indicator is given as:

$$X' = \frac{X - X_{MAX}}{X_{MAX} - X_{MIN}} * (-1)$$

Equation 3-2 Standardization of indicators values – sense -1

With all the indicators standardized, they will all be in a range in the range [0,1], independently of their sense or range, so that they can all be compared as similar from a quantitative point of view.

3.2.1.1.2. Normalization of indicators

As mentioned before, besides standardizing the actual and goal values of indicators, this work proposes a normalization that from the known actual and goal standardized values computes the normalized value of the indicator, that is, a measurement of the state of health of the indicator. This normalization is given by Equation 3-3 and Equation 3-4.

- If Sense of the indicator equals 1, i.e. the higher the value, the best performance the indicator has, then the **normalized** value of the indicator is given as:

$$X_{NORM} = \frac{X'_{Act} - X'_{Goal}}{X'_{Goal}}$$

Equation 3-3 Normalization of indicators values – sense 1

- If Sense of the indicator equals -1, i.e. the lower the value, the best performance the indicator has, then the **normalized** value of the indicator is given as:

$$X_{NORM} = \frac{X'_{Act} - X'_{Goal}}{X'_{Act}}$$

Equation 3-4 Normalization of indicators values – sense -1

Where X_{NORM} is the normalized value to calculate, X'_{Act} is the actual previously standardized value, and X'_{Goal} is the goal previously standardized value. This value ranges generally from – 1 to 1, nonetheless allowing the case of overshooting or undershooting the limits of the interval, which is still valid, and just represent the case of higher values than the upper limit or lower than the lowest limit[2].

To assess these normalized values of the indicators, a color scale has been defined. A low and a high threshold indicating from what and until what value a standardized measured is acceptable must be defined and used to delimit this coloring, as shown in Figure 3.22.

[2] What this means is that, for example, you can have for an indicator a reference interval of possible values like [5,20]. However, in some real cases a measured of the indicator may be higher than 20 or lower than 5, which would cause standardized values higher than 1 or lower than -1.

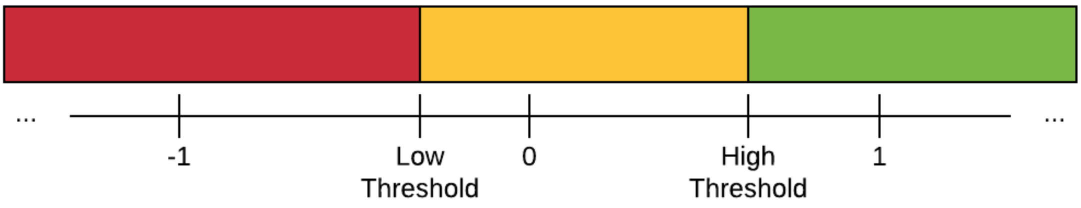

Figure 3.22 Color of standardized KA indicators from the low and high thresholds

From the previous coloring exercise, it is possible to primarily discuss about which indicators are in a bad state (red), which in an acceptable state (orange), and which in a very good state (green). The acceptable state is determined by the thresholds, which are determined by the client company and captured by the IT/SW professional in the rich picture, the problematic expression or any iteration among those.

3.2.1.1.3. Knowledge Assets Assessment

This step consists on using information of standardized-normalized indicators to assess the identified knowledge assets. This assessment comprehends the generation of a descriptive value that will determine the general state of health of the asset from a quantitative perspective. Assessment is given by the Equation 3-5.

$$KA_{VAL}^{n} = \sum_{i=1}^{m} WI_i^n * X_{NORM}^{i}$$

Equation 3-5 Equation of Knowledge Asset general valuation

Where KA_{VAL}^{n} is the valuation of the knowledge asset "n", which has "m" indicators, and with every normalized indicator X_{NORM}^{i} having a related weight representative of its importance of WI_i^n.

3.2.1.1.4. Strategic Goal Quantitative Assessment

This assessment of the strategic goal consists on taking all the knowledge assets individual valuations and calculating the quantitative state of achievement given by Equation 3-6.

$$SG_{VAL} = \sum_{k=1}^{n} W_k * KA_{VAL}^{k}$$

Equation 3-6 Equation of Strategic Goal achievement general valuation

Where the quantitative general valuation of a strategic goal achievement from the perspective of the company's intangible side (SG_{VAL}) is given by sum of the general valuations of every knowledge asset, multiplied by the corresponding given weight of every knowledge asset.

3.2.1.1.5. Impact quantitative assessment

The impact valuation of a knowledge asset is an alternative assessment that takes into consideration only the normalized indicators that are classified as "impact" indicators. To evaluate the subset of impact indicators, given a set of "p" normalized impact indicators for a knowledge asset "n", the valuation is given as:

$$I_{VAL}^{n} = \frac{\sum_{i=1}^{p} X_i^n}{p}$$

Equation 3-7 Impact Assessment for a Knowledge Asset

Where X_i^n is each of the p normalized indicators of impact that the knowledge asset n has.

3.2.1.1.6. Quality quantitative assessment

Similarly to the case of the impact valuation, the quality valuation considers only the indicators of the type $quality$ of a knowledge asset and calculates a general valuation of it. To evaluate the subset of quality indicators, given a set of q impact indicators for a knowledge asset n, the valuation of the quality is given as:

$$Q_{VAL}^{n} = \frac{\sum_{i=1}^{q} X_i^n}{q}$$

Equation 3-8 Quality Assessment for a Knowledge Asset

Where X_i^n is each of the q normalized indicators of quality that the knowledge asset n has.

As a general note, the general Strategic Goal Quantitative Assessment presented in 3.2.1.1.4 may be also given as in Equation 3-9, since the number of impact and quality indicators must sum up the same number of indicators shown in Equation 3-5Equation 3-6. If this were the chosen equation, given a set of $p+q$ impact and quality normalized indicators respectively for a knowledge asset n, the valuation would be given as:

$$KA_{VAL}^{n} = \sum_{i=1}^{p} WI_{i}^{n} * X_{NORM}^{i} + \sum_{j=1}^{q} WI_{j}^{n} * X_{NORM}^{j}$$

Equation 3-9 General linear valuation of a Knowledge Asset

Where,

- X_{NORM}^{i} is each of the $\boldsymbol{p}$ impact indicators,
- X_{NORM}^{j} each of the $\boldsymbol{q}$ quality indicators,
- WI_{i}^{n} is each of the related weights of the impact indicators
- WI_{j}^{n} is each of the related weights of the quality indicators

restricted to $\boldsymbol{p}+\boldsymbol{q}$ sum up the total number of indicators associated to the knowledge asset $\boldsymbol{n}$.

As it may be noticed, there have been presented three complementary valuations related to a knowledge asset:

- The general weighed valuation (Section 3.2.1.1.3).
- The impact valuation (Section 3.2.1.1.5)
- The quality valuation (3.2.1.1.6).

The main difference among these three valuations is that the general weighted valuation provides a quantitative value that represents the general state of the asset disregarding whether this asset is affecting the impact on strategic goals achievement or the quality related to this, but focusing on the importance that the indicators have in general, whereas the impact and quality valuations are specific on these aspects of quality or impact disregarding the weights, which are useful for the characterization presented next in section

3.2.2. The Knowledge Assets characterization model

This conceptual model complements the previously presented in section 3.2.1, which was focused on quantitative valuations of the knowledge assets from the values of the indicators of each of them. The characterization model starts from the obtained impact and quality valuations and proposes a practical characterization in terms of these.

3.2.2.1. Knowledge Assets Characterization

The characterization to be performed over every knowledge asset in this methodology is based on the initial proposal presented in (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2018; Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2017; Sanchez-Segura, Ruiz-Robles, Medina-Dominguez, et al., 2017). In addition, we extend such a proposal so that instead of considering only knowledge assets which have strictly both impact and quality, it considers also knowledge assets of only impact and knowledge assets of only quality. This extended characterization is proposed considering a wider range of possibilities regarding the impact and quality combinations, all of them equally important in real organizational contexts.

Knowledge Assets may be characterized in terms of their impact on an organizational business goal and their quality as organizational assets. There are three cases for characterizing the knowledge assets from their indicators type:

- Case 1: Knowledge assets with both impact and quality indicators.
- Case 2: Knowledge assets with only quality indicators.
- Case 3: Knowledge assets with only impact indicators.

All the three characterization cases are shown in Figure 3.23, case 1 pointed within a gray frame, case 2 within a yellow frame and case 3 within a pink frame.

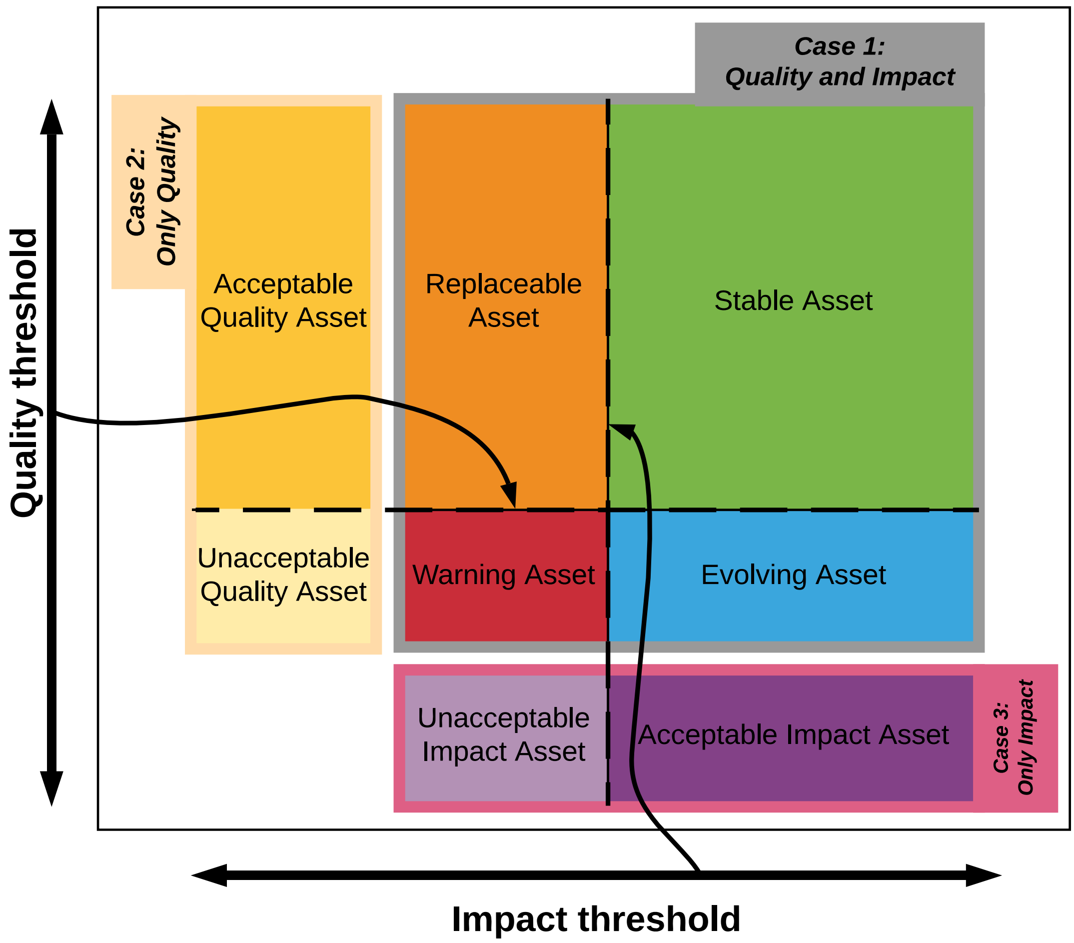

Figure 3.23 Extended characterization of Knowledge Assets

As shown in Figure 3.23, there are several colored quadrants representative of "states" that constitute the different levels of the characterization. The black segmented lines dividing the quadrants are thresholds of impact and quality that define the point in which the impact or quality of a knowledge asset may be considered acceptable or not.

The characterization thresholds define the values in which the knowledge assets quality and impact valuations switch from a bad or worst situation to a good or better and acceptable situation. In other words, these thresholds are barriers stablished for every company that define how demanding they will be with their organizational performance from their knowledge assets quality and impact.

Following are the three general cases of characterization and its corresponding characterization states.

3.2.2.2. Case 1 characterization (Both Impact and quality KAs)

It bases on information obtained from the assessment of both the quality and the impact described in section 3.2.1, so that considering two thresholds for the impact and for the quality the characterization is given as shown in Figure 3.24.

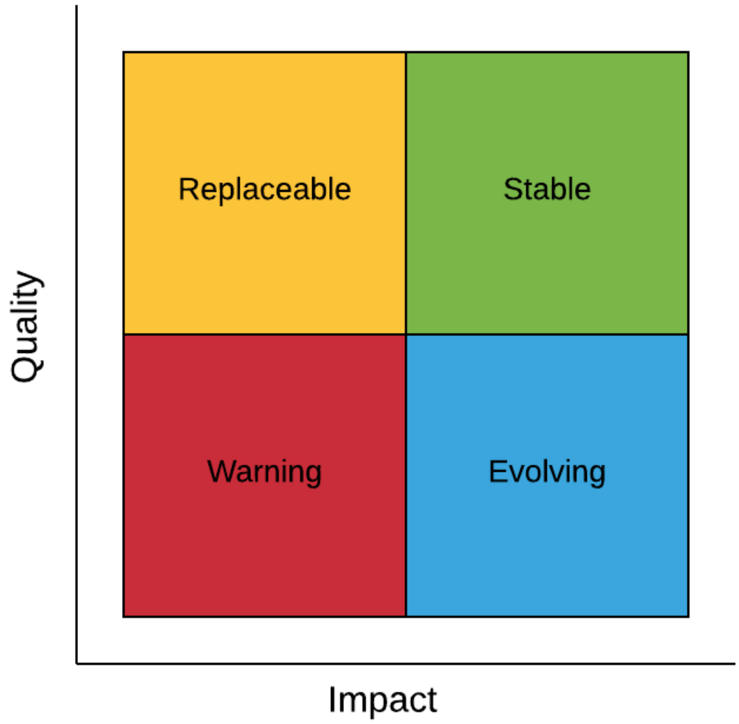

Figure 3.24 Characterization of Knowledge Assets from Impact and Quality

As seen in Figure 3.24, the characterization for assets of the case 1 is graphically represented as a four quadrants diagram. A knowledge asset may be characterized as Warning (Red), Replaceable (Orange), Evolving (Blue) or Stable (Green); depending on the valuations of the Impact and Quality obtained. The rules for characterization are defined as shown in Table 8.

Table 8 Rules for characterization. Case 1: Impact and Quality

Rules for characterization					
If	$I_{VAL} < I_{th}$	and	$Q_{VAL} < Q_{th}$	then	Warning
If	$I_{VAL} \geq I_{th}$	and	$Q_{VAL} < Q_{th}$	then	Evolving
If	$I_{VAL} < I_{th}$	and	$Q_{VAL} \geq Q_{th}$	then	Replaceable
If	$I_{VAL} \geq I_{th}$	and	$Q_{VAL} \geq Q_{th}$	then	Stable

The quality and impact thresholds (Q_{th}, I_{th}) will determine the transition from a possible state to the other, so that being very flexible (less demanding) the chance of a Knowledge Asset to be characterized as "Warning" is low, while being very demanding the chance of a Knowledge Asset to be characterized as "Stable" is high, just to exemplify. To illustrate this, in Figure 3.25 two cases have been represented: 1) with low impact and low-quality thresholds, and 2) with high impact and high quality thresholds.

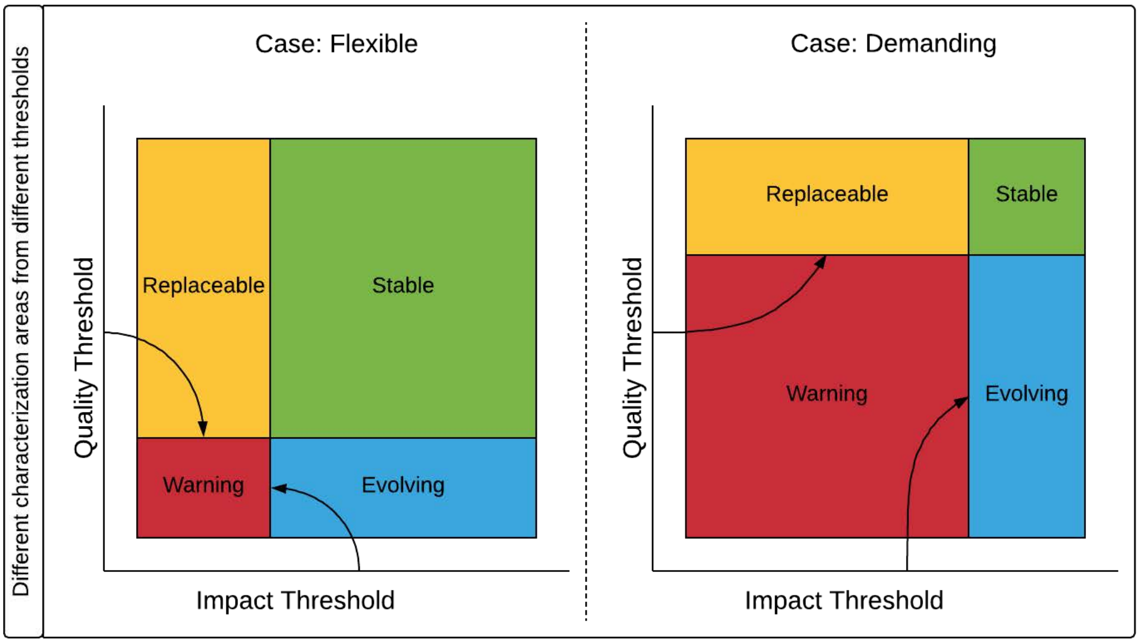

Figure 3.25 Characterization effect variation from impact and quality thresholds

As expected, the less demanding the IT/SW professional is (fixes the thresholds), the more likely the Knowledge Asset is to be characterized as "Stable", "Evolving" or "Replaceable". In contrast, the more demanding the IT/SW configures the model, the less probably the Knowledge Asset will be characterized as "Stable" and the more likely to be characterized as "Warning" will be.

3.2.2.3. Case 2 characterization (Only Quality)

This only quality characterization of Knowledge Assets considers two possible states: "Acceptable Quality Asset" and "Unacceptable Quality Asset". Switching from one state to another depends on the individual quality valuation of a Knowledge asset in regard to the Quality threshold that has been stablished. In Figure 3.26 the variation from the quality threshold is shown.

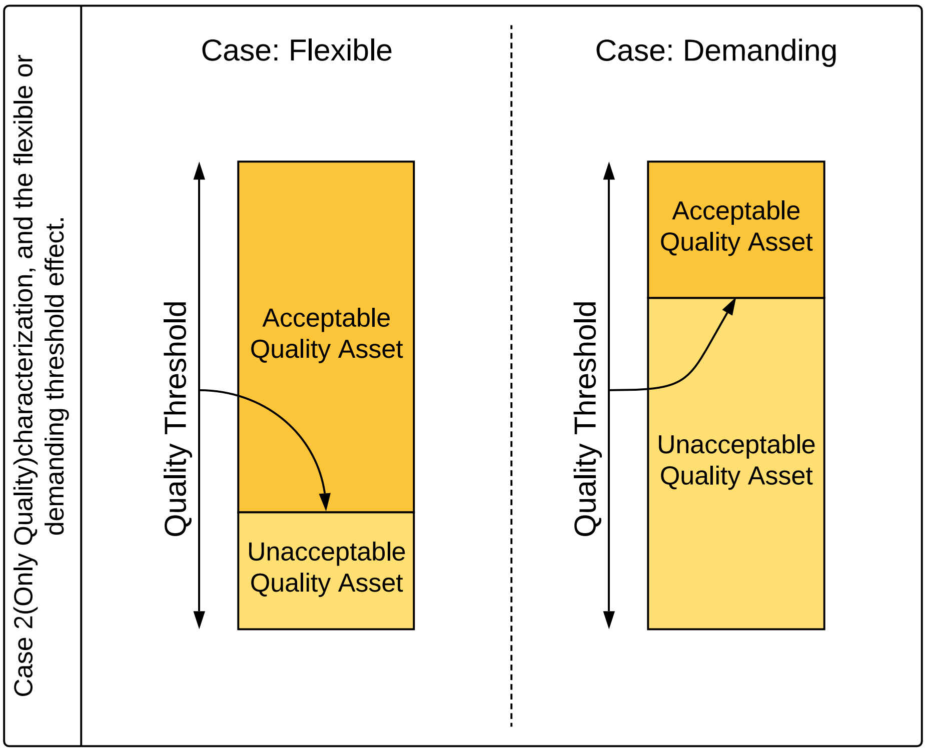

Figure 3.26 Case 2 - Only quality characterization and the effect of the threshold

As shown in the previous figure, there is a threshold that establishes the point in which a knowledge asset transits from one state to another among the two possible: The Acceptable Quality Asset, in bolder yellow, which is supposed to be the best, and the Unacceptable Quality Asset, in light yellow, which is supposed to be the worst.

The rules for this Quality Asset characterization are given by the value of the quality in regard to the established threshold, as shown in Table 9, in which both rules are given. In none of these cases may exist any impact value, but an only quality value that will determine the characterization state.

Table 9 Rule for characterization. Case 2 Only Quality

Rules for characterization					
If	$I_{VAL} \nexists$	and	$Q_{VAL} < Q_{th}$	then	Unacceptable Quality Asset
If	$I_{VAL} \nexists$	and	$Q_{VAL} \geq Q_{th}$	then	Acceptable Quality Asset

3.2.2.4. Case 3 characterization (Only Impact)

This only impact characterization of Knowledge Assets has two possible states: “Acceptable Impact Asset” and “Unacceptable Impact Asset”. Switching from one state to another depends on the individual impact valuation of a Knowledge asset in regard to the Impact threshold that has been stablished. In Figure 3.27 is shown the effect that the impact threshold has on the characterization in this case of absence of quality indicators.

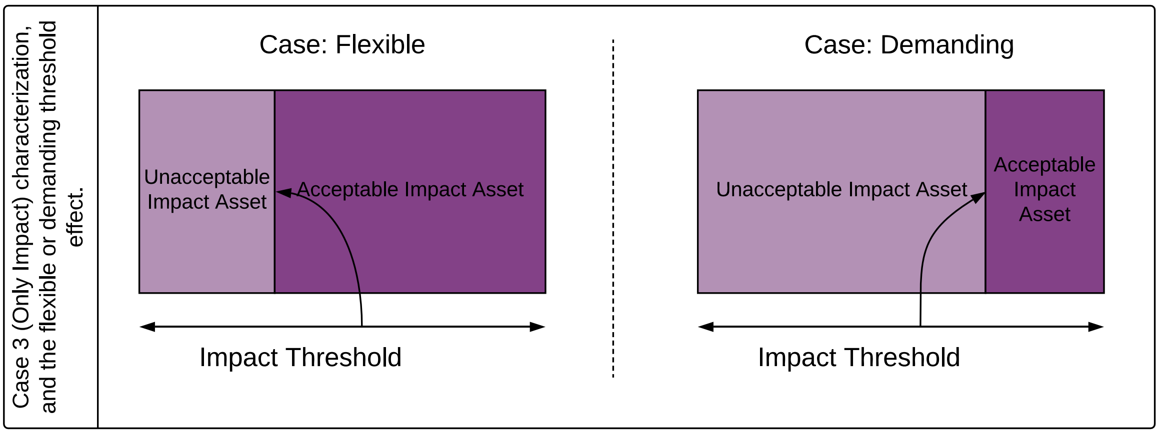

Figure 3.27 Case 3 - Only impact characterization and the effect of the threshold

The previous figure also shows that there is a threshold that establishes the point in which a knowledge asset transits from one state to another among the two possible: The Acceptable Impact Asset, in bolder purple, which is supposed to be the best, and the Unacceptable Impact Asset, in light purple, which is supposed to be the worst.

In other terms, the rule for this Impact Asset characterization is given by the value of the impact in regard to the established threshold, as shown in Table 10, in which both rules are given. In none of these cases may exist any quality value, but an only impact value that will determine the characterization state.

Table 10 Rule for characterization. Case 3 Only Impact

Rules for characterization					
If	$I_{VAL} < I_{th}$	and	$Q_{VAL} \nexists$	then	Unacceptable Impact Asset
If	$I_{VAL} \geq I_{th}$	and	$Q_{VAL} \nexists$	then	Acceptable Impact Asset

3.2.3. Recharacterization model using Markov chains

As described in section 3.1, besides providing a static analysis of the state of the knowledge assets (an actual picture), the SIPAC-framework aims at using the lessons of experimentation with real case studies that have accomplished with the following restrictions:

- Have deployed the SIPAC framework at least twice.
- Have implemented the suggested digital solution, after the first and before the second considered audit.
- Have granted permission to use its data for research.

Experiencing with several case studies that allowed the deployment of the SIPAC-framework and implemented the corresponding digital solution, have generated some data that opened the possibility of exploring such data to discover the behavioral patterns of knowledge assets, so that from these patterns, behavior estimation of knowledge assets of a new case study becomes possible.

3.2.3.1. Understanding the characterization process as a Markovian process

Since a knowledge asset is characterized in terms of its measures in a determined moment, it is possible to think of it as it can be in a different state in another moment. This is what really happens with the knowledge assets, that may be characterized after an organizational audit as one of the possible states but in the next audit it is characterized in another state, probably because some changes in organizational policy were made or as consequence of decision made.

3.2.3.2. Definition of states for each knowledge asset.

As stated in the characterization description section, there are eight possible characterization states for a knowledge asset. However, there are some conditions that must be considered:

- A KA with both impact and quality indicators (Case 1) may be characterized as Warning, Replaceable, Evolving or Stable.
- A KA with only impact indicators (Case 2) may be characterized as Acceptable Impact Asset or Unacceptable Impact Asset.
- A KA with only quality indicators (Case 3) may be characterized as Acceptable Quality Asset or Unacceptable Quality Asset.

The transition matrixes and state diagrams for such possible states of a KA can be represented as follows.

3.2.3.2.1. Case 1: both impact and quality driven KA.

For case 1, the transition matrix is shown in Table 11:

Table 11 Case 1 (KA with both quality and impact) state diagram

Transition probabilities		***Post***				
		Stable	Evolving	Replaceable	Warning	Σ
Pre	***Stable***	P11	P12	P13	P14	1
	Evolving	P21	P22	P23	P24	1
	Replaceable	P31	P32	P33	P34	1
	Warning	P41	P42	P43	P44	1

While the state diagram representative of both states and probabilities is shown in Figure 3.28.

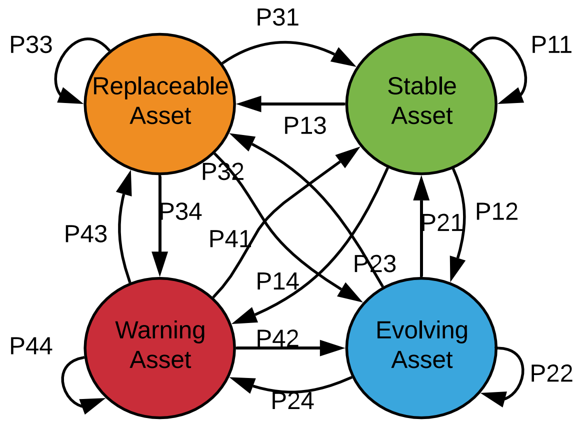

Figure 3.28 Case 1 (Ka with both impact and quality) state diagram

3.2.3.2.2. Case 2: only quality driven KA.

For case 2, the transition matrix is shown in Table 12:

Table 12 Transition matrix for the case of only quality knowledge assets

Transition probabilities	Unacceptable Quality Asset	Acceptable Quality Asset	Σ
Unacceptable Quality Asset	P55	P56	1
Acceptable Quality Asset	P65	P66	1

While the state diagram representative of both states and probabilities is shown in Figure 3.29.

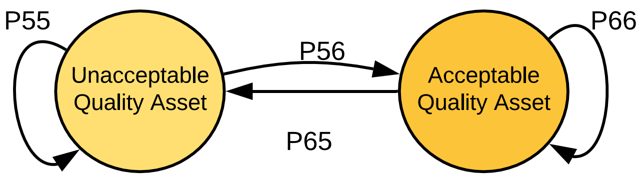

Figure 3.29 Case 2 (KA of only quality) state diagram

3.2.3.2.3. Case 3: only impact driven KA.

For case 3, the transition matrix is shown in Table 13:

Table 13 Transition matrix for the case of only impact knowledge assets

Transition probabilities	Unacceptable Impact Asset	Acceptable Impact Asset	Σ
Unacceptable Impact Asset	P77	P78	1
Acceptable Impact Asset	P87	P88	1

While the state diagram representative of both states and probabilities is shown in Figure 3.30.

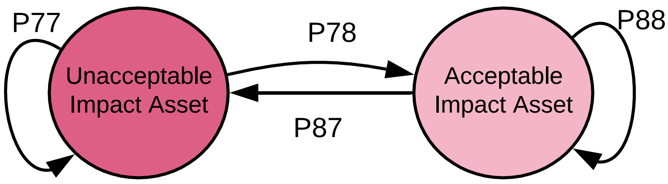

Figure 3.30 Case 3 (KA of only impact) state diagram

3.2.3.2.4. All cases: Transition matrix for all possible cases.

As a summary of all possible cases, Table 14 shows the all states transition matrix for the Markovian process of the characterization of the knowledge assets. By definition, there are three possible cases clearly distinguishable: both impact and quality, only impact and only quality knowledge assets. In Table 14 are shown the probabilities of possible transitions, while the others are shown as "-".

Table 14 Markov chain's transition matrix

Transition probabilities		Post								
		Stable	Evolving	Replaceable	Warning	Unacceptable Quality Asset	Acceptable Quality Asset	Unacceptable Impact Asset	Acceptable Impact Asset	Σ
Pre	***Stable***	P11	P12	P13	P14	-	-	-	-	1
	Evolving	P21	P22	P23	P24	-	-	-	-	1
	Replaceable	P31	P32	P33	P34	-	-	-	-	1
	Warning	P41	P42	P43	P44	-	-	-	-	1
	Unacceptable Quality Asset	-	-	-	-	P55	P56	-	-	1
	Acceptable Quality Asset	-	-	-	-	P65	P66	-	-	1
	Unacceptable Impact Asset	-	-	-	-	-	-	P77	P78	1
	Acceptable Impact Asset	-	-	-	-	-	-	P87	P88	1

The corresponding state diagram for the previous matrix is shown in Figure 3.31. There is a total of 8 possible states for a knowledge asset and the possible transitions are shown through the black arrows.

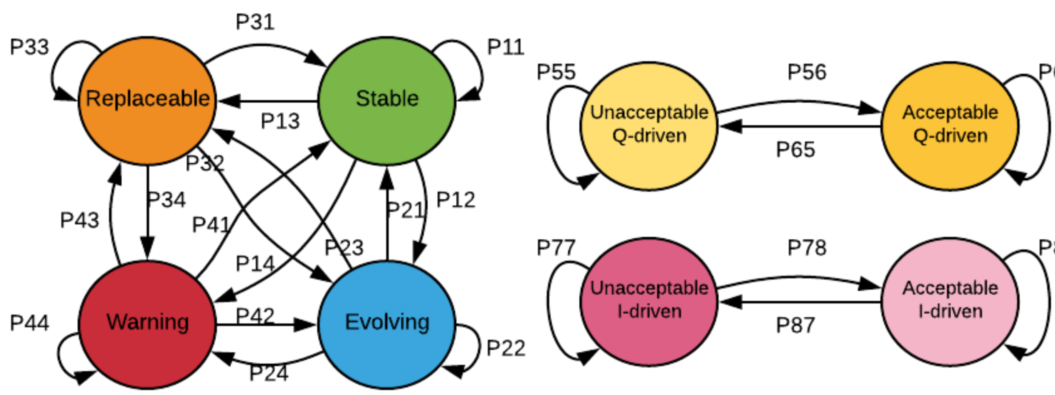

Figure 3.31 Full state diagram for the KA characterization

As it may be assumed, the cases of the characterization are mutually exclusive, i.e., a knowledge asset may correspond to only one of these three cases, which is why the probability matrix only shows valid probabilities within each of the cases, while the other spaces remain disabled.

3.2.3.3. The recharacterization of Knowledge Assets as an Experience-based Markovian Process

In order to discover the real probability values of the transitional matrix, an experience-based training was proposed taking advantage of the information available of companies (case studies) that have used the SIPAC-framework and implemented the suggested digital solution.

This matrix is generated by exploring each of the cases' audits and identifying the probability of knowledge assets to re-characterize or remain the same if the first and second audit are compared. The Figure 3.32 illustrates the process of exploring the information of cases available and updating the probability matrix, which is also presented as an automated method of the tool ahead presented in section 3.3.3.

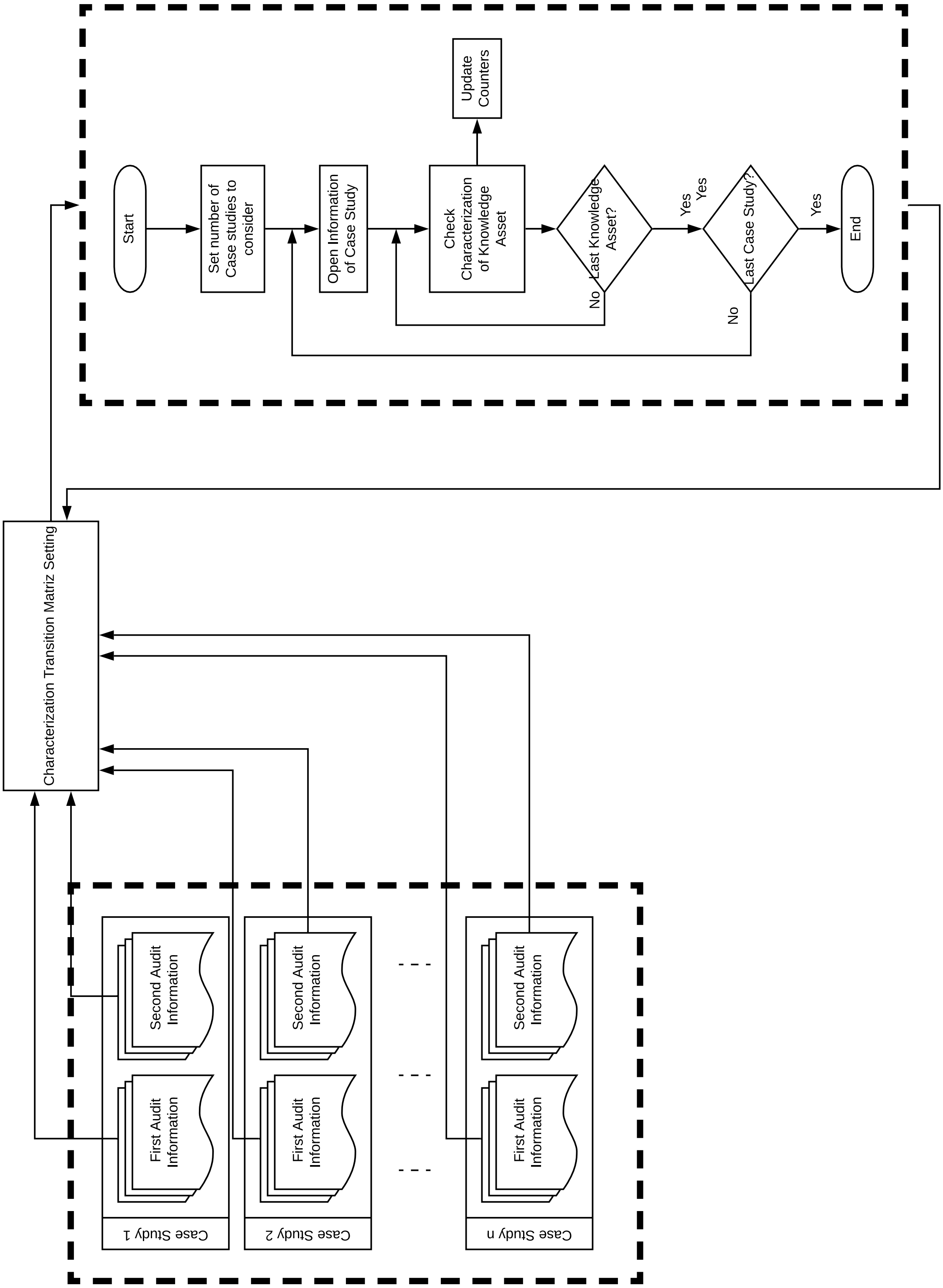

Figure 3.32 Probabilities of re-characterization geenration

For every knowledge asset, the previous characterization is identified as i, and the subsequent characterization is identified as j. Where the identification corresponds to the column ID of Table 15.

Table 15 Identification of characterization cases

ID	Case	Characterization
1	1	Stable
2	1	Evolving
3	1	Replaceable
4	1	Warning
5	2	Unacceptable Quality Asset
6	2	Acceptable Quality Asset
7	3	Unacceptable Impact Asset
8	3	Acceptable Impact Asset

In order to obtain the probability matrix, first an occurrence matrix must be obtained by exploring the previous and subsequent characterization states of every knowledge asset. Form this, the occurrence Occ_i^j of a transition is defined as the count of times in which knowledge assets switch from the previous i characterization state to the subsequent j characterization state. The whole set of possible transitions is presented in Table 16.

Table 16 Occurrence matrix from training

		Subsequent Characterization State								
		1	2	3	4	5	6	7	8	$\sum Occ_i$
Previous Characterization State	1	Occ_1^1	Occ_1^2	Occ_1^3	Occ_1^4	0	0	0	0	$\sum Occ_1$
	2	Occ_2^1	Occ_2^2	Occ_2^3	Occ_2^4	0	0	0	0	$\sum Occ_2$
	3	Occ_3^1	Occ_3^2	Occ_3^3	Occ_3^4	0	0	0	0	$\sum Occ_3$
	4	Occ_4^1	Occ_4^2	Occ_4^3	Occ_4^4	0	0	0	0	$\sum Occ_4$
	5	0	0	0	0	Occ_5^5	Occ_5^6	0	0	$\sum Occ_5$
	6	0	0	0	0	Occ_6^5	Occ_6^6	0	0	$\sum Occ_6$
	7	0	0	0	0	0	0	Occ_7^7	Occ_7^8	$\sum Occ_7$
	8	0	0	0	0	0	0	Occ_8^7	Occ_8^8	$\sum Occ_8$
		$\sum Occ^1$	$\sum Occ^2$	$\sum Occ^3$	$\sum Occ^4$	$\sum Occ^5$	$\sum Occ^6$	$\sum Occ^7$	$\sum Occ^8$	$\sum_{i=1}^{8}\sum_{j=1}^{8} Occ_i^j$

From this occurrence matrix the probability matrix can be directly degenerated. For this re-characterization probability matrix estimation to make sense, some restrictions must be considered.

- Type q (both impact and quality) knowledge assets can only be characterized as 1, 2, 3 or 4.
- There is a considerable number of case studies $n = n_1 + n_2 + n_1 + \cdots + n_n$, each with a determined k_n number of knowledge assets, summing up $k = k_1 + k_2 + \cdots + k_n$.
- The total number of knowledge assets considering the total cases for training, corresponds to the total number of transitions of the occurrence matrix, so:

$$k = \sum_{i=1}^{8} \sum_{j=1}^{8} Occ_i^j$$

- For each case study we have two audits: previous and subsequent to the implementation of the suggested digital solution.

Given a ***n*** number of case studies, and for so the occurrence matrix given before, for each I known previous ***i*** state, the probability of transition to the ***j*** state is given by Equation 3-10

$$p_i^j = \frac{Occ_i^j}{\sum Occ_i}$$

Equation 3-10 Probability of re-characterization of a knowledge asset definition.

The previous probability equation and the considered restrictions to the type of knowledge asset from their quality or impact nature, allows us to know the transitional probability matrix to use for the model of re-characterization of knowledge assets, as shown in Table 17.

Table 17 KA Transitional probability matrix

		Subsequent Characterization State								
Previous Characterization State		1	2	3	4	5	6	7	8	$\sum p_i$
	1	p_1^1	p_1^2	p_1^3	p_1^4	0	0	0	0	1
	2	p_2^1	p_2^2	p_2^3	p_2^4	0	0	0	0	1
	3	p_3^1	p_3^2	p_3^3	p_3^4	0	0	0	0	1
	4	p_4^1	p_4^2	p_4^3	p_4^4	0	0	0	0	1
	5	0	0	0	0	p_5^5	p_5^6	0	0	1
	6	0	0	0	0	p_6^5	p_6^6	0	0	1
	7	0	0	0	0	0	0	p_7^7	p_7^8	1
	8	0	0	0	0	0	0	p_8^7	p_8^8	1

From the previous matrix, it can be said that a given knowledge asset previously characterized as i can only be recharacterized as

- $\{1|2|3|4\}\ if\ (i = 1|2|3|4)$ [i.e. the case of both quality and impact]
- $\{5|6\}\ if\ (i = 5|6)$ [i.e. the case of only quality]
- $\{7|8\}\ if\ (i = 7|8)$ [i.e. the case of only impact]

3.2.4. The re-characterization as an implementation of the Instance-based Learning (IBL) model

3.2.4.1. Decisions from experience adjustment

3.2.4.1.1. The instances definition

The IBL (instance-based learning) model (Lejarraga, Dutt, & Gonzalez, 2012) focuses on characterizing the learning of dynamics tasks through instances which are stored in a "memory" representing the experimentation with decision making events. The instances to be considered in the dynamic decision-making process of the SIPAC-framework refer to the digital solution selection, and are the triplets defined to represent the memory of an expert "decision-maker" in the context of the implementation of a digital solution from the deployment of the SIPAC-framework. According to the IBL model, instances are composed of a situation "S", a decision "D" and an obtained utility "U". We describe the instances of the experience-based software solution selection problem below, emulating the process of decision making in regard to the selection of a digital solution within a company organizational context.

The specific combination of triplets Situation-Decision-Utility for the software selection problem is shown in Table 18.

Table 18 Structure of an instance: situation, decision and utility

<table>
<tr><td rowspan="3"></td><td colspan="3">Instances</td></tr>
<tr><td>Situation (S)</td><td>Decision (D)</td><td>Utility (U)</td></tr>
<tr><td>Transition from the "PRE" characterization state to the "POST" characterization state
PRE→POST</td><td>Decision to be made by the decision maker in the given situation (S)</td><td>Income earned from making the decision (D) in the situation (S)</td></tr>
<tr><td rowspan="16">Type 1: both impact and quality</td><td>Warning→ Warning</td><td rowspan="24">A: Implement a specific technological solution aligned with the client's business goal and supported by client know-how

B: Do not implement any change at the company</td><td rowspan="24">Income earned</td></tr>
<tr><td>Warning→ Evolving</td></tr>
<tr><td>Warning→ Replaceable</td></tr>
<tr><td>Warning→ Stable</td></tr>
<tr><td>Evolving → Warning</td></tr>
<tr><td>Evolving → Evolving</td></tr>
<tr><td>Evolving → Replaceable</td></tr>
<tr><td>Evolving → Stable</td></tr>
<tr><td>Replaceable → Warning</td></tr>
<tr><td>Replaceable → Evolving</td></tr>
<tr><td>Replaceable → Replaceable</td></tr>
<tr><td>Replaceable → Stable</td></tr>
<tr><td>Stable → Warning</td></tr>
<tr><td>Stable → Evolving</td></tr>
<tr><td>Stable → Replaceable</td></tr>
<tr><td>Stable → Stable</td></tr>
<tr><td rowspan="4">Type 2: only quality</td><td>Unacceptable Quality Asset → Unacceptable Quality Asset</td></tr>
<tr><td>Unacceptable Quality Asset → Acceptable Quality Asset</td></tr>
<tr><td>Acceptable Quality Asset → Unacceptable Quality Asset</td></tr>
<tr><td>Acceptable Quality Asset → Acceptable Quality Asset</td></tr>
<tr><td rowspan="4">Type 3: only impact</td><td>Unacceptable Impact Asset → Unacceptable Impact Asset</td></tr>
<tr><td>Unacceptable Impact Asset → Acceptable Impact Asset</td></tr>
<tr><td>Acceptable Impact Asset → Unacceptable Impact Asset</td></tr>
<tr><td>Acceptable Impact Asset → Acceptable Impact Asset</td></tr>
</table>

3.2.4.1.1.1. Situation (S)

In dynamic decision making, in accordance to the IBL model, the situation of an instance is defined by all the elements that describe a subsystem state at any time in which a decision is made. They could be regarded as *state variables* that describe the subsystem at a given time and distinguish it from the subsystem state at another point in time. For the problem at hand, *situation* in the proposed model means a pair of states for each knowledge asset, a preceding one and a subsequent one. The knowledge assets state is determined according to the characterization of knowledge assets described in section 3.2.2 based on the work of (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2017; Sanchez-Segura, Ruiz-Robles, Medina-Dominguez, et al., 2017), which may characterize each knowledge asset as evolving, stable, warning, replaceable, acceptable/unacceptable of only quality and acceptable/unacceptable of only impact. Since there are eight possible characterization states for the knowledge assets and two transitional states (pre and post decision), a total of 4^2(type 1)+2^2(type 2)+2^2(type 3)=24 pairs of states are used to define the possible situations of these instances as the transition between two of these eight possible characterization states, taking into consideration that knowledge assets of both quality and impact have four possible states, while only impact or only quality knowledge assets may have two possible states (see Table 18, before). For example, the *situation* of an instance could be the transition of a knowledge asset from *Evolving* to *Stable* after a decision is made.

3.2.4.1.1.2. Decisions (D)

The decision to be considered in this model is defined as the selection of one of two alternatives: (A) Implement a technological solution suggested by the IT/SW professional as the best alternative for achieving the client's business goal based on the client know-how, or (B) Do not implement any change at the company (see column 2 of Table 18). These decisions can be regarded as experience-based decisions (Gonzalez, 2013), since the decision maker will discover the outcomes and their probabilities while addressing the stated problem with abstract tools and models, such as simulations).

The IBL model is open to the possibility of considering more than two decisions. As far as we are concerned here, it makes more sense to consider the real options open to the client company when it has to make a decision to meet its needs: whether or not to accept the IT/SW professional's knowledge-based proposal.

The decision made will result in significant and far-reaching changes to the client company, since big decisions entail big responsibilities. Irrespective of the decision made on whether or not to implement the technological solution, knowledge assets can mutate. Consequently, the state of the company's knowledge assets can, according to this model, change, leading to a chain reaction within the company. Accordingly, the company can, for example be more sustainable (among other benefits) the better state of the knowledge assets is. It is not currently possible to predict the evolution of a company with respect to a change in the state of its knowledge assets. Therefore, the aim of the proposed model is to predict the impact of the implementation of a software or technological solution proposed by a software engineer on the state of the client company's knowledge assets.

3.2.4.1.1.3. Utility (U)

Generally speaking, utility (U) can, according to the IBL model, be regarded as the outcome of making a decision D in the situation S. For the digital solution selection decision-making problem, the utility is determined by the difference between the income of a business case in the previous audit and the income in the subsequent audit, i.e., given the previous (I_p) and subsequent (I_s) incomes of a company, the utility (U) of its related instances is defined by Equation 3-11.

$$\boldsymbol{U = \Delta I = I_p - I_s}$$

Equation 3-11 Utility as the variation of income of a company

The decision maker is considered to be the company stakeholder responsible for determining which decision to make, i.e., the chief information officer, the chief executive officer, the IT director, etc. Company success is reflected in the characterization of its knowledge assets: a good decision will result in better characterized knowledge assets, and a bad decision will not lead to changes or will degrade the knowledge asset characterization. Ultimately, this will have a direct effect on organizational profit. In this model, utility is defined as the difference of a company's revenue, as explained by Equation 3-11, which comes as an effect of strategic decisions and how these affect each knowledge asset, and by extension on the company's profit.

For the decision maker, this instance-based learning model the utility is expected to represent the effect of decisions, which is why good decisions are expected to generate a positive utility (reward), and bad decisions are expected to generate a poor or even negative utility (punishment).

Assuming that several case studies used the SIPAC-framework, a generic utility matrix can be obtained, similarly to the occurrence or probability matrixes previously presented. This generic utility matrix is an estimation of the effectivity of the SIPAC-framework on its commit to improve organizational knowledge assets from the implementation of digital solutions specifically aligned with strategic goals achievement. Table 19 illustrates the generic utility matrix, which the more cases are used the more precise will be.

Table 19 Reward/Punishment (utility) for knowledge assets characterization transition

		Post-decision state (t+1)							
		Stable (S)	Evolving (E)	Replaceable (R)	Warning (W)	Acceptable Quality Asset	Unacceptable Quality Asset	Acceptable Impact Asset	Unacceptable Impact Asset
Pre-decision state (t)	Stable (S)	R_{S-S}	R_{S-E}	R_{S-R}	R_{S-W}	--	--	--	--
	Evolving (E)	R_{E-S}	R_{E-E}	R_{E-R}	R_{E-W}	--	--	--	--
	Replaceable (R)	R_{R-S}	R_{R-E}	R_{R-R}	R_{R-W}	--	--	--	--
	Warning (W)	R_{W-S}	R_{W-E}	R_{W-R}	R_{W-W}	--	--	--	--
	Acceptable Quality Asset	--	--	--	--	R_{AQ-AQ}	R_{AQ-UQ}	--	--
	Unacceptable Quality Asset	--	--	--	--	R_{UQ-AQ}	R_{UQ-UQ}	--	--
	Acceptable Impact Asset	--	--	--	--	--	--	R_{AI-AI}	R_{AI-UI}
	Unacceptable Impact Asset	--	--	--	--	--	--	R_{UI-AI}	R_{UI-UI}

According to Table 19, the utility for a knowledge asset previously characterized as *evolving* and subsequently characterized as *stable* is $R_{E\text{-}S}$. This should correspond to a specific variation on a company's revenue, however, it may be representative of other forms of utility that can be measured and compared so enabling the generation of a difference, or ΔI.

$$\text{If } CH_t = E \text{ and } CH_{t+1} = S\text{, then } R(Evolving \rightarrow Stable) = R_{E-S}.$$

Generally speaking, let us suppose that a knowledge asset has been characterized as *evolving* and is recharacterized as *stable* as a result of making the decision to implement the technological solution X, and the decision maker was rewarded with a positive difference of 80(%). The instance could be defined, for example, as:

- Situation (S) = Evolving→Stable
- Decision (D) = Implement technological solution X
- Utility (U)= 80.

3.2.4.2. The process of dynamic decision making

In this proposal, the technology selection decision-making problem process is conceived as a dynamic decision-making process from the perspective of the Instance Based Learning theory, which is shown in Figure 3.33.

The IBL-model has been widely used to represent several types of decisions, as presented in section 2.8.1, however we have used it to represent the dynamics of a very different kind of decisions: strategic decisions in regard to a digital solution implementation. While frequently used to represent trivial decisions own of the human mind, our research proposes to mimic such cognitive process, aiming to design a method to explore and valuate choices before making proper decision, first from a simulated model but at last willing to nurture real decision making.

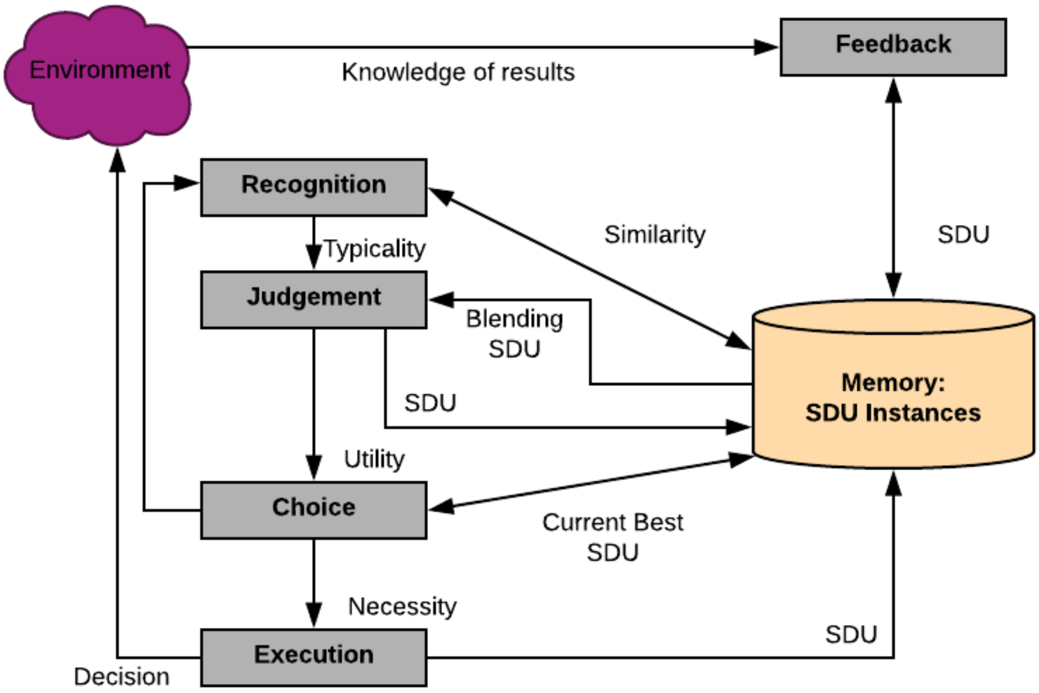

Figure 3.33 The IBLT process

This process related to making decisions in the IBL-model is better understood by explaining the following subprocesses that represent the decision-making learning process implicit in the implementation shown before in Figure 3.16, based on instances with triplets of information about experiences containing a situation (S), a related decision (D) and the utility obtained (U).

3.2.4.2.1. Recognition

Experience-based decisions in any field depend on repeated decisions and trial and error. This can turn out to be extremely expensive and unaffordable in the technological domain, because the implementations of software and digital solutions is expensive if thought for mere exploration. Generally, only consultants, consultancy firms and very good decision makers who charge people or companies massive bills for giving advice or providing a consulting service have the experience required to choose between technological solutions. When thousands or billons of euros are at risk, the services of a talented decision maker who has already had several experiences in making similar risky decisions and achieved good outcomes will be required to make the choice between two or more alternatives. Therefore, it is necessary to account for previous experiences on the use and implementation of digital solutions, which is what the experienced decision-maker has. These experiences represent *instances* including information on decisions made under similar conditions; instances that are used while needed as a result of an expert ability to connect and correlate situations and variables by similarities.

The instances refer to or contain information on how decisions regarding a technological solution have been made in the past but are not easily accessible. The decision making based on this is potentially very useful, however, it is based on a paradigm that we believe should evolve towards a decision-making approach that is closer to the client's reality, that is, more clearly linked with the client's business needs.

We propose a perspective shift with respect to how software engineers make decisions about the most suitable solution for a client from a technological viewpoint. Clients have business goals to achieve and are very much aware that business goal achievement will guarantee survivability. Any action taken by the company, including, of course, technological options in the knowledge era, must be based on the client's business goals and know-how. This leads to the question of how a software engineer can demonstrate that the proposed solution is aligned with the client's business goal. The purpose of the model proposed here is to provide the client with evidence of why the proposed solution relates to both its know-how and its business goals.

Based on memories of decisions and situations accounting for company know-how and business goal alignment, the recognition is represented in this simulation model by the knowledge assets characterization. Simulation modelling will explore all possibilities and create memories that are impossible to investigate in real life, building a set of references that can be queried when a new decision has to be made and an experienced opinion is required.

3.2.4.2.2. Judgement

Judgement involves evaluating the expected utility of alternatives based on experience or heuristics (Gonzalez, 2017). This software selection decision-making model will judge between alternatives based on simulated experiences that previously explored the alternatives and their related situations, decisions and utility.

Experienced decision makers routinely enact this judgement process intuitively when they resort to their memory and experience to compare environmental and special conditions and user needs. The actual procedure is to activate their memories to recall what the results (outcomes) of each of the alternatives would be. Our model implements this cognitive subprocess by storing and comparing simulated instances (experiences) that represent the decision maker's memories of the results previously achieved using the different alternatives at hand. For each pair of alternatives, this model uses the *blending* mechanism to estimate which option is best. Given that each instance will be associated with one of two decisions, and each of the instances has an associated utility, the *dominant* (higher) average utility will define the blended value for each of the decisions (as detailed in Section 3.3.2.). This will determine the best of the two alternatives for selection.

For example, the state of a company's knowledge assets (warning, evolving, replaceable or stable) may have changed as a consequence of simulated decisions. In the hypothetical scenario that a company's knowledge asset switched from warning to stable as a consequence of implementing a software or technological solution, the company's defined utility is expected to be very good. It will, in any case, be better than for the again hypothetical scenario in which another technological solution for the same company failed to change the state of the knowledge asset from warning or slightly improved its state to replaceable.

3.2.4.2.3. Choice

The act of choice consists of selecting the best alternative based on the above judgement. Thanks to the judgement subprocess, the decision maker can create a criterion for selection based on the expected utility, i.e., the highest blended value. The simulated model compares the results based on experiences with all of the alternatives under evaluation (two in our case, see column 2 of Table 18). It then selects the alternative decision that is expected to yield the best possible outcome as the best choice. In this model, the decision criterion is denoted by the blended value, an IBL model artefact that calculates a value for each of the choices as a function of activation and results.

3.2.4.2.4. Execution

The execution subprocess is the implementation of the selected decision, or, in other words, the implementation of the technological solution that the model considers best for satisfying the client's needs. In industry, the technological solution is deployed with or without the intervention of the expert. Big companies have their own personnel with experience in deploying technological solutions who receive dynamic feedback and supervision. In small- and medium-sized companies, however, the consulting role is mostly performed by an expert who is paid an hourly rate for evaluating the situation, advising on decision making and providing feedback after solution implementation. Execution in this simulated model is determined by the company's knowledge asset transition probabilities.

Good or bad decision making in regard to the software solution would, in real life, entail high economic and performance risks that not every company can afford. Through simulation modelling, however, a company can experiment without putting economic or organizational factors at risk, gaining, at the same time, valuable knowledge that will support decision making and provide a general understanding of company dynamics.

The effect of implementing a solution at a client company will be represented by the recharacterization of the intangible assets as a result of solution deployment. This in turn depends on the pre-calibrated probabilities of transition determined for each client organization (see Table 20), i.e., a company with a better maturity level will have higher probabilities of recharacterizing its knowledge assets after the deployment of an adequate software solution.

Table 20. Transition probability matrix related to a decision.

Transition probabilities		*Post*				
		Stable	Evolving	Replaceable	Warning	Σ
Pre	***Stable***	P11	P12	P13	P14	1
	Evolving	P21	P22	P23	P24	1
	Replaceable	P31	P32	P33	P34	1
	Warning	P41	P42	P43	P44	1

3.2.4.2.5. Feedback

The feedback subprocess consists of updating the utility of an instance according to its activation based on several experiences. Although the transition will be determined by a transition probability matrix, there is a small probability of counterintuitive selection in simulation modelling. Accordingly, the model can explore in breadth all the possibilities and update the utility based on the better choices.

The learning mechanism is implemented in any IBL model implementation by a feedback loop. If the model is to be really dynamic, a learning process should be enacted for each of the experiences. In this model, after an experience has been *gained*, its related instance that is stored in memory is updated. Formally, feedback entails selecting the instances to be reinforced and the rate of reinforcement of the utility of these instances (Gonzalez, 2013).

In this model, the activation parameter of an instance agent, as well as the instance's expected utility, is updated as part of the feedback. The pool of instances available for comparison at the time of the memory query is then updated to give a clear picture of the best and worst instances. This causes the model to choose the alternative that would produce the best outcome. Since the decision-making process is simulated repeatedly, the impact of recognizing and updating the instances as representative of better and worse rewards is very useful for both the software engineer (who can demonstrate the benefits of good decision making, increasing the probabilities of making a deal) and the client (who can foresee the benefits of making good decisions aligned with company business goals achievement).

3.2.4.3. Implementation of learning mechanisms through simulation models

As part of the above decision-making process, there are several mechanisms enabling the learning process in the proposed dynamic decision-making model. The Smart Decision-Making Module of the simulation module appears here and will implement all the presented decision-making model.

The learning mechanisms represented in this model were originally presented first as part of the ACT-R cognitive architecture, and second as part of the IBL model. The most representative mechanisms are described below.

3.2.4.3.1. Prepopulation

In view of the complexity of the situations dealt with here, involving a transition between states, all the options need to be considered to begin with. For this purpose, a prepopulation of agents (instances) is initially deployed. The prepopulation process consists of creating all possible decision-making process instances. To do this, all the choices for the pre and post characterization states should be considered, as shown in Figure 3.45. Given that there are 4^4 possible transitions between before (PRE) and after (POST) characterization states and two possible decisions (N_D), the number of initial instances will be determined as follows:

Number of initial instances:

$$N = N_D * PRE^{POST} = 2 * 4^4 = 32\ instances.$$

3.2.4.3.2. Blending

The blending mechanism is inspired by *blending* in the original proposal introduced by Lebiere (Lebiere, 1999). It is used to assess the attractiveness of different alternatives based on previous outcomes. Given that the simulation model is used to carry out several experiments, instances saved in memory contain attributes that can be used to compare the alternatives. In the particular case of the software selection problem, the comparison is carried out as a selection model based on the blended values calculated for each of the choices. In previous experiences, all the choice options and outcomes will have been saved as instances. The best option will represent the decision (A or B) with the greatest expected utility (reward) based on previous experiences.

3.3. Technological layer: operational and technological artefacts

3.3.1. Spreadsheet for conducting knowledge audit interviews.

The SIPAC-framework comprehends in Stage 2 the collection of information of the complex situation related to an organization's objectives and knowledge state. In order to facilitate the work of interacting with companies, stakeholders and relevant information holders, and aiming to collect relevant information, a 10-sheets excel document with a specific format was used. This spreadsheet comprehends 10 sections, each one representing a specific step of the data collection process. The general aspect of this document is shown in Figure 3.34.

- Step 1: Business goal definition
- Step 2: Business requirement specification
- Step 3: Process definition
- Step 4: Generic classification of Knowledge Assets.
- Step 5: Knowledge Assets definition.
- Step 6: Knowledge Assets classification as Intellectual Capital.
- Step 7: KA's Indicators definition.
- Step 8: KA's Indicators parametrization.
- Step 9: Knowledge Assets valuation.
- Step 10: Knowledge Assets Characterization.

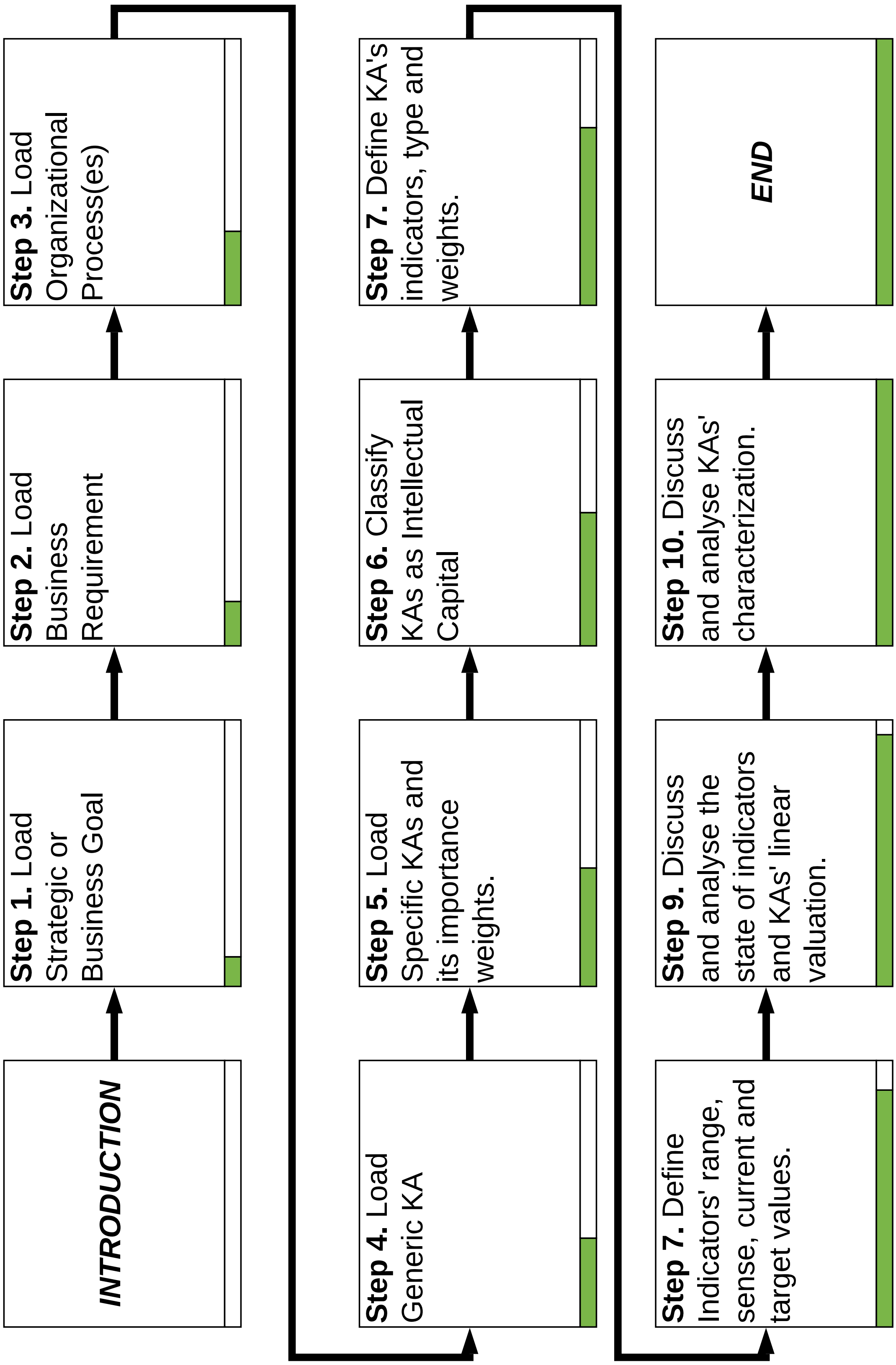

Figure 3.34 Data collection spreadsheet

Important to note is that this spreadsheet although useful for managing and obtaining the information, has the main use of effectively collecting the information, which is then processed and migrated to more reliable and exploitable formats such as databases and web applications.

Specifically in accordance with the SIPAC-framework, the information collected in the spreadsheet is uploaded to the application that will be ahead presented in section 3.3.2, which also exports it so that can be then imported by the simulation tool presented in section 3.3.3.

3.3.2. Tool for knowledge audit information upload and reports generation.

To be used also while the stage 2 of the SIPAC-framework is deployed, this tool consist in a web application available at http://spaengineering.sel.inf.uc3m.es/ aimed at collecting all the information of a company, such as the business goal, processes, knowledge assets, indicators of knowledge assets, etc. Importantly, this tool is able to export .csv files with the specific format that the simulation tool of the next section requires.

One might say that both the spreadsheet presented in section 3.3.1, and this application are aimed at the same thing, however, the difference is given by the effective use that can be made of each of them, since the spreadsheet is useful for collecting information at the moment of interacting with the client company stakeholder, providing a general view in a format familiar to the client and allowing immediate changes and corrections as needed. Differing from this, the technological tool of this section is intended to allow the upload of correct and validated information that has been already double checked by the intervenor (The IT/SW professional) and the client.

This technological tool was developed considering the steps involved in the deployment of a knowledge audit of the SIPAC-framework, that is, the methodological steps that have been mentioned in the first layer (section 3.1) of the entire proposed solution. The software engineer must follow a series of steps in order to record the corresponding information and thus have the reports and data available. The step-by-step process of using this technological tool includes:

- Step 1 consists in choosing the strategic objective that must be reached and the process that must be improved.
- Then, in step 2, the specific knowledge assets of the organization are identified. When all these have been identified, they are classified into the three types of intellectual capital according to the Intellectus model (Bueno, del Real, Fernández, et al., 2011): human capital, structural capital and relational capital.
- In step 3, the link between intangible assets and business objectives is established through the processes of the organization.
- Then, in step 4, the indicators that measure these intangible assets are defined and identified, which will be decisive for the characterization proposed in section 3.2.2.
- In step 5, the current and target values of the indicators of the intangible assets within the organization are specified, the range of values within which the indicator may be, and whether it is of the quality or impact type.
- Finally, step 6 includes the storage of information, the static characterization of assets according to the characterization model of section 3.2.2, and the generation of reports, both in PDF format and in CSV format so that it can be used by the tool simulation presented in the next section 3.3.3.

The step-by-step use of this technological tool is presented in Figure 3.35.

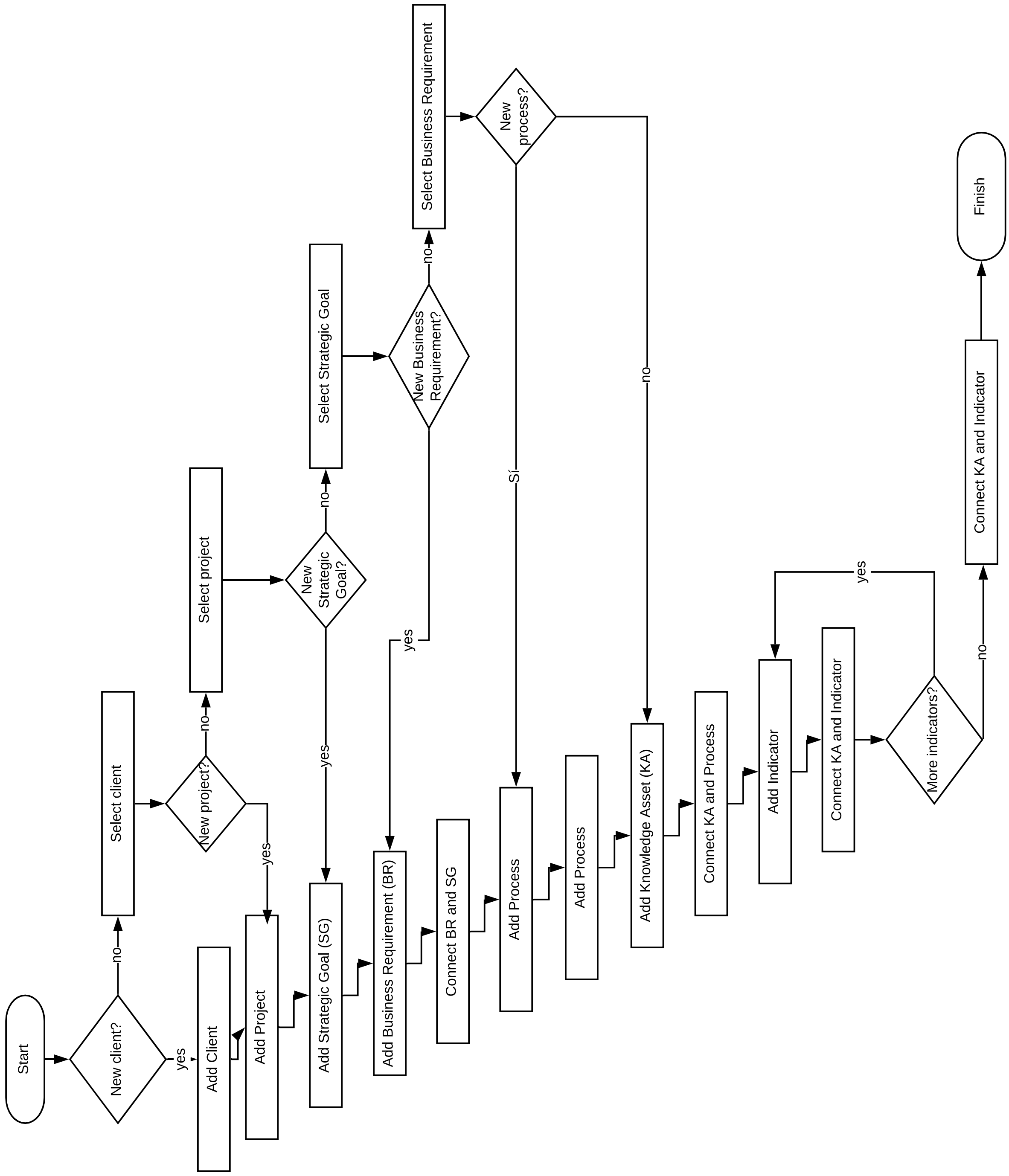

Figure 3.35 Workflow for the KA's database management technological tool

In regard to the reports that may be obtained through the manipulation of this tool, an example is the shown in Figure 3.36. This figure shows a graph that illustrates the existent relations between a strategic goal and the identified knowledge assets, as well as the relations between a knowledge asset and its related indicators. Besides just showing the relations, there is a colors code for the indicators and the knowledge assets that corresponds to the characterization colors proposed in section 3.2.3.

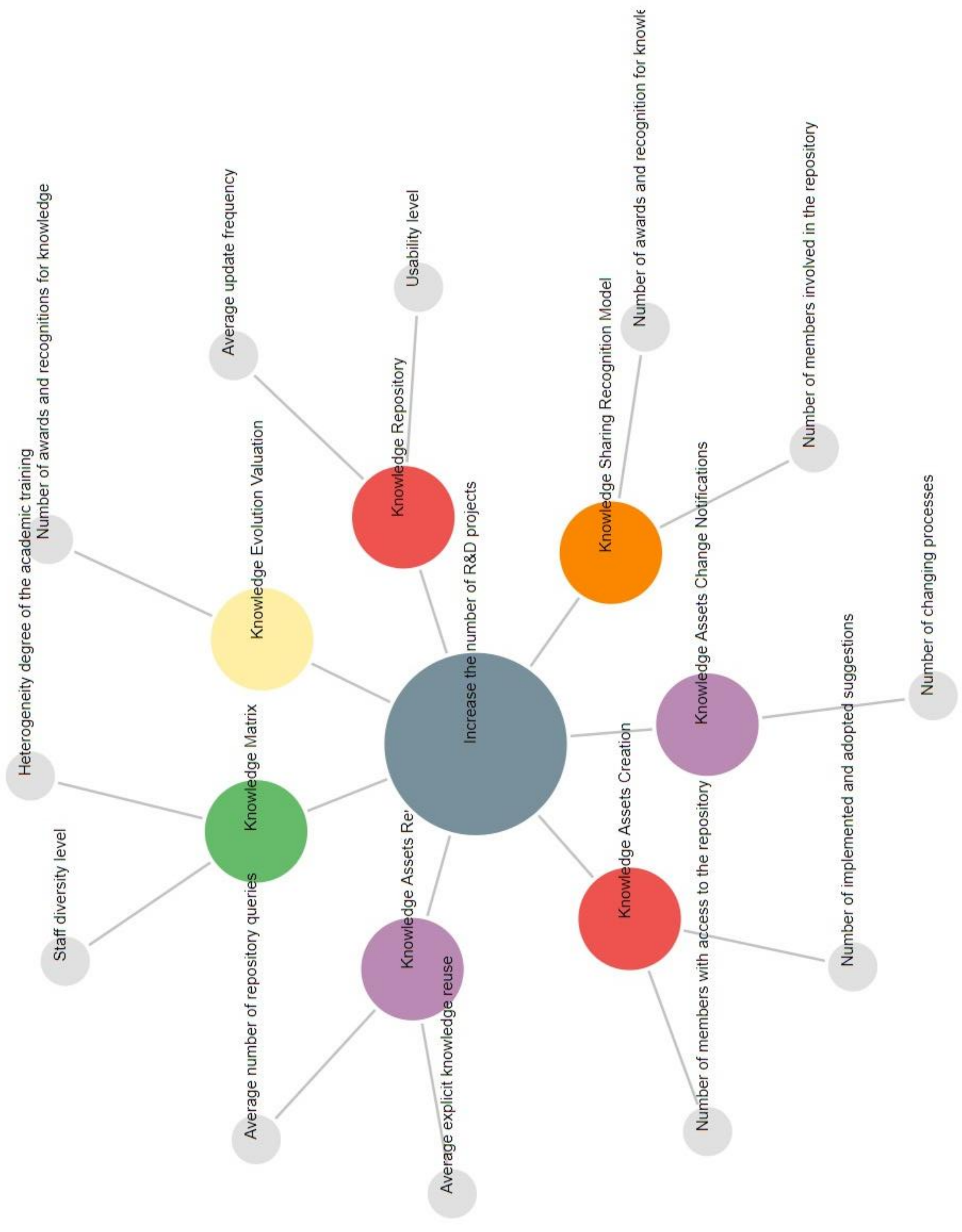

Figure 3.36 Graph relating a strategic goal, the knowledge assets and the corresponding indicators

3.3.3. Simulation model of knowledge assets behavior.

The SIPAC-framework suggests the use of this simulation model in two of the stages that it comprehends. Section 3.3.3.1 presents the simulation model module that characterizes knowledge assets in correspondence to stage 4, and section 3.3.3.2 presents the simulation model module aimed at representing the prediction of the impact that the SIPAC-framework technological proposal may have on the knowledge assets evolution, based on an IBL-model representation of dynamics decisions in this regard. Both simulation modules become an input for decisions to be made in the real organizational context.

3.3.3.1. Agents-based characterization of knowledge assets.

In what follows we present the description of the module "valuation and characterization" of the simulation model which concerns the initial characterization of knowledge assets. The other parts of the simulation tool regarding decision making will be presented as the decision-making module, ahead in section 3.3.3.2.

By using this agents-based model, the IT/SW professional can automatically represent the process of characterization of the knowledge assets of a company. To do so, the model manipulator (i.e., the IT/SW professional or even a company stakeholder) has several alternatives:

- To select from preloaded cases a specific case characterization.
- To upload a csv file with information of a new case and characterize its knowledge assets.
- To manually step-by-step load data of a new case and do the static characterization.

Besides characterizing, the model manipulator can set the impact and quality thresholds that define the characterization, that is, the values of standardized quality and impact valuations, so that the characterization may be more or less flexible form the configured thresholds.

It is important to note that this characterization has been described as "static" since it represents the states of the knowledge assets at the time the previous audit is made, so it is possible to strategically open discussions like:

- How would the knowledge assets characterize if they were in a better state?
- How would they re-characterize if we as decision makers are more flexible (configuring lower impact and quality thresholds) or more demanding (higher impact and quality thresholds).
- What means that, as a whole, most of the knowledge assets tend to characterize as stable or warning, as an example.
- What assets do we need to strategically focus on if our interest is to improve the impact on the strategic goals?
- What assets are in best state so that we can use them as levers or inputs for a strategic improvement deployment?

3.3.3.1.1. The control panel for valuation and characterization

The control panel for characterization, shown in Figure 3.37, allows the IT/SW professional to use the model to valuate and characterize the knowledge assets of a client company. This control panel guides the IT/SW professional through four general steps for using it to characterize knowledge assets.

Step 1: Reset stored information and load data

This section allows the manipulator to reset any pre-stored temporal data, any knowledge assets existent, and any value that could be previously been computed within previous experiments. In other words, it prepares the model to perform a new experiment.

The "Train from other cases" button calls for function to read external information of case studies in csv format. Particularly, this button loads previous audits of case studies so that ahead in following steps this information can be used for both showing the static characterization for different audits or for training the simulation model presented in section 3.3.3.2.

Step 2: Data loading mode selection and operation

From the execution of the previous "Train from other cases" button, the simulation model has some pre-stored cases useful when simulation tools is used to show how it operates yet, i.e. it is useful in the process of discussion with a client about the effectiveness of the SIPAC-framework and all co-related provision of services by the IT/SW professional. The illustration of pre and post SIPAC-framework intervention audits and thus the knowledge assets states is usable to encourage a client to decide to take advantage of the SUIPAC framework and allows its deployment.

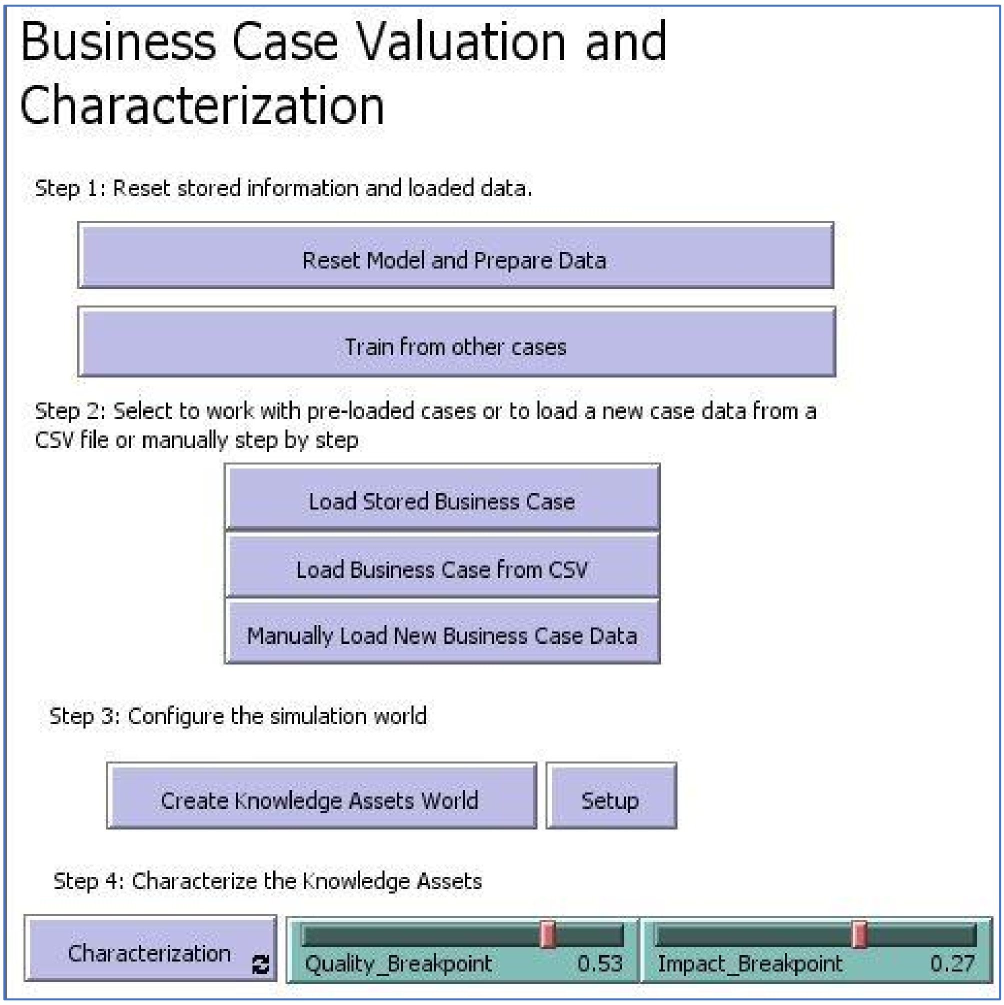

Figure 3.37 The control panel for characterization

Also, this panel allows the IT/SW professional to load a specific case study from a CSV file (using the "Load Business Case from CSV" button), which is useful when stages 1, 2, 3 and previous steps of stage 4 of the SIPAC-framework have already been carried out. This button allows the IT/SW Professional to load the company's audit information to work with it. The CSV file should have been previously generated by other support tools such as the application presented in section 3.3.2.

Less used but still useful, this simulation model also has a button (Manually Load New Business Case data) to load one by one all the information data of a case study. It is hardly ever used since the information has usually been collected in advance through a compatible application for it (The Systemic Process Assets Engineering tool for Knowledge Audit, available at (http://spaengineering.sel.inf.uc3m.es/).

Step 3: Simulation World Configuration

The "Create Knowledge Assets World" button prepares the simulated world to function with the knowledge assets according to the SIPAC-framework. Among other tasks:

- The simulation window is resized,
- The quadrants for the graphical characterization are created,
- The section for decision making (operating in stage 6) is created, and
- The background colors representing the characterization are fixed.

At this moment, no abstract Knowledge Assets agents exist yet, nor any kind of valuation or characterization has been performed.

The "setup" button takes information of knowledge assets that was previously selected and creates the agents representative of such assets. More details about the structure of these agents is given ahead. The following Figure 3.38, shows the creation of uncharacterized and still unevaluated knowledge assets agents.

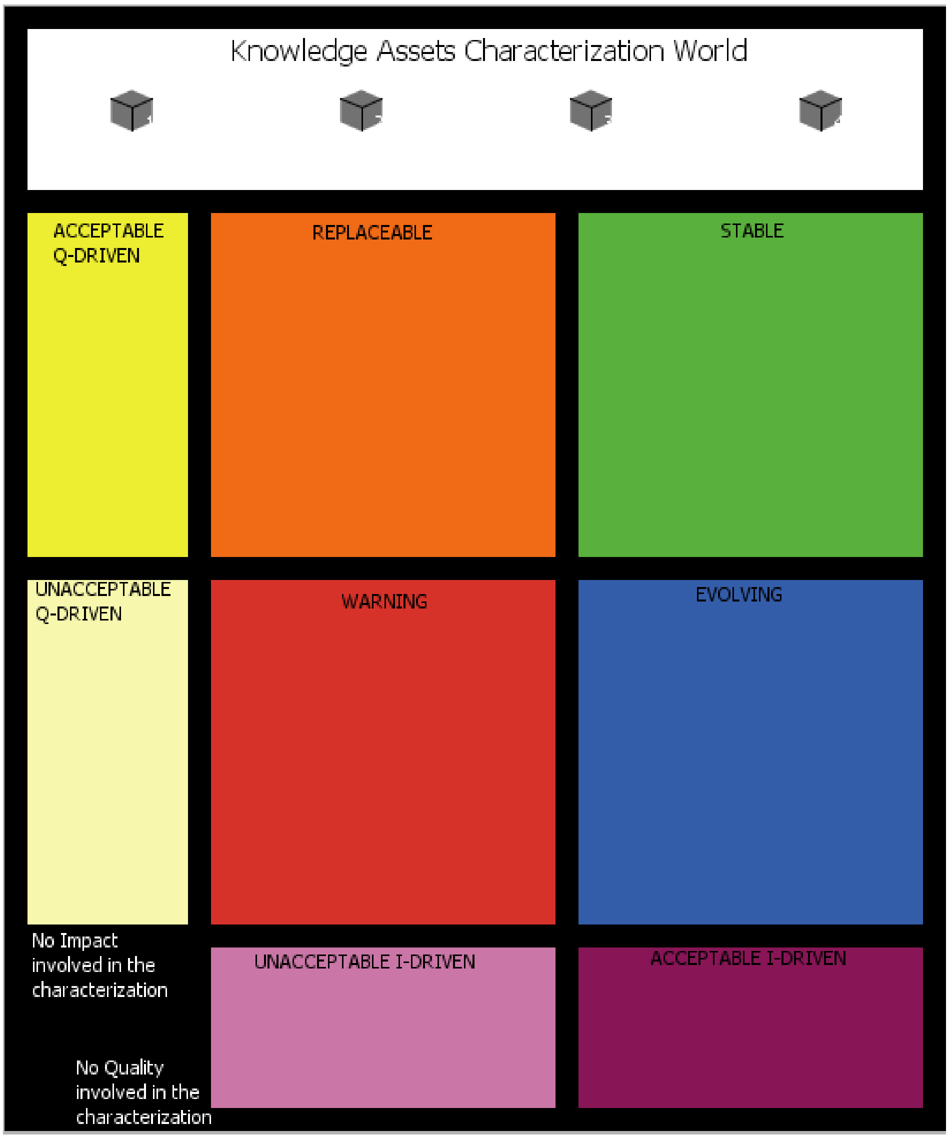

Figure 3.38 Uncharacterized Knowledge Asset Agents Creation

The structure of the Knowledge Assets agents

A Knowledge Asset agent is an abstract representation of a client company knowledge asset. As such, it contains explicit information previously read from the CSV file of the company like:

- The position (xcor and ycor) in which it should be located, also in accordance to the characterization state and the thresholds.
- An identification label assigned at the time of the agent's birth (a sequential number).
- A shape and size for practical graph representation.

- The type of knowledge asset, that is, whether it is of both quality and impact, or of only impact or quality (property: typeofka).
- The weight that the knowledge asset has for the achievement of the strategic goal (property: weight).
- The impact valuation obtained from its indicators (property: impact).
- The quality valuation obtained from its indicators (property: quality).
- The general valuation (property: normalizedindvalue).
- The obtained characterization code (property: characterized).

The Figure 3.39 shows the Netlogo window of inspection of an agent, which in this case shows the knowledge assets agents information and properties.

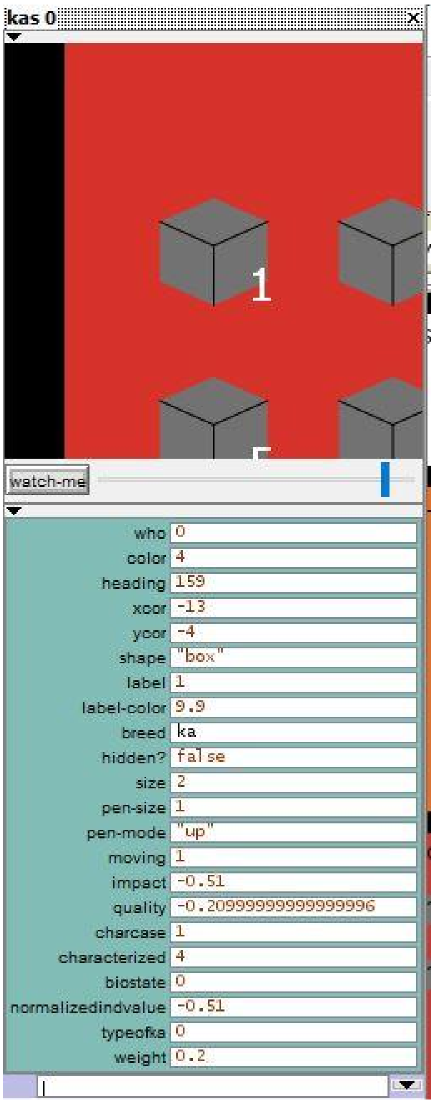

Figure 3.39 Example of explicit properties of a Knowledge Asset Agent

Step 4: Knowledge Assets Characterization

By pressing the "Characterization" button, the simulation model uses the simulation world to show the results of the characterization made. This characterization is internally calculated, and the result becomes evident by the position of the asset in the quadrants, which must be in accordance to the color specification previously explained. An example of this for the case of four existent knowledge assets is presented in Figure 3.40, where the six identified assets of the company are characterized as "Warning", so getting place in the red quadrant of the characterization space.

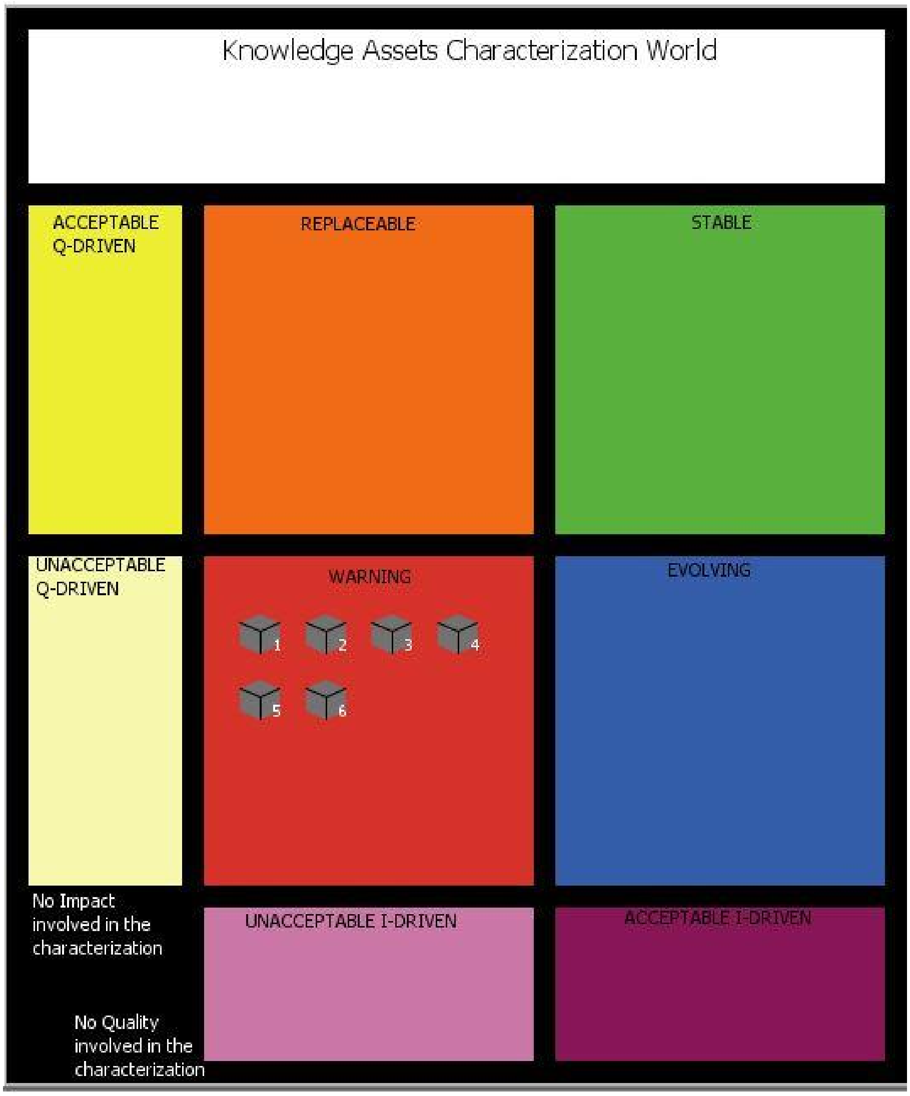

Figure 3.40 Characterization and simulation environment

It may be noticed that, besides the characterization space shown before there is also a section which is intended to represent other kind of agents: the decisions; this will be shown later in section 3.3.3.2.

3.3.3.1.2. The information panel.

The information board of the simulation model presents quantitative information of the knowledge assets valuation, characterization and other descriptive information. An example of this is shown in Figure 3.41.

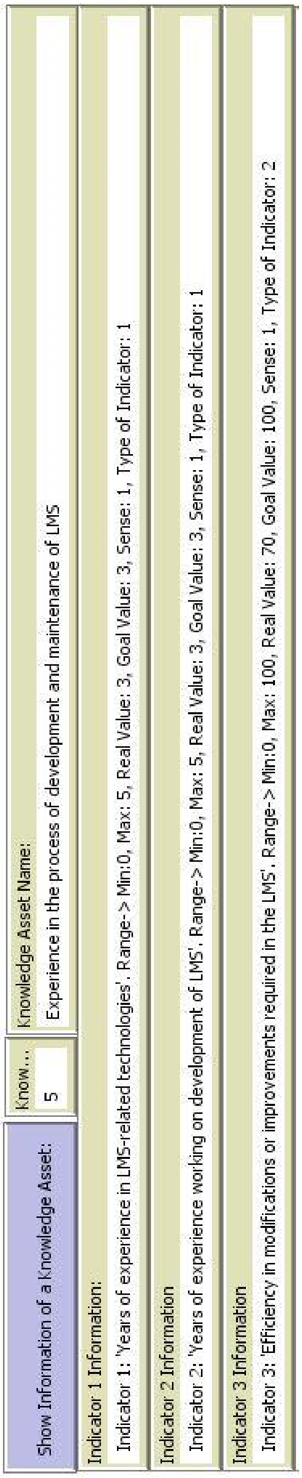

Figure 3.41 The KA information panel of the simulation model

For this case, the information panel shows the information of the knowledge asset 5, which has three indicators. For each indicator there is information about the name of the indicator, the range of possible values for such indicator, the real and goal values, the sense and the nature type of the indicator: whether it is of quality or impact.

3.3.3.2. Agents-based dynamic decision-making model.

This subsection presents the part of the simulation tool that is used to represent the process of dynamic decision making described previously. The general aspect of the control board of this part of the simulation panel looks like Figure 3.42.

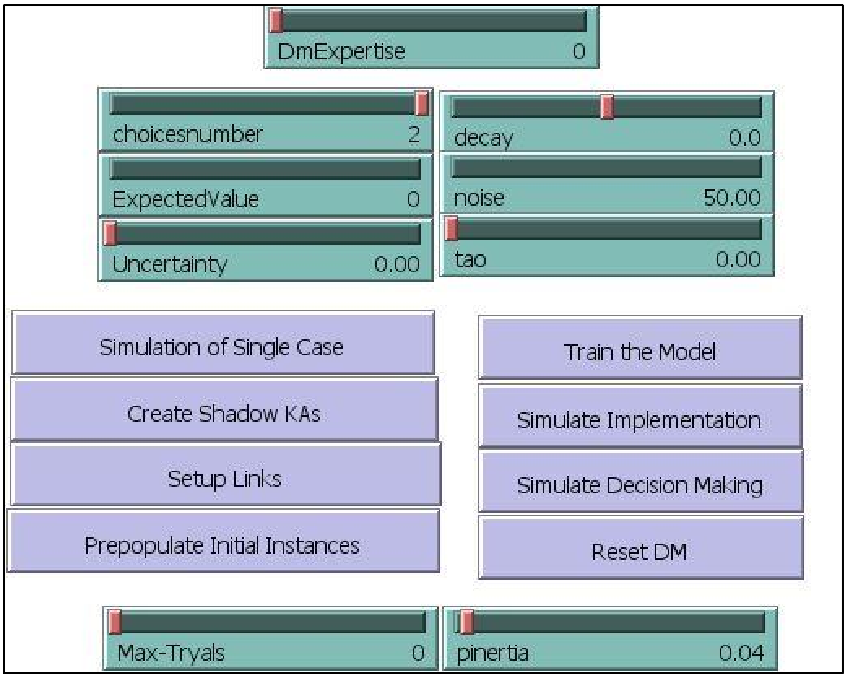

Figure 3.42 Decision-making simulation panel

The functionalities for every button of this simulation panel is shown in the following Table 21.

Table 21 Buttons and functionalities of the decision-making module of the simulation tool

Button	Functionality
Simulation of Single Case	It launches the process of simulating through the use of the Instance Based learning model the process of decision making for a single case that has been previously loaded in the Case study Valuation and Characterization module of section 3.3.3.1.
Create Shadow KAs	It calls the internal function to clone the existent knowledge assets, so that while the process of simulation the possible re-characterization can be illustrated from comparing the states of original and cloned knowledge assets, which would be clearly differentiated by their label string.
Setup Links	It calls a function to create links that will connect the original and the cloned knowledge assets. It is an optional feature not an indispensable future for operation with the model, however it is useful when the number of knowledge assets is big.
Prepopulate initial instances	This function calls a function to create other type of agents: the instances. It creates all possible instances of memory containing the triplet with the possible transitions of states, the decision made and the expected utility. All this according to the conceptual model presented in section 3.2.4.
Train the model	In case the upload and training form other cases button were not been called in the valuation and characterization module, it is needed to call it here since the probabilities of recharacterization and the expected utilities are given by previous uses of the SIPAC-framework.
Simulate implementation	From the creation of the Instance-based learning model instances, this button calls the function to start exploring the decisions made and evaluating the obtained utility. I summary it is and exploratory execution that simulates decision-making and the utility obtained, so that the memory contains the instances needed to then make better choices.
Simulate Decision-making	Given a specific case, which was previously imported and loaded in the valuation and characterization module, this button calls for a function that estimates this specific case's expected utility.
Reset Decision-Making	It deletes all previously set up results and variables values.

3.3.3.2.1. The instances agent-based representation

To represent the instances that constitute the memory, similarly to the representation of knowledge assets, we used a specific type of agent. This “instance” agent has all the information corresponding to the conceptual model described in 3.2.4. Specifically, the instances agents have own properties such as:

- The position in the simulation window.
- The label showing the specific instance information (the situation and the decision).
- The color representing one decision or another.
- The previous situation.
- The subsequent situation.
- The utility related to such instance.
- The preactivation.
- The activation.
- The occurrence.
- The probability of retrieval from decisions from experience exploration.

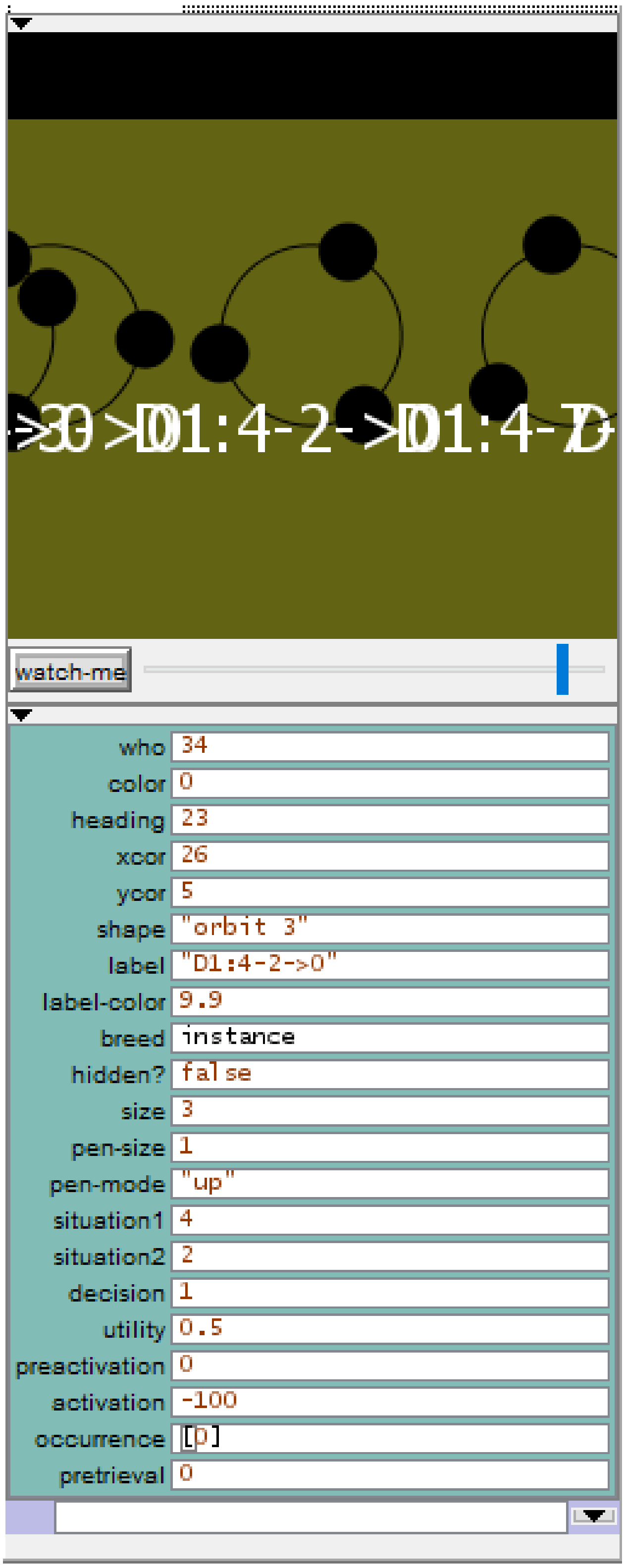

Figure 3.43 Instances agent-based simulated representation

The processes related to the IBL-model were programmed internally as part of the Netlogo model. Specific methods of the IBL-model such as the recognition, judgement, choice, execution or feedback were programmed and constitute the internal process described in Figure 3.33.

This simulated approach implements memory recognition through a method called *Recognition-Census*. Census accounts for the instances, which it clusters according to their affinities. Every instance is represented by a simulated agent storing a situation, decision and utility. Depending on frequency of use, every instance will be associated with a specific activation, occurrence and retrieval probability. In the recognition phase, all the instances are identified, filtered and differentiated to provide a general overview of stored memories, emphasizing on those needed for contextual constraints (previous given characterization) (See Figure 3.44).

```
to Recognition-Census                       ; Function to know how many...
                                            ; instances there are.

  let counter count Instance                ; Census of instances

  ask Instance with [Situation1 = prestate][ ; Select only instances with the..
                                            ; precharactrization that coincides...
                                            ; with the actual one for the Knowledge Asset.

  set ycor ycor + 20                        ; Move the selected instances and make...
                                            ; them closer to the decision maker
  ]
end
```

Figure 3.44 Recognition call using NetLogo

In this model, the prepopulation was coded as illustrated in Figure 3.45, where:

- The number of choices is denoted by *choicesnumber*, which is a global variable that can be set from the main simulation panel.
- There are up to four pre and post characterization states
- The utility is set by means of the customizable reward matrix, which is read using the *checkreward* function.
- Activation is initially set at -100, according to the original model (Lejarraga, Dutt, & Gonzalez, 2012).
- Preactivation is set at 0, since the instances have not yet been used.
- Retrieval probability is set at 0. It is updatable according to usage.
- Occurrence is a vector that stores the simulation trials in which the instance is activated. It is initially set to [0].

```
to populateinitialinstances                        ; Name of the function
  set stateofDMP "Populating Initial Instances"                      ; Message to be shown in the main simulation panel
  wait 0                                                             ; Intentional delay for deploying the previous message
  let contch 1                                                       ; Auxiliary variable for controlling the number of choices
  let contst 1                                                       ; Auxiliary variable for controlling the number of "pre" characterization states
  let contst2 1                                                      ; Auxiliary variable for controlling the number of "post" characterization states
  while[contch <= choicesnumber][                                    ; Loop for creating all the instances related to each decision
    while[contst <= 8][                                              ; Loop for creating all the instances related to each "pre" characterization state
      while[contst2 <= 8][                                           ; Loop for creating all the instances related to each "post" characterization state
        let sit1 contst                                              ; The "pre" characterization state is set as the auxiliary contst
        let sit2 contst2                                             ; The "post" characterization state is set as the auxiliary contst
        let uti checkreward sit1 sit2                                ; The utility is fixed as read from the reward matrix [Through a function called checkreward]
        let act -100                                                 ; The activation of each instance is initially fixed at -100
        let preact 0                                                 ; The preactivation of each instance is initially fixed at -100
        let pret 0                                                   ; The probability of retrieval of each instance is initially fixed at -100
        let occu [0]                                                 ; The occurrence of each instance is initially fixed at -100
        if (((sit1 = 1) or (sit1 = 2) or                             ; Conditions for the cases 1) both Impact and Quality, 2) Only Quality and 3) Only Impact
          (sit1 = 3) or (sit1 = 4))and ((sit2 = 1) or
          (sit2 = 2) or (sit2 = 3) or (sit2 = 4))) or
        (((sit1 = 5) or (sit1 = 6))and ((sit2 = 5) or
          (sit2 = 6))) or (((sit1 = 7) or (sit1 = 8))and ((sit2 = 7) or (sit2 = 8)))
        [createInstance sit1 sit2 contch uti preact act pret occu   ]   ; This is a call to the function createInstance with its parameters
        set contst2 contst2 + 1                                      ; Auxiliary variable contst2 is increased (for changing among pre states)
      ]
      set contst2 1                                                  ; Auxiliary variable contst2 is set at 1
      set contst contst + 1                                          ; Auxiliary variable contst is increased (for changing among post state)
    ]
    set contst 1                                                     ; Auxiliary variable contst is set at 1
    set contch contch + 1                                            ; Auxiliary variable contch is set at 1 (for changing among choices)
  ]
  set stateofDMP "Initial Instances have been created"
end
```

Figure 3.45 Code for prepopulating instances

Also internally, the method of blending was coded as shown in Figure 3.46. This mechanism was also coded according to the formal definition presented in section 3.2.4.2.

```
to goblending
    set stateofDMP "Judgement-Blending"
  wait 0.5
let aux 1
  while [aux <= choicesnumber][
    let aux2 mean [pretrieval] of Instance with [Decision = aux]
 ;   set (word "blendedvaluech" aux) aux2
    if (aux = 1)[set blendedvaluech1 aux2]
    if (aux = 2)[set blendedvaluech2 aux2]  ; In case of more choices, copy this line again
    set aux aux + 1
  ]
  set CH1monitor blendedvaluech1
  set CH2monitor blendedvaluech2
  set stateofDMP "Making a choice"
  wait 0.5
  if (blendedvaluech1 > blendedvaluech2)[set TDecision lput 1 TDecision]
  if (blendedvaluech1 < blendedvaluech2)[set TDecision lput 2 TDecision]
  if (blendedvaluech1 = blendedvaluech2)[set TDecision lput (random 2 + 1) TDecision
    set DECmonitor item trial TDecision
    set stateofDMP (word "Decision Number " trial " was made, opting for choice " DECmonitor)
  ]
end
```

Figure 3.46 The blending mechanism as NetLogo code

It is not very useful to paste in this document all the code related to the implementation of the decision making module, since it is going to be available at (https://promise.sel.inf.uc3m.es), however special attention should be paid to the use of the outputs obtained through the manipulation of the simulation model, which is the main input to discussion and real decision making to the final stages of the SIPAC-framework.

3.3.3.2.2. The simulation output

The software engineer may use the simulation model to:

- Show the potential clients how the characterization module generates a visual report with characterized knowledge assets representing the state of health of a company's knowledge. In this phase, the model is useful since it increases the flow of visual information that goes from the IT/SW professional to the client while simplifying the language used to argue the usefulness and effectiveness of the SIPAC-framework as a general approach to support decision making in regard to the digital solution implementation.
- Easily manipulate the IBL-model implementation to show what are the effects of good and bad decisions in regard to the digital solution selection.
- Prospectively simulating from a real initial audit what is the expected future state of the assets from their current status and the experience offered by the SIPAC-framework as matrix of digital knowledge-oriented solutions.

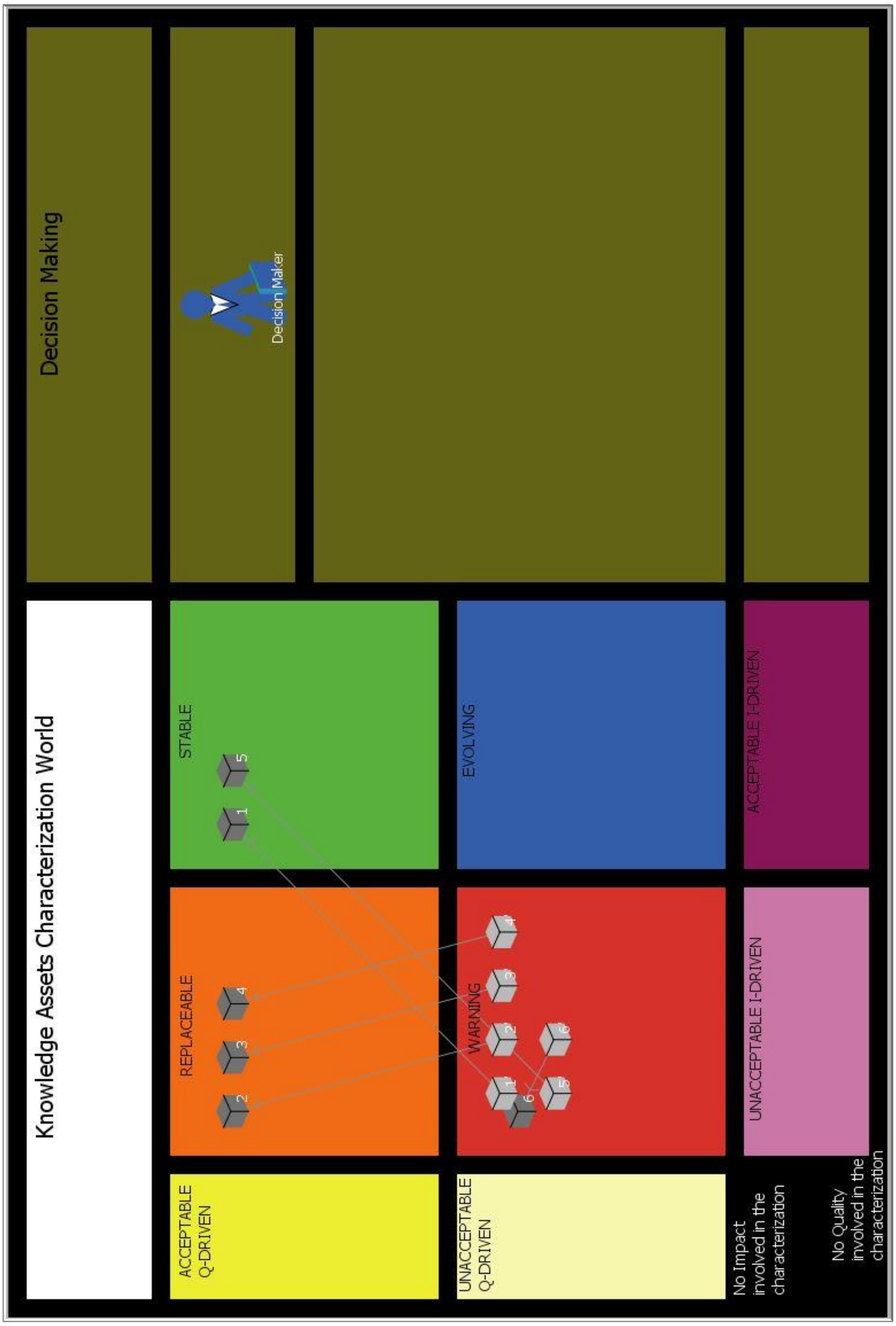

Figure 3.47 Decision-making simulation graphical output

Finally, and as a last functionality of the simulation model, this saves reports with the results of the characterization made, which is useful if future studies are needed considering the information generated by the SIPAC-framework simulation model.

4. Experimentation with a case study: The ISVA

This chapter contains the description of the experimentation with the solution presented in chapter 3 in an organizational context. Although this methodology has been used in several cases, whose main results are shown in chapter 5, in this chapter we have selected one of these cases, to illustrate step by step how this methodological framework operates.

4.1. Description

4.1.1. The organization: The Institute for Vehicle Safety Assurance (ISVA).

According to its official webpage[3], The Duque de Santomauro Institute for Vehicle Safety Assurance, ISVA, based at the Carlos III University in Madrid, is a research and development institution operative since the 03//22/2000. Officially, the main objectives of the ISVA are[4]:

- To create scientific multidisciplinary teams generating the appropriate knowledge for considering the complexity of problems related to automobile safety.
- To promote the work carried out by the previous teams, making it available to the public when it is potentially interesting. To this purpose, an appropriate knowledge forum must be created through pertinent activities.

[3] http://isvateam.sel.inf.uc3m.es/

[4] https://www.uc3m.es/ss/Satellite/UC3MInstitucional/en/Detalle/Organismo_C/1381806616391/1371206581851/_Duque_de_Santomauro__Institute_of_Motor_Vehicle_Safety

- To form technically reliable opinions with a scientific basis regarding the Institute's topics is a priority for the Institute.
- To create a channel of communication and exchange among specialists and institutions related to the automotive sector, coinciding with the Institute's scientific research objective.

With activities in different areas within the automotive and transport sector, among its main responsibilities there are:

- Major modifications laboratory.
- Traffic accident reconstruction laboratory.
- Postgraduate and further training courses targeting industry professionals.
- Calculations and testing.
- Technical assistance for industry: services and consulting.
- Automotive R&D projects related especially to road safety.
- Scientific research reported in international publications, PhD theses and research papers.

Additionally, among the main lines of research and interest, it can be mentioned:

- Influence of the human factor in driving (safety).
- Study on the different aspects related to the Technical Vehicle Inspection stations (ITV).
- Research and Reconstruction of traffic accidents.
- Development of intelligent systems and their application to vehicles, traffic control and accesses.
- Application of communication technologies to vehicles.
- Development and application of sensors to vehicles.
- Analysis of the vehicle's structural behavior facing static, dynamic or impact charges.
- Dynamic vehicle test.
- Certification of significant reforms in automobiles.

- Drafting of rules related to technical aspects of automobiles., Collaboration with official institutions in this regard.

4.2. Experimentation – A step by step example of use

4.2.1. Stage 1. Initial approximation to the client company problematic situation.

As an organization, the ISVA has a wide set of people working on it. Each of them has a defined role and some specific functions that complement the main activity each professional has within the university, i.e. researcher, teacher, lab manager, etc. In general, the ISVA is constituted by a team that contains specialist in the fields of mechanical engineering, software engineering, systems engineering and automation, electronic technology, continuum mechanics and structural analysis.

Since it belongs to a university, the main activity of the ISVA must be aligned with research, development of technologies and the creation of knowledge in general, useful in the context of vehicle safety assurance, i.e. for automotive industry manufacturers, government and regulatory institutions, and people using transport in general.

The ISVA goes beyond research on the development of parts of cars, or implementation of integrated networks, it focuses on complex topics in which the human factor activity has an effect on vehicles safety, such as the decision-making process of drivers, the causes of accidents and how prevention is the most important line of action, or the effect of avoiding rules in vehicles use.

As a wrap-up of this description, the rich picture shown in Figure 4.1 shows the interaction of all people, institutions, stakeholders and technology involved in the ISVA activity.

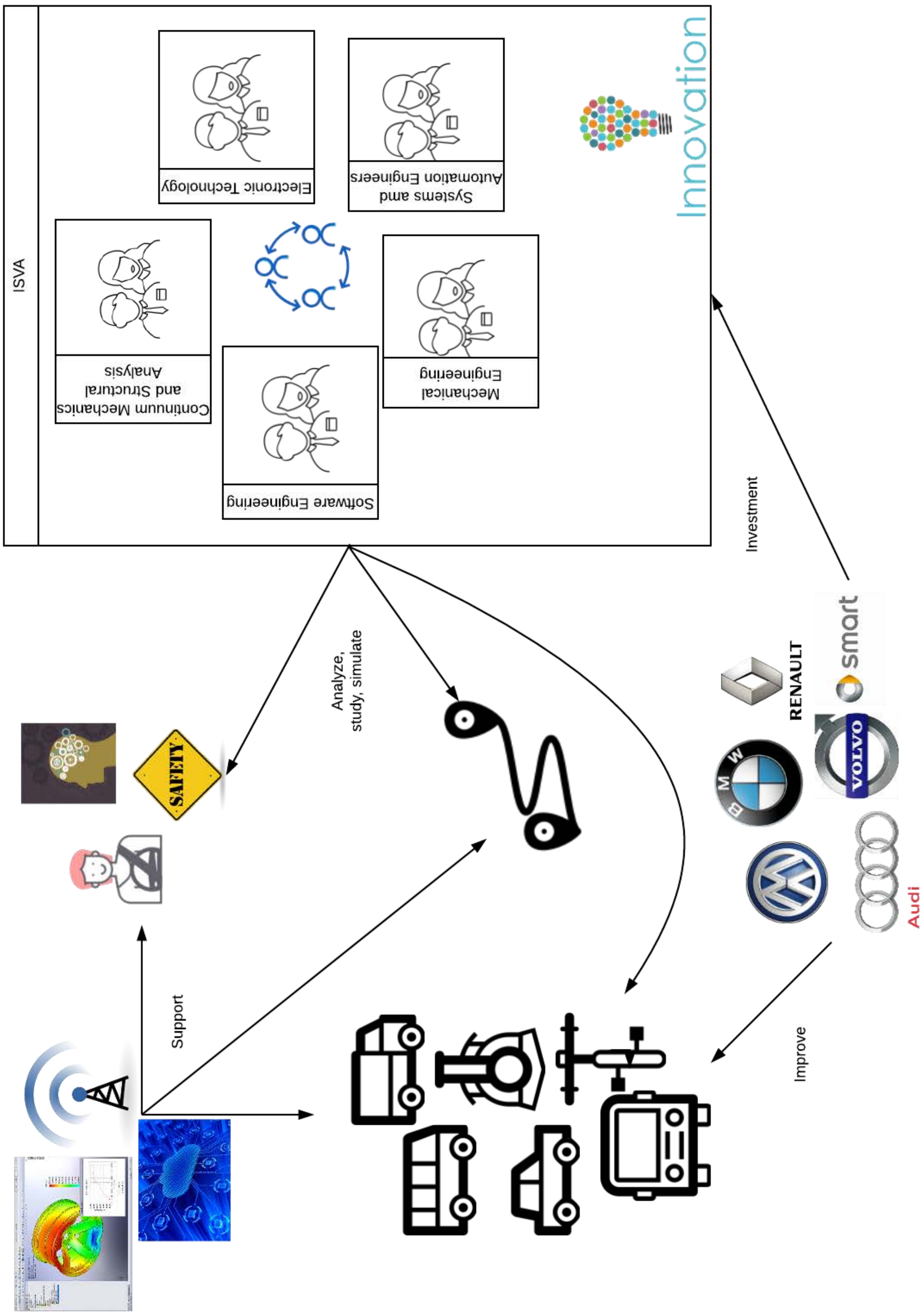

Figure 4.1 Rich Picture: The ISVA Case Study

The rich picture is useful for discussions on the operation of the ISVA in the following subsection, in which the main goals and other knowledge related artifacts will be defined.

4.2.2. Stage 2. Strategic Organizational Expression.

This stage comprehends the structuration of the information with the aim to identify what are the elements that define the mission (goals), the procedures to pursue such a mission (the organizational processes) and the knowledge assets needed to do so. As explained in chapter 3, the stage 2 is aimed at structuring the complex and problematic situation identified in stage 1, which is mainly expressed in the rich picture of Figure 4.1.

4.2.2.1. Organizational Processes and Strategic Goals Identification

4.2.2.1.1. Organizational Processes:

According to the description of the ISVA, the main processes are related to research, development of technology and innovation management improvement.

4.2.2.1.2. Business Goal:

The main business goal that push forward in the direction of achieving the organizational mission is the increase of the number of project proposals that are both received and proposed by the ISVA to institutions and by public and private calls for projects.

4.2.2.2. Knowledge Assets Generic and Specific Identification and Definition

According to the proposed solution, first a generic knowledge asset was proposed and then specified into an operative asset for the case of the ISVA.

4.2.2.2.1. Knowledge Assets Identification and Definition

Table 22 Case ISVA: Knowledge Assets generic and specific definition

Generic Knowledge Asset	Specific Knowledge Asset
Innovation model	• **Knowledge repository:** since there is no a repository in which ISVA members can effectively share their knowledge is a problem affecting the organization performance. The existence of such a repository would allow a better approach to the business goal.
Organization and Processes model	• **Knowledge sharing recognition model:** it is important to recognize the effort of specific members of ISVA that volunteer to share their knowledge. The actions related to that knowledge sharing must be recognized, so that it becomes both a reward and an incentive.
Production model	• **Knowledge assets creation:** Creating knowledge assets is important since it encourages the main business goal achievement. Since these knowledge assets are shared in the repository, they can be used by other users and so widely help to improve organizational performance.
Production model	• **Knowledge assets reuse:** not reusing the knowledge assets represents a bottleneck in the endeavor of achieving the business goal, so implementing such reuse as a knowledge asset would solve this bottleneck and support future improvement.
Organization and Processes model	• **Knowledge progress assessment:** according to business experts, what is not measured cannot be improved. Assessing the knowledge of people and their will to learn and keep developing knowledge and research would push forward the direction of a knowledge based general improvement.
Service Execution model	• **Knowledge assets changes notification:** since knowledge assets need to be used to be useful, this knowledge asset would cover the activity of people on knowledge assets from their changes on them.
Organization and Processes model	• **Knowledge matrix:** such a representation provides a general panorama on what are the fields of knowledge that members of the ISVA better manage, so the strengths that the ISVA may base to search for excellence.

4.2.3. Stage 3. Definition of relevant systems.

With all the knowledge assets identified and the business goal clear, it is useful then to proceed with the methodology and recognize the variety of perspectives that may affect the functioning of the ISVA. As stated before, there are several people with different roles influencing the ISVA performance, i.e., professors, students, lab managers, researchers, etc. This variety of people is related to a variety of perception on the goal or mission of the ISVA. Following are the main root definitions identified.

4.2.3.1. Declaration of root definitions (RDs)

In Table 23, the first column identifies the RDs, the second column shows the formal RDs according to Peter Checkland's proposal, the third column the stakeholder of such RD, and finally the fourth column explain the worldview (weltanschauung) related to such root definition.

Table 23 Root definitions for the ISVA case study.

ID	Root definition	Stakeholders	Weltanschauung
1	A vehicle-safety-aimed research system	University researchers	The ISVA is aimed at using their personnel to develop research and publishable results, allowing researchers to test their knowledge in the specific domain of vehicle safety.
2	An innovative vehicle safety technology developing system	Automotive industry	Since vehicles are present in traditional and smart cities, new technologies must be developed, so the ISVA should point to the discovery and development of potential population's needs and the technological solutions to such needs.
3	A vehicle safety themes learning and empowerment center	Students, lab members, and other university personnel	Students and researchers must take advantage of the ISVA to learn and form themselves as specialists in the fields of research that the institute comprises.
4	An operative vehicle-safety-related issues innovation, research and technology development system	Managers, executives, and strategy designers.	The ISVA must point to becoming a reference and authority in the automotive industry and its related research fields, for which the empowerment from members knowledge is essential and the acquisition of new projects allowing real practice is the main goal.

4.2.3.2. Selection of the relevant knowledge-driven root definition

Following our methodology, the root definition that most clearly points to the reinforcement of the ISVA from a strategical point of view is the RD number 4, so is the one selected to serve as kick-off point for building the CATWOE structure of the following step.

4.2.3.3. Definition of the CATWOE

The CATWOE is built as originally presented in Checkland's work since its use is similar, so it was incorporated in this methodology. For the ISVA, the elements of the CATWOE are shown in Table 24.

Table 24 Definition of the CATWOE for the ISVA case study.

C	People, in general, considering: drivers that directly benefit from safety vehicle improvements, al people using vehicles that in the future incorporate potential developments, automotive companies that will incorporate the improvements into their production line so obtaining more benefit and competitiveness.
A	All directors, management staff, researchers, students and lab members affiliated to the ISVA and actively participating in the main activities.
T	An institution with passive activity and limited projects to work with becomes an institution with many more projects to work with, all of them well managed and with a knowledge management platform that supports such an activity.
W	The ISVA is a research and development organization that operates as part of the Carlos III University of Madrid, being in charge of projects that is able to manage in an effective and efficient manner, based on the knowledge that has built upon its operating years and taking advantage of the knowhow that the ISVA
O	Private and public organizations, individuals and research institutions asking the ISVA project design, execution or management.
E	All automotive production regulations. All safety constraints that must be considered regarding environmental laws (emissions), road conditions, etc. Research requirements by Spanish and European research institutions.

With the main root definition, the CATWOE elements, the business goal and the knowledge assets identified, we can proceed to do the systemic assessment and characterization of stage 4.

4.2.4. Stage 4. Systemic Assessment and Characterization.

To prepare the information that will later be used to characterize the knowledge asset, first it is necessary to connect the business goals, in case that there is more than one, with the knowledge assets, and after that we focus on defining the indicators that will allow an appropriate measurement of the knowledge assets.

4.2.4.1. Linking Knowledge Assets and Business Goals

Since a unique strategic goal was defined in 4.2.2.1.2, all the subsequently defined knowledge assets are directly connected to it, and the corresponding weights are defined as in Table 25.

Table 25 ISVA - Linking Knowledge Assets and Business Goals

Strategic Goal	Knowledge Asset	Weight
Increase the number of project proposals	Knowledge repository	0.4
	Knowledge sharing recognition model	0.1
	Knowledge assets creation	0.1
	Knowledge assets reuse	0.1
	Knowledge progress assessment	0.1
	Knowledge assets changes notification	0.1
	Knowledge matrix	0.1

In case there were more than one strategic goal this is the space where a correlation matrix should be defined for each strategic goal.

4.2.4.2. Knowledge Assets Indicators definition

The indicators for the knowledge assets that were defined for the ISVA correspond to the following list shown in Figure 4.2. In this list, besides the name of the indicators, other information is given, such as the type of indicator (1 for quality, 2 for impact), the range of possible values (minimum and maximum possible value), the sense (1 for the case in which more is better and -1 for the case in which less is better), and finally the current and goal measurements.

Knowledge Assets	Indicators of KA	Type of Indicator 1=Quality 2=Impact	Range		Sense (1 or -1)	Current Value	Goal Value
			Min	Max			
Knowledge repository	Usability level	2	0	100	1	0	100
	Average refresh rate	2	0	100	1	0	20
Knowledge sharing recognition model	Number of awards and recognitions to shared knowledge	1	0	5	1	0	3
	Number of people involved in the repository	2	0	22	1	22	22
Knowledge assets creation	Number of suggestions implemented or contributed	1	0	10	1	0	10
	Number of employees with access to the repository	2	0	22	1	0	22
Knowledge assets reuse	Number of successive uses of the explicit knowledge	1	0	20	1	0	20
	Average repository query frequency	1	0	22	1	0	22
Knowledge progress assessment	Number of awards and recognition of the progress made	1	0	5	1	0	3
Knowledge assets changes notification	Number of processes of change and transmission of knowledge	2	0	5	1	0	5
Knowledge matrix	Degree of heterogeneity of academic training	1	0	10	1	6	10
	Degree of diversity in the composition of the template	2	0	5	1	5	5

Figure 4.2 Case ISVA: Measuring indicators

The description for every indicator is provided next:

- **Usability level:** to evaluate how easy is for the members of the institute to use the repository.
- **Average refresh rate:** The use that is given to the repository will be controlled and evaluated, if the personnel updates frequently or does not use it for any problem
- **Number of awards and recognitions to shared knowledge:** It will take the account of the rewards provided to do it in a controlled manner and not reward for anything.
- **Number of people involved in the repository:** The reward will be made in relation to the number of people who use the repository.

- **Number of suggestions implemented or contributed:** The number of knowledge assets in the repository will be controlled. In this way every time you share something new will not go unnoticed.
- **Number of employees with access to the repository:** The relationship between the number of people using the repository and the number of assets in it is observed to keep the repository statistics up to date.
- **Number of successive uses of the explicit knowledge:** The accesses to each asset are controlled and thus to know how much useful it is being for the personnel.
- **Average repository query frequency:** Like the previous one but more generic since it considers accesses to the repository to make queries.
- **Number of awards and recognition of the progress made:** We use one indicator to account for the worker`s satisfaction when they realize that their contribution of knowledge assets is valued through the number of awards and the recognition regarding the contributions.
- **Number of processes of change and transmission of knowledge:** To evaluate the notification of changes in knowledge assets we use a single indicator to control the number of changes and their transmissions.
- **Degree of heterogeneity of academic training:** To control all the different topics within a department.
- **Degree of diversity in the composition of the template:** To control all the topics that exist in the entire template.

4.2.4.3. Agents supported Knowledge Assets abstract representation

As proposed in the methodology, we use a tool for representing the knowledge assets of the ISVA. This tool, presented as part of the second layer of our proposal (section 3.3.3), consist on an Agent-based model related to the SIPAC-framework, in which the knowledge assets are represented as agents in a simulated world in which they "live". The seven knowledge assets of the ISVA are initially created as shown in Figure 4.4. (Note that this creation previously requires importing the data of the assets in .csv format, which can be generated through the tool "Systemic Process Assets Governance", available at “http://spaengineering.sel.inf.uc3m.es/index/SPAG.php”). As an illustration of the csv format generated by this tool and imported by the SIPAC-framework simulation model, shows for the ISVA the general information and the one for the first knowledge asset.

```
ID,Business Case Name,Business Goal,Business Requirement,Process, Maximum Possible Number of Knowledge
Assets,Maximum Possible Number of Indicators,KACount, Date, Digital Solution
Option,AGE,EXTRAVERSION,NEUROTICISM,AGREEABLENESS,OPENNESS,CONSCIENTIOUSNESS,DMExpertise,Revenue,Currency

6,Duque de Santomauro Institute for Vehicle Safety Assurance,Increase the number of project
proposals,Research and Development,R%D Management
Improvement,10,6,7,11092015,N,NA,NA,NA,NA,NA,NA,35,85000,€

Data:

ID,Generic Intangible Asset,Name of Asset,Type of Intellectual Capital,Type of Intangible,Number of Effective
Indicators,Weight,List of Indicators

KA1,Model of Innovation,Knowledge repository,Structural Capital,Knowledge about People,2,0.4

Indicator
Name,Type,MinVal,MaxVal,Sense,ActualValue,GoalValue,Age,Extraversion,Neuroticism,Agreeableness,Openness,Co
nscientiousness,Weight

Usability level,2,0,100,1,0,100,1,1,1,1,1,0.5

Average refresh rate,2,0,100,1,0,20,1,1,1,1,1,0.5
```

Figure 4.3 CSV format to be imported by the SIPAC-framework simulation model

In this step, the assets are created with no valuation or characterization made on them, which is why they are located in the upper white-background section of the simulation world.

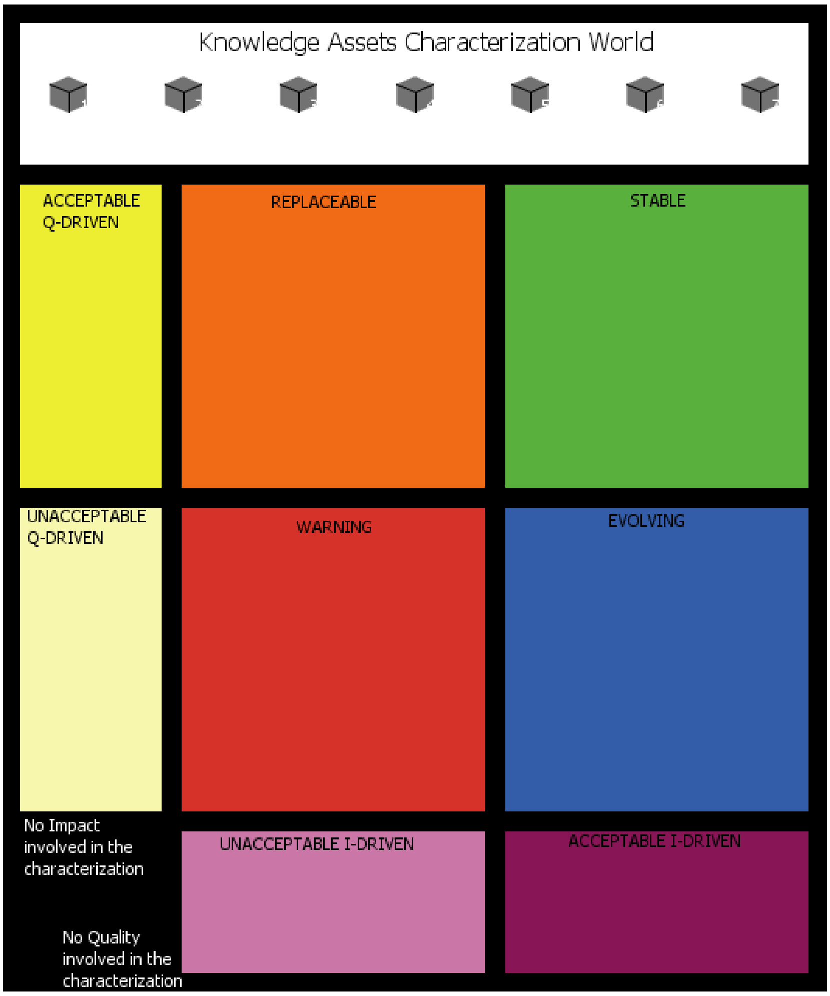

Figure 4.4 Case ISVA: Knowledge Assets agent-based abstract representation

After the knowledge assets were created, they were assessed and characterized through the "Characterization" button that is available in the simulation panel.

To illustrate how this valuation is made (although internally), Figure 4.5 shows the calculated values, also described in chapter 3: standardized value, general impact value (if applicable), general quality valuation (if applicable) and the general linear valuation of the intangible.

4.2.4.4. Agents supported Knowledge Assets Valuation

There is a valuation for every indicator of every knowledge asset, which for the ISVA case is shown in the column "Standard Indicator Normal Value" of Figure 4.5.

Knowledge Assets	Indicators of KA	Standardized Value		Standard Indicator Normal Value	Quality Standardized Mean	Impact Standardized Mean	Linear value of KA
		Actual	Goal				
Knowledge repository	Usability level	0	1	-1.00	N/A	-1.00	-1.00
	Average refresh rate	0	0.2	-1.00			
Knowledge sharing recognition model	Number of awards and recognitions to shared knowledge	0	0.6	-1.00	-1.00	0.00	-0.50
	Number of people involved in the repository	1	1	0.00			
Knowledge assets creation	Number of suggestions implemented or contributed	0	1	-1.00	-1.00	-1.00	-1.00
	Number of employees with access to the repository	0	1	-1.00			
Knowledge assets reuse	Number of successive uses of the explicit knowledge	0	1	-1.00	-1.00	N/A	-1.00
	Average repository query frequency	0	1	-1.00			
Knowledge progress assessment	Number of awards and recognition of the progress made	0	0.6	-1.00	-1.00	N/A	-1.00
Knowledge assets changes notification	Number of processes of change and transmission of knowledge	0	1	-1.00	N/A	-1.00	-1.00
Knowledge matrix	Degree of heterogeneity of academic training	0.6	1	-0.40	-0.40	0.00	-0.20
	Degree of diversity in the composition of the template	1	1	0.00			

Figure 4.5 Case ISVA: Illustration of valuation

For the ISVA, the specific agent-based characterization is shown in Figure 4.6.

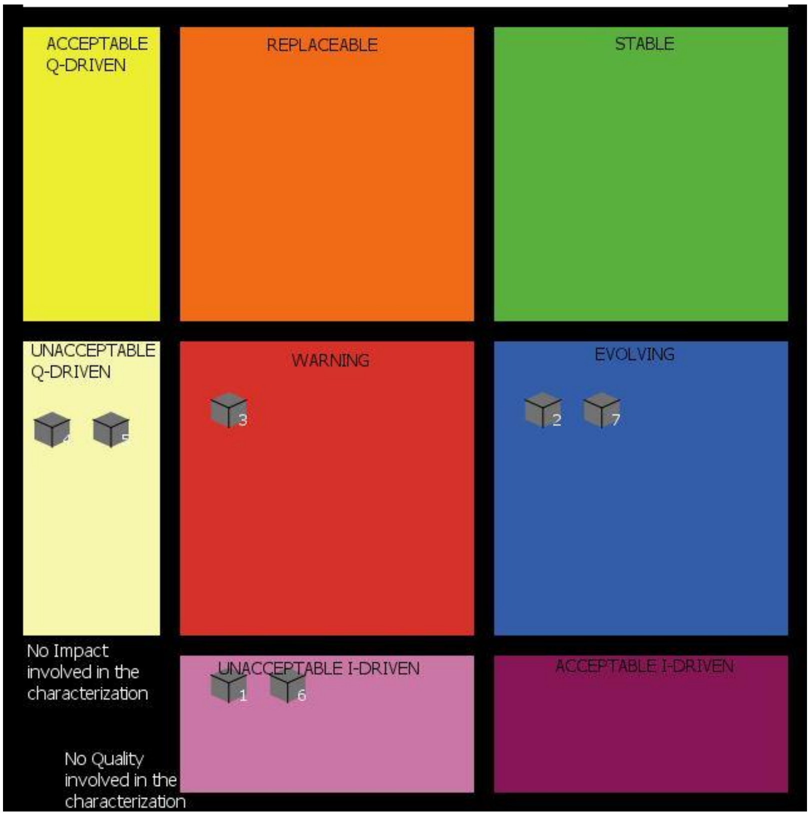

Figure 4.6 Initial Agent-based ISVA Knowledge Assets characterization

The simulation tool also provides specific information of the knowledge assets valuation through a monitor panel. Following is the generated valuation for every knowledge asset, in which we can see the general quality and impact valuation, and the specific information for the knowledge asset. This information was imported from the .csv file, however is useful to have in the display when using the simulation tool for discussions and decision making.

4.2.4.4.1. Knowledge Assets 1: Knowledge repository

As shown in Figure 4.7, the Knowledge Asset 1 (Knowledge Assets Repository), which is an only impact asset, has an impact valuation of -1, which means that is 100%under its desired value. This is justified because such a repository does not exist nor any equivalent to it.

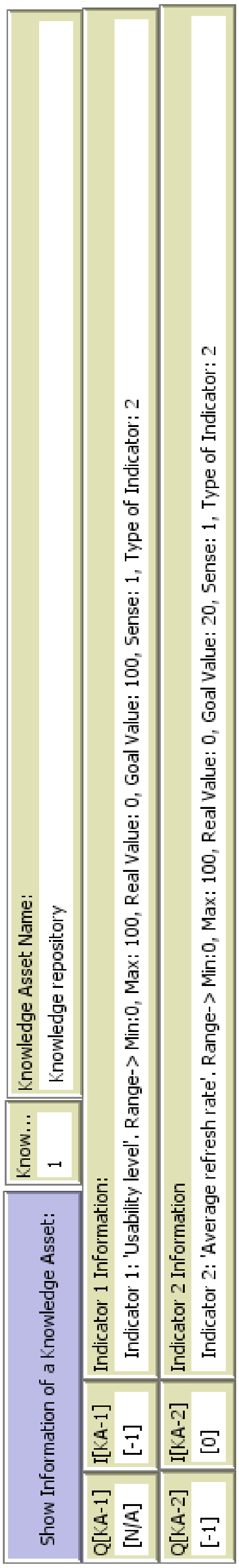

Figure 4.7 Case ISVA: Knowledge Asset 1 state and valuation monitors

4.2.4.4.2. Knowledge Assets 2: Knowledge sharing recognition model

The knowledge asset 2 (Knowledge sharing recognition model), which is a both impact and quality indicator, has impact and quality valuations of 0 and -1 respectively (See Figure 4.8). This means that it needs to improve its quality indicator primarily (the number of awards and recognitions to shared knowledge), while its impact indicator (Number of people involved in the repository) is at the goal value, so it is necessary to maintain it as it is.

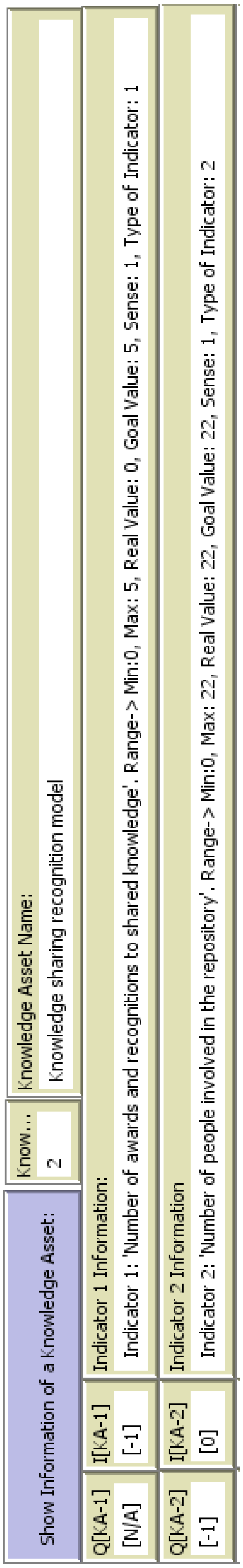

Figure 4.8 Case ISVA: Knowledge Asset 2 state and valuation monitors

4.2.4.4.3. Knowledge Assets 3: Knowledge assets creation

The knowledge asset 3 (Knowledge assets creation), which is a both impact and quality indicator, has impact and quality valuations of -1 and -1 respectively, as shown in Figure 4.9. This means that the ISVA needs a general improvement strategy considering both its quality indicator (the number of suggestions implemented or contributed) and its impact indicator (the number of employees with access to the repository).

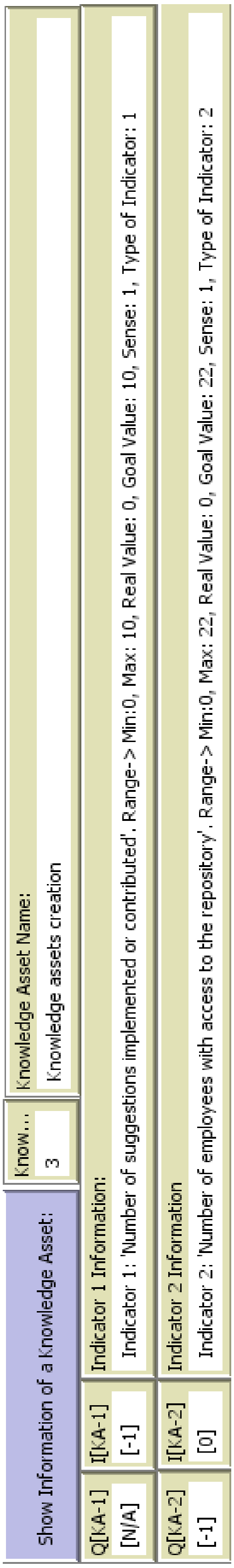

Figure 4.9 Case ISVA: Knowledge Asset 3 state and valuation monitors

4.2.4.4.4. Knowledge Assets 4: Knowledge assets reuse

In the case of knowledge asset 4, the "Knowledge Assets reuse", it is an only quality KA. Its quality valuation is at -1, meaning that both the "Number of suggestions implemented or contributed" and the "Average repository query frequency" need a strategy that help them to improved, since they are 100% far from their goal, due to their inexistence.

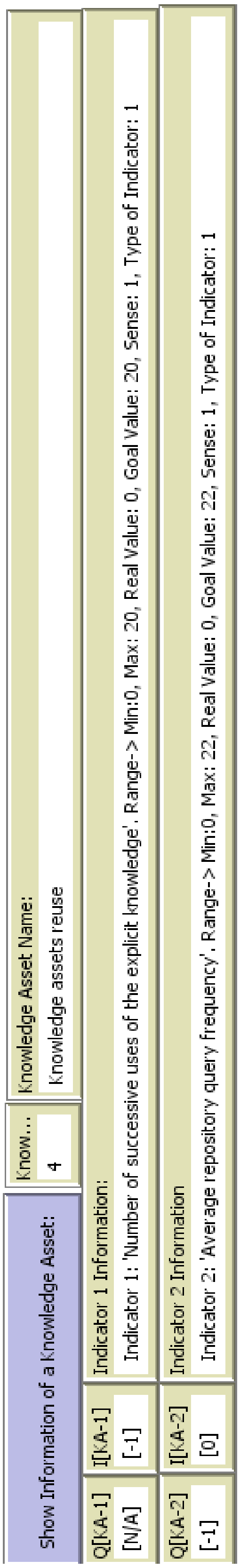

Figure 4.10 Case ISVA: Knowledge Asset 4 state and valuation monitors

4.2.4.4.5. Knowledge Assets 5: Knowledge progress assessment

The knowledge asset 5 (knowledge progress assessment) is an only quality KA, whose only indicator, the "number of award and recognitions to the progress achieved" must be empowered. This valuation suggest that the global strategy must consider actions helping to increase the number of recognition for progress within the ISVA activity.

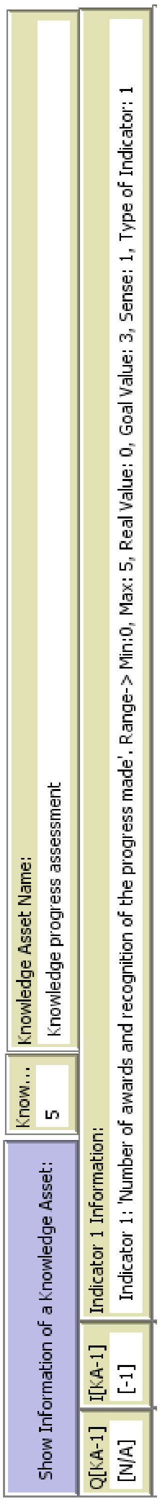

Figure 4.11 Case ISVA: Knowledge Asset 5 state and valuation monitors

4.2.4.4.6. Knowledge Assets 6: Knowledge assets changes notification

The “Knowledge assets changes notifications”, the KA 6, is an only impact indicator with a valuation of -1. This means that the “number of processes of change and transmission of knowledge” that it considers need to be increased. At this stage, this valuation is useful since it suggests the inclusion of this specific requirement in the global strategy.

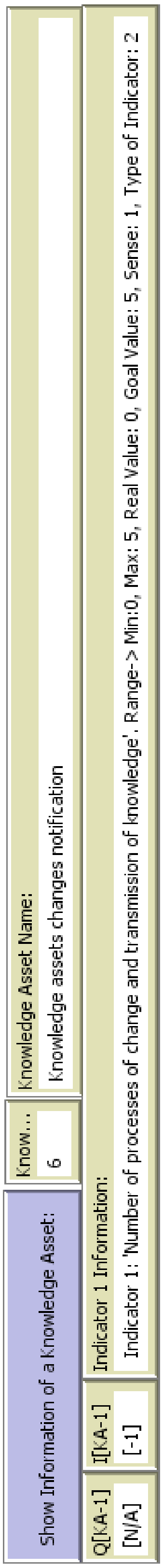

Figure 4.12 Case ISVA: Knowledge Asset 6 state and valuation monitors

4.2.4.4.7. Knowledge Assets 7: Knowledge matrix

The knowledge matrix, the number seven of the ISVA's knowledge assets, is a both quality and impact KA with valuation of -0.4 and 0.0 respectively, which means that the quality is pretty far from its goal, so there is a need of improving the "heterogeneity of academic training" (the quality indicator). On the other side, the "degree of diversity in the composition of the template" (the impact indicator) is at an acceptable level that could remain as it is.

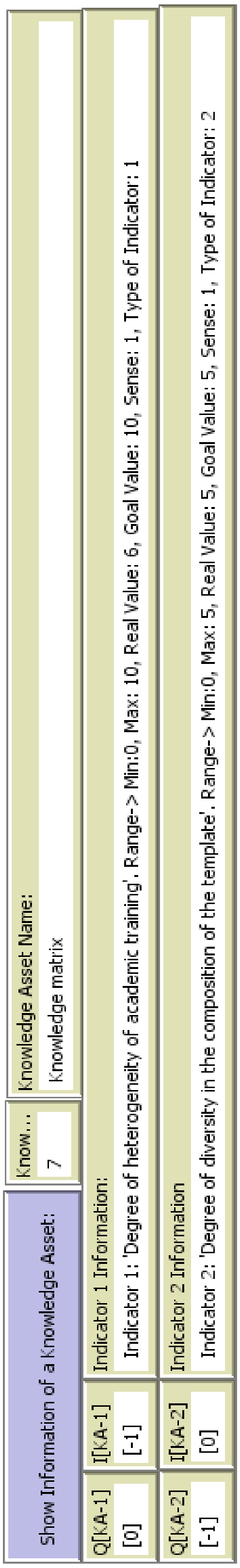

Figure 4.13 Case ISVA: Knowledge Asset 7 state and valuation monitors

4.2.4.5. Agents supported Knowledge Assets Characterization

The characterization for the knowledge assets is given by the impact and quality valuations, as described in section 3. This characterization can be of type 1 (KA2, KA3 and KA7, with both impact and quality available), of type 2 (KA4 and KA5, with only quality valuation available) and type 3 (KA1 and KA6, with only impact valuation available). In the ISVA, the thresholds were set up to 0.00 each, defining the following characterization states, shown in Figure 4.14.

Knowledge Assets	Type of Characterization	Description	Characterization
Knowledge repository	3	Only Impact	Unacceptable Impact-driven
Knowledge sharing recognition model	1	Quality and Impact	Evolving
Knowledge assets creation	1	Quality and Impact	Warning
Knowledge assets reuse	2	Only Quality	Unacceptable Quality-driven
Knowledge progress assessment	2	Only Quality	Unacceptable Quality-driven
Knowledge assets changes notification	3	Only Impact	Unacceptable Impact-driven
Knowledge matrix	1	Quality and Impact	Evolving

Figure 4.14 Case ISVA: Characterization illustration

By using the simulation tool this characterization is made automatically from the information read through a .csv file. Besides this, the tool allows the manipulation of the threshold sliders, which allow us to be more or less demanding. The initial characterization with the thresholds set up to 0.00 each, is as follows in Figure 4.15.

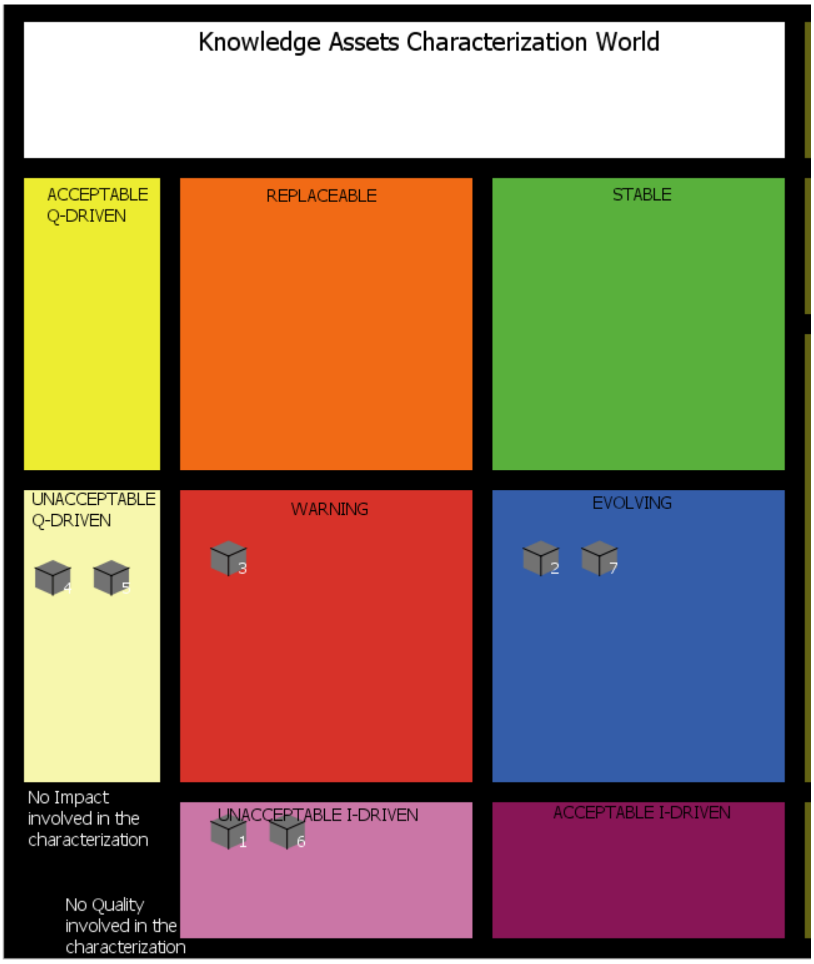

Figure 4.15 Characterization of Knowledge Assets: The ISVA

As said, one can be more or less demanding, so in the following Figure 4.16 are shown both the case in which one is less demanding, so flexible, or more demanding.

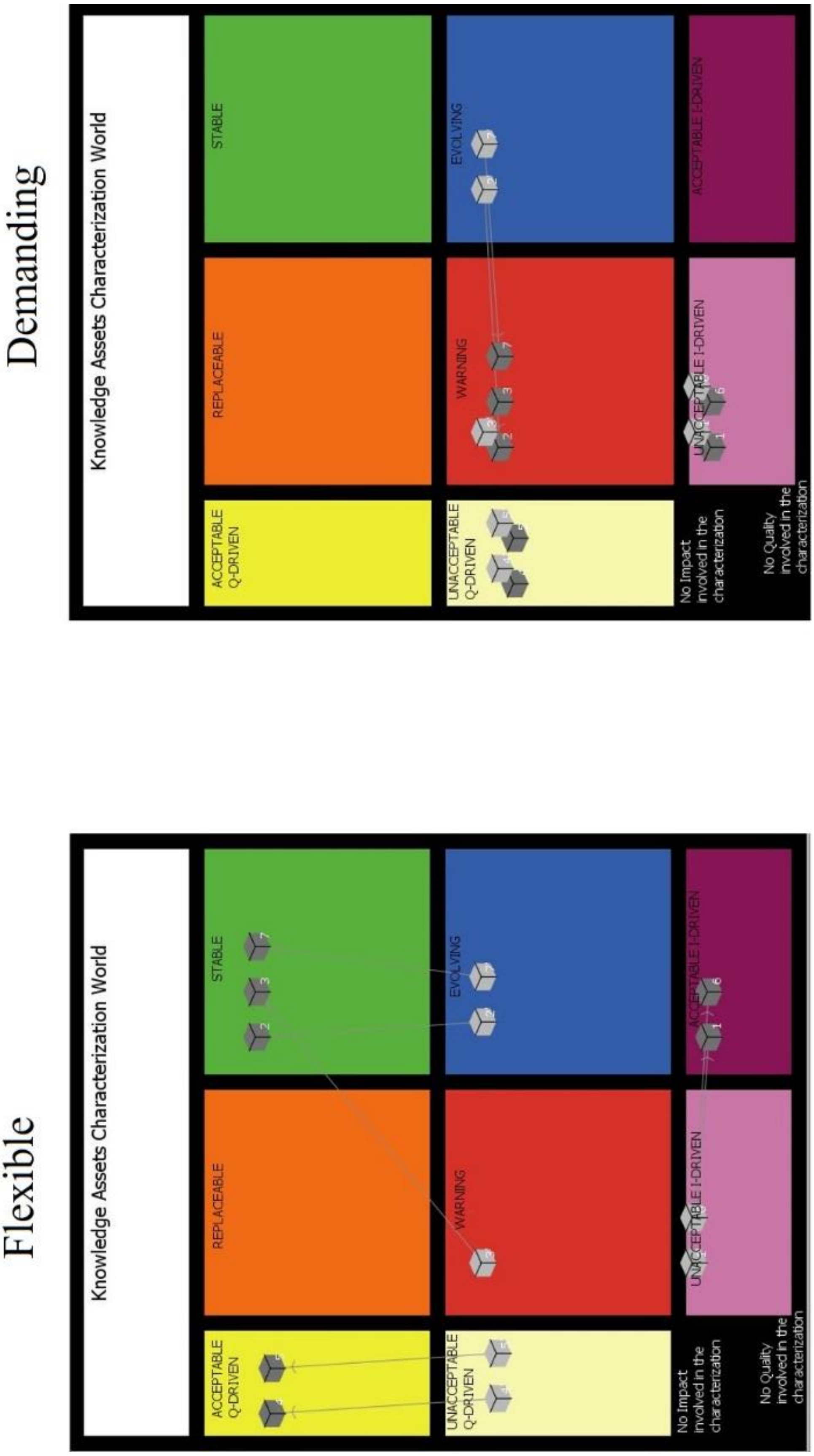

Figure 4.16 Case ISVA: Flexible and Demanding characterization cases.

As shown in Figure 4.16, in the case that we are flexible, the knowledge assets of the ISVA characterize in one of the three desirable cases: stable, acceptable Impact Asset or acceptable Quality Asset. In the case that we are more demanding, the knowledge assets locate in one of the more undesirable cases: warning, unacceptable Impact Asset or unacceptable Quality Asset.

This game of playing with the thresholds generated interesting discussions since it allowed the main stakeholders to set themselves better indicators goals so that in future studies their knowledge assets become more easily stable or acceptable.

4.2.5. Stage 5. Improvement Plan Definition.

Proposal:

The implementation of a technological solution to provide the ISVA with a platform for knowledge sharing, promotion, disposal and backup. There were several alternatives to choose from, however the selection of the best alternative considered the specific ISVA capabilities at the time of the implementation in terms of budget, infrastructures and technician support. The solution consisted on the implementation of a Cyn.in system, which is a platform, a software service with specific features for both intranet and public space implementation. In spite of advertisement, forums, and specific websites promoting the features of CYN.in, there was an important need to demonstrate the ISVA the impact of selecting the suggested technological solution and the risks of avoiding so, since from experience of the SIPAC-framework, it shall be the more appropriate solution. The next stage covered this need.

4.2.6. Stage 6. Smart Decision-Making systemic analysis.

At this point, it was necessary to illustrate the ISVA the impact of the decision to be made on implementing or not the suggested technological solution, so the second functionality of the agents-based model played an important role.

4.2.7. Stage 7. Strategic Discussion

The ISVA directory board decided to implement the suggested solution, which means that an agreement was needed and a process of development of the solution kickedoff. By the moment this thesis was being finished a second audit has been made after a two year period, with significant improvements on the knowledge assets system and with the particularity of the emergence of another solution proposal, since the first one had already started an improvement process, but organizational culture development was ready for a different more participative digital solution, which was reinforced by the fact that the Cyn.in system stopped providing service.

5. Validation

The empirical validation of this doctoral thesis has been carried out through real case studies, specifically, 11 small and medium enterprises participated, from different industrial fields, but all of them with a common need: to improve their business performance through a digitization strategy or solution. This experimental process has been documented in internal reports, with some information being subject to privacy limitations. In this chapter we present the most relevant information of these experimental processes as an illustration of the validity that this methodological framework has on real organizational contexts.

We had access to companies which allowed their knowledge assessment through this framework. In all cases there has been at least one organizational stakeholder willing to provide information about the organizational processes and any other aspect that the IT/SW consultants, who are in charge of deploying the SIPAC-framework, may ask. In all cases there have been around 3-4 IT/SW professionals intervening in the deployment of this framework. Specifically, these IT/SW professionals oversaw interacting with the organizational stakeholders and step by step deploying this framework, including the initial immersion and subsequent related interactions.

5.1. Introduction

As an introduction, in this chapter we present again the general objective, the related hypotheses, and the planning that was considered to carry out the validation process. After doing this, data analysis and its related discussion is presented.

5.1.1. Research objective

The general objective considered in this research was stated in chapter 1 as:

"*To develop a methodological and technological framework to guide IT/SW professionals to identify and use their client's knowhow and its alignment with the client's business goals, as the basis to identify better digital solutions that provide business value to their clients*"

In relation with this research objective, four hypotheses to be tested were identified. Following are these.

5.1.2. Hypotheses

The hypotheses behind this research objectives were presented also in chapter one. They are stated in such a way that reflect the contextual interest of software engineers and information technology professionals to be able to demonstrate their clients in need of digitalization why their proposal is correct from the perspective of its alignment with strategic goals achievement and considering the important value that the know-how of an organization has.

The first hypothesis refers to the process of identifying the best software solutions to implement in an organizational context.

> H1: "*By using the SIPAC-framework, and following all its methodological guidance, IT/SW professionals can effectively elicitate the processes, know-how and knowledge related assets of their client organizations*".

The second hypothesis refers to the effect that the deployment of the SIPAC-framework has from the perspective of the knowledge assets of the company, i.e., given that knowledge assets can be measured and characterized, by watching at them is a good way to check how good or bad the SIPAC-framework is on suggesting digital a solution strategy.

> H2: "*From the implementation of the strategy or digital solution that the SIPAC-framework helps the IT/SW professional to propose to their clients, the state of organizational knowledge assets can be improved so that the organizational business goal is better pursued*".

The third hypothesis regards the predictive capabilities that the SIPAC-framework gives to the IT/SW professional, i.e., the SIPAC-framework has been prepared to learn from previous cases and be trained to predict knowledge assets evolution for new cases.

H3: "*The SIPAC-framework is effective at predicting a company's' knowledge assets evolution, based on information about its effectiveness in previous experiences*"

The fourth hypothesis refers how experiencing with the SIPAC-framework has been for the IT/SW professionals in charge of deploying it in organizational context. Important aspect to test with this hypothesis is how they perceived the framework, how hard the concepts management was, how instructive was for them and how promising is in their opinion.

H4: "*SW/IT professionals are satisfied with the process of deploying and experimenting with the SIPAC-framework in real organizational contexts*"

5.2. Planning of experimentation

Since this research proposal consist on several elements directly representing an aspect of organizational performance, it is needed to deploy it in real organizational contexts so that the real-world[5] correctly provides the problems and organizational needs that the methodology aims to solve.

5.2.1. Case study selection process

This methodology was designed to be deployed in organizations in need of implementation of technological solution for organizational digitization, considering both private companies and public institutions, since knowledge, which is the main point of interest to improve organizational performance from our scope, is present in all kind of organizations. Knowledge itself is complex, so by the time this thesis was developed, it was more feasible to work with small and medium organizations that should be more likely to share their experiences and more interested in knowledge based general improvements to become more competitive, with minimum risks.

The aspects to consider for selecting such companies were:

- Size of the company in terms of people.

[5] As defined in the methodological proposal (Chapter 3).

- Accessibility to high level organizational performance information.
- Interest in digitization.
- The need to improve business through digital solutions.

5.2.2. Design of the experimental processes

The experimental process for every company is self-contained in the proposed methodological approach described in chapter 3, however, the general process of applying this methodology to several companies with the aim to observe and validate this proposal is bigger and is briefly described here from Figure 5.1.

First, it was necessary to select the case studies, companies, that better fit the kind of company that this methodology has been thought for: organizations in need of a digitization strategy whose main information provider (organizational stakeholder) is available and willing to provide insightful information and to improve its organization from the state of their knowledge assets and using information technologies advantage.

Second, the experimentation comprehends the total deployment of the methodological framework, that is, the stage by stage transit of the IT/SW professional interacting with the company when corresponding. To do so, important is to remember the stages of the methodological layer:

- Stage 1. Initial approximation to the client company problematic situation.
- Stage 2. Strategic Organizational Expression.
- Stage 3. Definition of relevant systems.
- Stage 4. Systemic assessment and characterization.
- Stage 5. Knowledge-based Model Adjustment Validation.
- Stage 6. Smart Decision-Making Module Design.
- Stage 7. Strategic Discussion.

Third and last, it was necessary to provide the companies the feedback about the experimentation that they allowed us to do, and also to ask some feedback about their perspective of our experimentation and the advantage they can envisage from it.

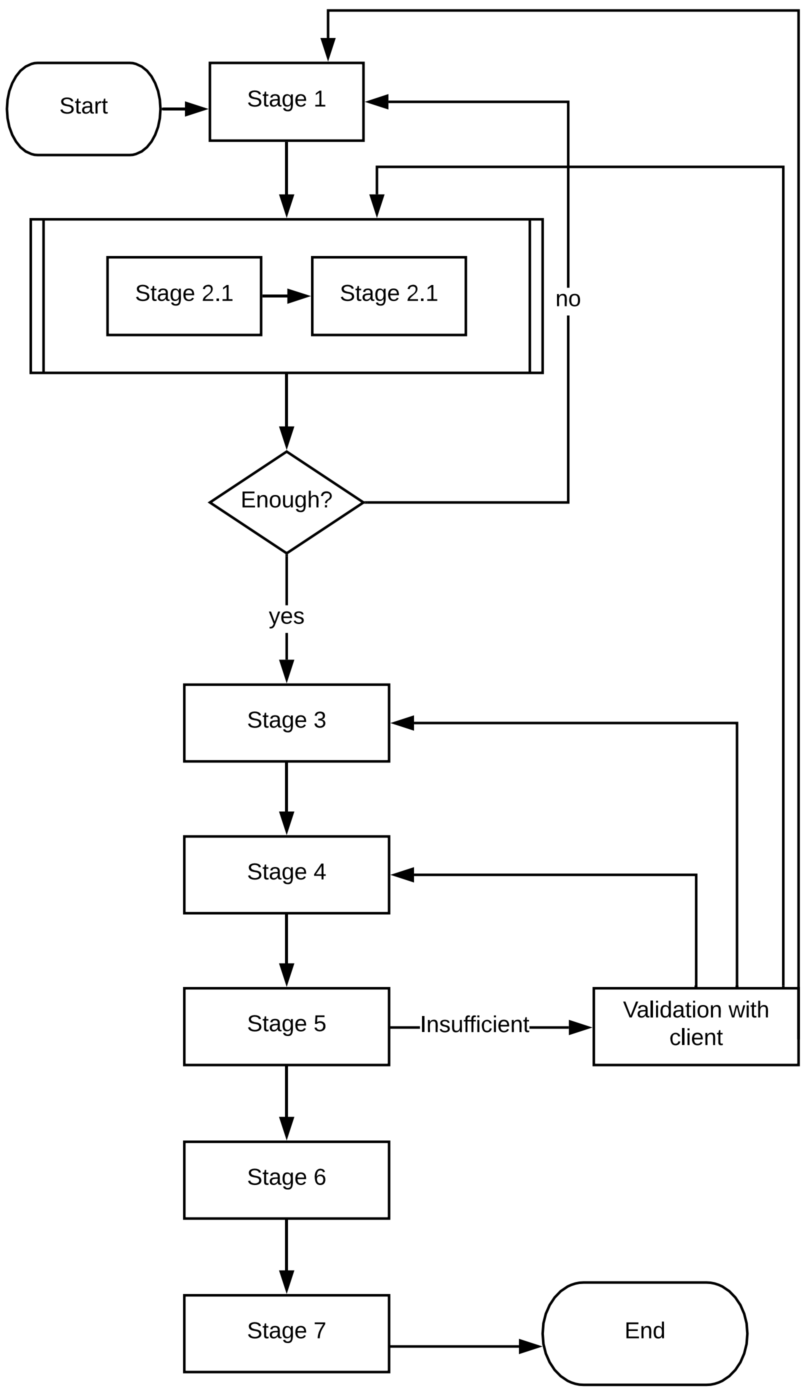

Figure 5.1 Experimental process

5.3. Analysis of the experimental process

In this subsection, first the list of companies adopting the SIPAC-framework is presented. Specific information is given about their geographical location, the ambit in which it operates, the size in terms of the number of employees, and the sector in which the related services provision or product development is framed.

5.3.1. Participating companies

There is a total amount of 11 companies participating in the validation process. The complete list is shown in Table 26.

Table 26 List of companies participating in the validation

ID	Company	Ambit	Location
A	ISVA- Duque de Santomauro Institute for Vehicle Safety	Innovation, Research and Development	Spain
B	EXA.PE	Software development	Peru
C	ETIPS.CL	Software development	Chile
D	VicMicro S.L.	Technological and Digital services	Spain
E	Tejados Ruiz S.L.	Construction	Spain
F	Grochel-MARKETING Soluciones Constructivas S.L.	Construction	Spain
G	Grochel-FORMATION Soluciones Constructivas S.L.	Construction	Spain
H	Pymeconsult	Professional services	Spain
I	Gráficas Mafra, S.L.	Graphic Art	Spain
J	CERAMA, S.L.	Construction	Spain
K	URIX	Construction	Spain

Case A corresponds to the ISVA, the Duque de Santomauro Institute for Vehicle Safety, a research institution functioning as part of the Universidad Carlos III de Madrid, in Spain. As shown in chapter 4, it constitutes a research institution in which a several members of a multidisciplinary team develop research projects. The ISVA is an institute that belong to a public university, however, the kind of research that it leads is totally financed by both public and private sponsors of different sizes. Since the main activity of the ISVA is research, its mission is oriented to the consolidation of the bigger number of project proposals.

Case B, EXA, is an IT company specialized in two activities:

- The provision of a learning management software system for corporate use (LMS), as a service (SaaS).
- The development of corporate training learning contents.

The main target clients for EXA are small and medium enterprises, in the context of Chilean and Peruvian companies, where also the development and maintenance team have personnel. EXA is a growing company with good prospects to continue in the market from a competitive perspective, since it is becoming a reference in its field of specialization.

Case C, ETIPS, is a small company specializing in the development of customized software for web applications and smart devices. Its development and directory board are distributed between Chile and Perú, however their clients may come also are from a wider number of south American countries such as Venezuela. With the kind of developments that ETIPS works on, their main goal is related to its functioning effectiveness, clearly expressing the need to decrease personnel movements and improving the learning curve of its employees so that no developments are affected as new requirements of technology domain emerge from the client's needs.

Case D, Vic Micro, is a small company in the business of repairs and maintenance of electronic and informatic devices, located in Madrid, Spain.

Case E, Tejados Ruiz, is a small company located in Madrid, Spain, that specializes in the repair of roofs. The objective of the business pursued by Tejados Ruiz S.L is the improvement of the positioning with respect to other competing companies in the sector of roof repairs.

Case F-G, Grochel Soluciones Constructivas, is a Spanish construction company capable of facing a huge range of different projects within the construction sector, from the building or maintenance of a multinational's offices to the bathroom of a middle-class family; and from last generation materials with new processes developments to a simple installation of plasterboard. The mission of the company is to

Case H, PymeConsult, is a microenterprise of professional services (accounting, legal and financial), constituted in 1999, with the mission of taking charge of all the formal obligations of client companies (facing the Ministry of Finance, Social Security, Public Administrations, etc.) not directly related to the development of their main business. The vision of the company is to become a professional partner of the client companies, not only in their formal obligations but in the totality of their business activities, so providing constructive solutions to projects with a very high level of personalization.

Case I, Graphics MAFRA is a company in the graphic art business, with the mission of providing highly customizable visual support to customers, who can be from any field. It is a family-type company whose control is distributed 50% between two brothers. The business objective of the company is to improve the number of clients that are captured and maintained and, therefore, the number of sales and the general return of investment.

Case J, CERAMA, S.L., is one of the pioneer companies in Spain in the manufacture of ceramic materials for construction. It is known for being one of the companies that gave the Sagra region the global capital of the manufacture of structural ceramics. The mission of the company is to lead the market for the manufacture of ceramic materials for construction. Among its objectives are the improvement of job security, the achievement of greater energy efficiency in the production process and that the products and their production meet the environmental demands of the market.

Case K, URIX, is a company in the construction sector, dedicated to carrying out works in large companies, kitchens and homes. It is a small company, composed of two permanent persons, but with a dynamic size in the sense that personnel are hired as projects require it. Like any other company, its main interest is to generate income to develop in the market and be competitive.

5.3.2. Testing hypotheses

5.3.2.1. Hypothesis 1

H1: "*By using the SIPAC-framework, and following all its methodological guidance, IT/SW professionals can effectively elicitate the processes, know-how and knowledge related assets of their client organizations*".

In general, this hypothesis refers to the capability of the SIPAC-framework to help the IT/SW professionals to identify the knowledge assets of an organization. As stated in chapter 3, the process of identifying the knowledge assets starts in the first stage of the SIPAC-framework's methodological layer, in which a general initial immersion in the problematic situation is performed. Actually, the IT/SW professional goes to the organizational situation with no predefined or pre-stated knowledge structures regarding the specific organizational knowledge, the knowledge assets or any other knowledge construct of the organization.

Following with the methodological layer, in stage two the IT/SW professional must structure the organizational information following the general guidelines provided, which will guide him in the process of identifying first what is the general business goal of the company, but also what are the business requirements for achieving such business goal, the related processes, what kind of intellectual capital is present in the organization, the generic knowledge assets associated to the functioning of the organization, and finally the specific knowledge assets, its indicators and the measurements for such indicators (See Figure 5.2).

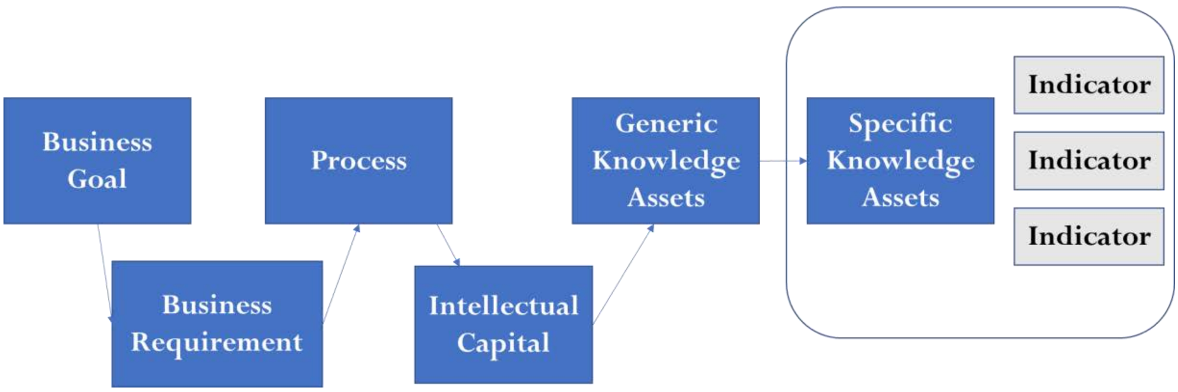

Figure 5.2 Knowledge Assets elicitation process

In general, considering the eleven cases of experimentation, the list of identified knowledge assets is shown in Figure 5.3 and Figure 5.4. Although much more information related to the knowledge assets was collected, for illustrative purposes only the process and the knowledge assets are shown here. Partial results of this experimentation has been previously published in (Sanchez-Segura, Ruiz-Robles, Medina-Dominguez, et al., 2017).

ID	Business Case	Process	Specific Knowledge Asset
A	ISVA- Duque de Santomauro Institute for Vehicle Safety	Research and Development	Knowledge repository
			Knowledge sharing recognition model
			Knowledge assets creation
			Knowledge assets reuse
			Knowledge progress assessment
			Knowledge assets changes notification
			Knowledge matrix
B	EXA.PE	Improvement in marketing through the technological service	Kick-off meeting document
			Propietary web project management system
			Customer communication skills at a technical and managerial level
			Course development process experience
			Experience in the process of development and maintenance of LMS
			Knowledge of the process of development and maintenance of LMS
C	ETIPS.CL	Customer loyalty	Knowledge of proprietary software components of the company
			Repository of documents
			Knowledge in the use of Mysql
			Experience in PHP
			Experience in Zend Framework 1.12
			Knowledge in the use of web technologies
			Experience in Jquery and Bootstrap
			Ease to be ordered and follow programming standards or process regulations
			Teaching ability
D	Vic Micro S.L.	Improvement in the Reparation Process	Repairs history
			Repair process report
			Check the web about the status of the product by the client
E	Tejados Ruiz S.L.	Improvement in marketing through the technological service	Customer maintenance model
			Model of recruitment and management of young clients
			Model of recruitment and management of clients in adulthood
			Brand model

Figure 5.3 Knowledge Assets elicitation - Part 1.

ID	Business Case	Process	Specific Knowledge Asset
F	Grochel-MARKETING Soluciones Constructivas S.L.	Marketing	Model of the corporate image
			Model of communication with the client
			Customer loyalty model
			Customer satisfaction model
			Model of personalization of products and services
G	Grochel-FORMATION Soluciones Constructivas S.L.	Training of company employees	Mentorig model
			Information organization model
			Model and quality improvement
H	PymeConsult	Improve the transmission of knowledge of repetitive tasks to be able to focus on other business areas.	High qualification of employees academically, endowed with higher degrees.
			Synthesized documentation of internal processes of the company
			Model of communication between employees
			Training model for new employees
			Organizational model and storage of knowledge
			Automated processes through technological tools
I	Gráficas Mafra, S.L.	Marketing and production process	Marketing Process: Company-client communication model
			Production Process: Internal management model
			Production Process: Supplier-company communication model
			Marketing Process: Brand Model: Web Page
			Marketing Process: Client acquisition model: Presence in SSNN
J	CERAMA, S.L.	Production process	Training courses for workers.
			Communication between workers.
			Sustainable development plan
			Quality of the final product
K	URIX	Process of improvement in Online Marketing. Social networks. Greater visibility	Automation model for uploading web content.
			Content synchronization model with social networks.
			Customer loyalty model.

Figure 5.4 Knowledge Assets elicitation - Part 2.

As may be seen in Figure 5.3 and Figure 5.4, not only the knowledge assets were identified, but also the processes, and other important knowledge-related aspects. One important thing to note is that the SIPAC-framework was effective for identifying the knowledge assets with no discrimination on what the sector of the company or the size was, demonstrating adaptability and a robust knowledge elicitation capacity.

Regarding the usefulness of the SIPAC-framework, we went beyond the results and asked the 37 IT/SW professionals in charge of deploying the general framework two specific questions:

- *As software engineer or similar, how useful was for you the SIPAC-framework as a support for your selection of the best digital solution to implement in your client company considering that you must adjust to the alignment between strategic goals and the company's knowhow?*
- *How do you value the adaptability of the SIPAC-framework to different enterprises, considering sector and size of the company?*

It is remarkable the high percentage of professionals giving a positive feedback on the usefulness of the SIPAC-framework Figure 5.5. In a 1-5 scale, with 1 being the lower valuation and 5 being the higher valuation, 76% of respondents gave the SIPAC-framework a 5 out of 5, and 21% of respondents gave it a 4 out of 5. In contrast, only 3% of respondents gave a 3 out of 5, while no 1 or 2 out of 5 valuations were obtained.

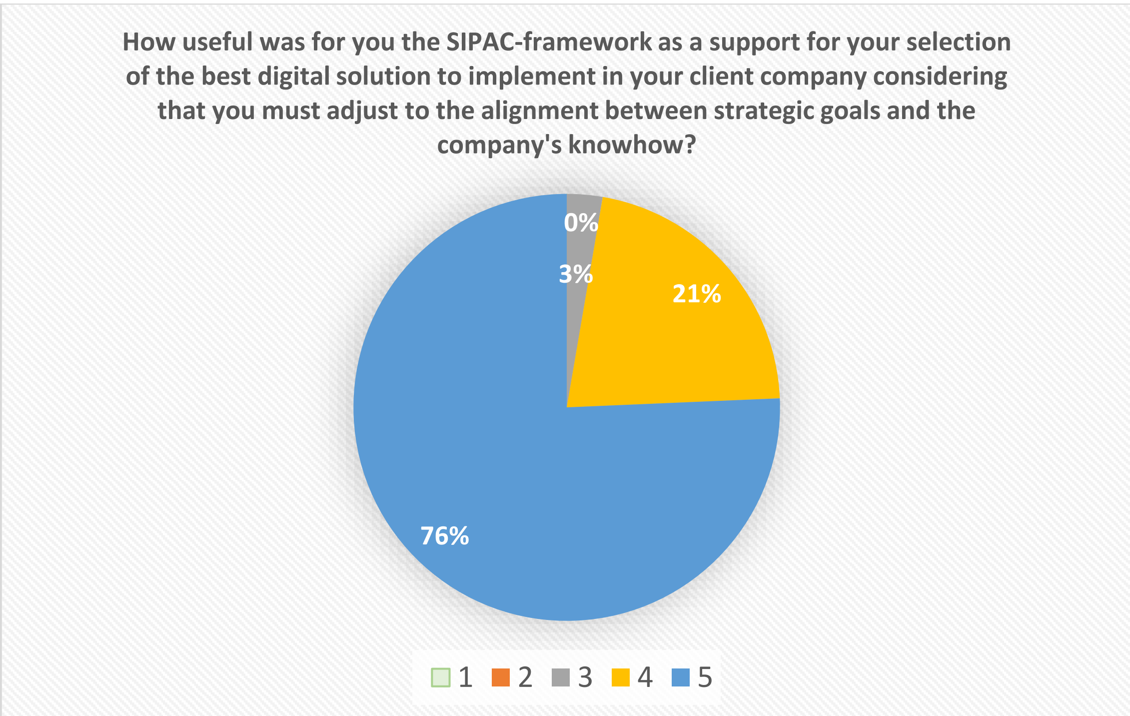

Figure 5.5 Usefulness of the SIPAC-framework

These results are very promising given that the SIPAC-framework is an innovative approach being for the first time introduced to the SW/IT professional practice, and is important to affirm that this first attempt has obtained very positive opinions, so that other professionals in the near future may become willing to adopt it when thinking on designing solutions specifically aligned with strategic goals alignment for better business value creation.

The second question was referred to how adaptable the SIPAC-framework was for being used in the creation of solutions for companies in different sectors. For exploring so, given that the eleven cases belonged to different sectors, such as construction, information technology or administrative services; the next step was to ask the opinion of the IT/SW professionals on the adaptability of the SIPAC-framework to be used in different sectors of the industry. The results are also very positive, obtaining an 81% of answers with a 5 out of 5, and a remaining of 19% of 4 out of 5.

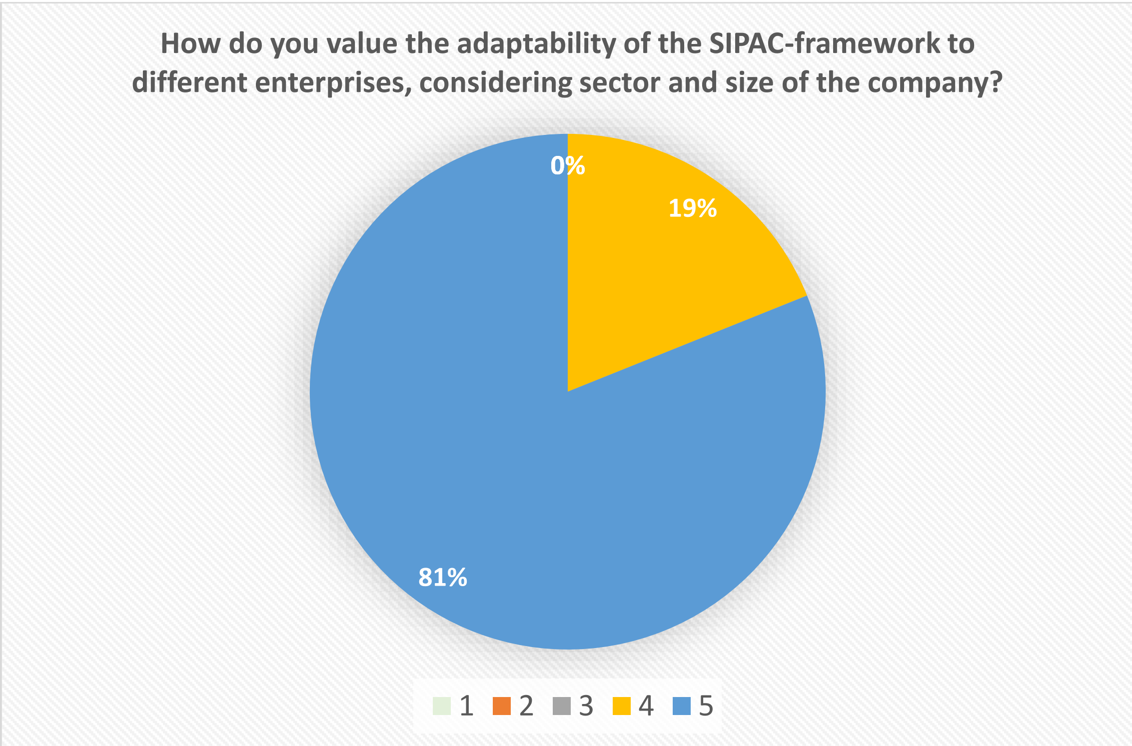

Figure 5.6 Adaptability of the SIPAC-framework

Given that in the current times digital solutions and strategies are needed in all sectors of industry, and that technologies implementation is a transversal task occurring in all industries, the adaptability of the SIPAC-framework can be affirmed and supported.

The SIPAC-framework allowed the identification of specific knowledge assets of different nature, from the "Customers satisfaction model" related to the marketing process of a marketing-sector company (Case I), to the "Repairs history", an asset of a company in the sector of technological devices service and maintenance (Case D), in which the reputation is the most important thing to take care of.

The ability to work with the framework must reside in the IT/SW professional, not in the client company, which is why in our experimentation most of the cases were successful and this is a generalizable behavior expected for future cases willing to use the SIPAC-framework.

As a summary, the SIPAC-framework has demonstrated to be an effective tool for guiding the IT/SW professional in the process of elicitation of their client's knowledge for using it in their posterior digital solutions design process, with no discrimination on such client's sector of industry or size.

5.3.2.2. Hypothesis 2

H2: "*From the implementation of the strategy or digital solution that the SIPAC-framework helps the IT/SW professional to propose to their clients, the state of organizational knowledge assets can be improved so that the organizational business goal is better pursued*".

From the experimentation process, the eleven cases audited revealed the results presented in Figure 5.7. In such figure, there are two clearly differentiated sections, the left one showing the general count of characterization states for the knowledge assets of the 11 cases **before** the implementation of the SIPAC-framework suggested digital solution. The one to the right shows the count proportions of the characterization states **after** the implementation of the suggested digital solution. In this count, it has been considered important the business case that was considered, which is shown in the first column. Each of the horizontal lines corresponds to one of the cases previously mentioned in Table 26.

ID	Preceding audit									Subsequent audit								
		Statistics									Statistics							
	N° of KAs	% Stable Asset	% Evolving Asset	% Replaceable Asset	% Warning Asset	% Unacceptable Quality Asset	% Acceptable Quality Asset	% Unacceptable Impact Asset	% Acceptable Impact Asset	N° of KAs	% Stable Asset	% Evolving Asset	% Replaceable Asset	% Warning Asset	% Unacceptable Quality Asset	% Acceptable Quality Asset	% Unacceptable Impact Asset	% Acceptable Impact Asset
A	7	14%	14%	0%	14%	29%	0%	29%	0%	7	14%	29%	0%	0%	29%	0%	14%	14%
B	6	33%	33%	17%	17%	0%	0%	0%	0%	6	33%	33%	17%	17%	0%	0%	0%	0%
C	9	11%	22%	44%	22%	0%	0%	0%	0%	9	33%	22%	22%	22%	0%	0%	0%	0%
D	3	0%	0%	0%	33%	33%	0%	33%	0%	3	33%	0%	0%	0%	0%	33%	0%	33%
E	4	0%	0%	0%	75%	0%	0%	25%	0%	4	25%	50%	0%	0%	0%	0%	0%	25%
F	5	20%	0%	20%	20%	20%	0%	20%	0%	5	60%	0%	0%	0%	0%	20%	0%	20%
G	3	0%	0%	0%	33%	67%	0%	0%	0%	3	33%	0%	0%	0%	33%	33%	0%	0%
H	6	0%	0%	17%	17%	17%	17%	17%	17%	6	0%	33%	0%	0%	0%	33%	0%	33%
I	5	0%	20%	20%	60%	0%	0%	0%	0%	5	20%	40%	0%	40%	0%	0%	0%	0%
J	4	25%	25%	0%	50%	0%	0%	0%	0%	4	50%	0%	50%	0%	0%	0%	0%	0%
K	3	0%	0%	0%	0%	0%	0%	100%	0%	3	0%	0%	0%	0%	0%	0%	33%	67%

Figure 5.7 Characterization results (Before vs. After Implementation)

Following is the analysis of results comparing the pre and post phases of the experimentation for each of the characterization cases: both quality and impact, only quality and only impact. Specifically, in the following subsections are analyzed all the knowledge assets from the perspective of their pre and post characterization state, regardless the company they belong to or other restrictions.

5.3.2.2.1. Case 1: Both Quality and Impact Knowledge Assets

Considering all the knowledge assets identified in the 11 cases involved in the thesis validation, having both type of indicators, impact and quality, before the implementation of the digital solution, most of them were characterized as "Warning" (43%), some (22%) were Replaceable, some (19%) Evolving, and a few were "Stable" (16%) (Figure 5.8).

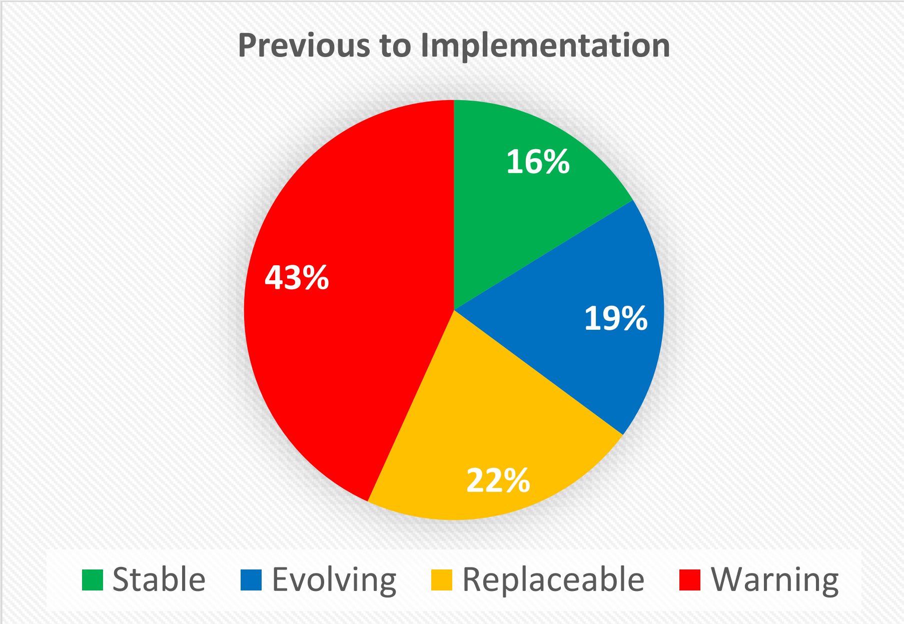

Figure 5.8 Case 1 characterization before implementation.

As seen, the previous situation gives a general idea of the not so healthy state of characterization of the knowledge assets before any digital solution was proposed and implemented by the IT/SW professional. The proportion of stable knowledge assets is quite lower than the one of warning or replaceable knowledge assets, which together account for a 65% of knowledge assets in a state that is directly affecting negatively the organizational performance if seen from how good or bad is the alignment between these and the strategic goals.

But these previous numbers belong to the first part of the SIPAC-framework deployment. The most important data to note regards how these numbers changed drastically after the digital solution was implemented, when the company's knowledge assets were assessed for the second time. It was obtained a majority of Stable (41%) knowledge assets, followed by a 32% characterized as Evolving, a 14% as Warning and a 13% as Replaceable. These results can be observed in Figure 5.9.

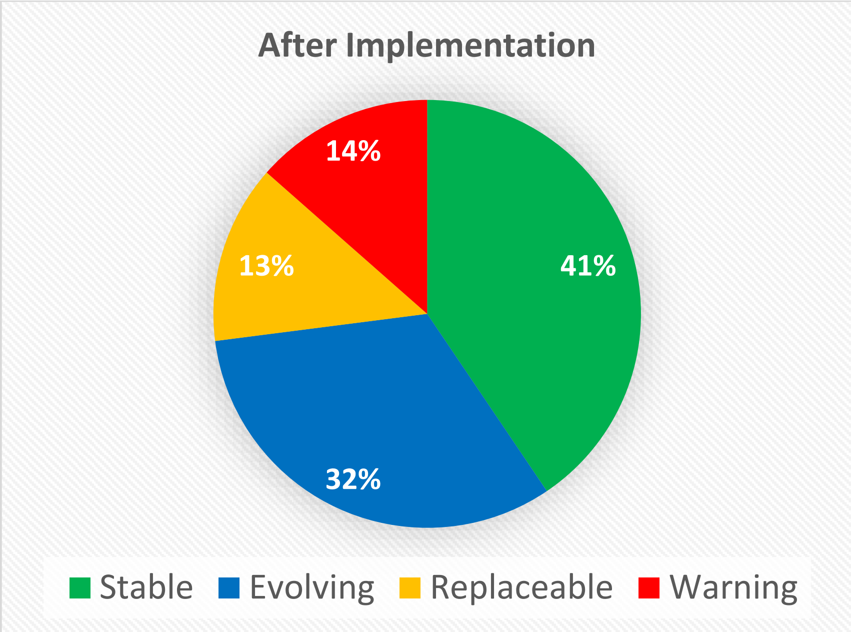

Figure 5.9 Case 1 characterization after implementation.

If considering that Stable is a "good state" and that Evolving is a state that still can be used to positively support the organizations business, the remarkable fact is that 73 % (41% Stable plus 32% Evolving) of organizational knowledge assets are in a good or acceptable shape, and are those the ones from which the business strategist must take advantage and invest to better pursue strategic goals achievement (since the existing alignment achieved through the implementation of the digital solution or strategy).

5.3.2.2.2. Case 2: Only Quality Knowledge Assets

Considering all the knowledge assets identified in the 11 cases involved in the thesis validation, having only quality indicators (Case 2 of the characterization), there is a considerable improvement as well if the results before and after the implementation of the digital solution are compared. While before implementation the proportion of Knowledge Assets characterized as of "Unacceptable Quality" was the 87% (Figure 5.10), this proportion is only 37% after the implementation (Figure 5.11), what means that the implemented solution had an improvement effect. A so high percentage of unacceptable quality knowledge assets suggests that in most of the cases the quality of knowledge assets regarding the strategic goals achievement was not correctly being cared, and this represent a general attenuator for organizational performance.

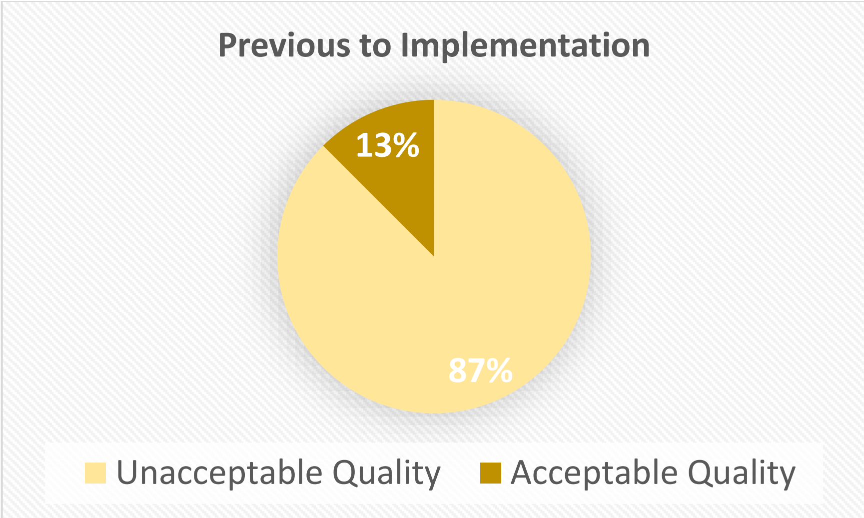

Figure 5.10 Case 2 characterization before implementation

Contrasting with the previous results, in the assessment after the implementation of the digital solution, the proportions of "Acceptable Quality" Knowledge Assets increased significantly from 13% before the implementation (Figure 5.10) to 63% after the implementation (Figure 5.11), representing a positive effect for the company in terms of the quality of the knowledge assets contributing to strategic goals achievement from the alignment of the digital solution or strategy implemented.

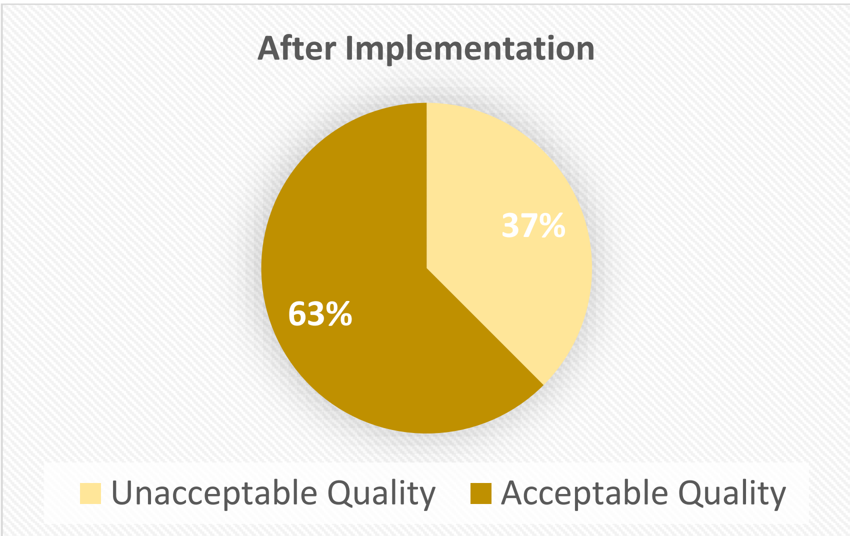

Figure 5.11 Case 2 characterization after implementation

In practical terms, the increase on the number of acceptable quality knowledge assets over the number of unacceptable knowledge assets supports the fact that the SIPAC framework's suggested solution helps to effectively improve the quality of the knowledge assets, representing an aspect in which the company/organization must lever to improve organizational performance.

5.3.2.2.3. Case 3: Only Impact Knowledge Assets

Considering all the knowledge assets identified in the 11 cases involved in the thesis validation, having only impact indicators, there was also a significant improvement in their characterization. The proportion of "Unacceptable Impact" decreased from 90% (Figure 5.12) before the implementation of the digital solution, to 20% (Figure 5.13) after the implementation of the digital solution.

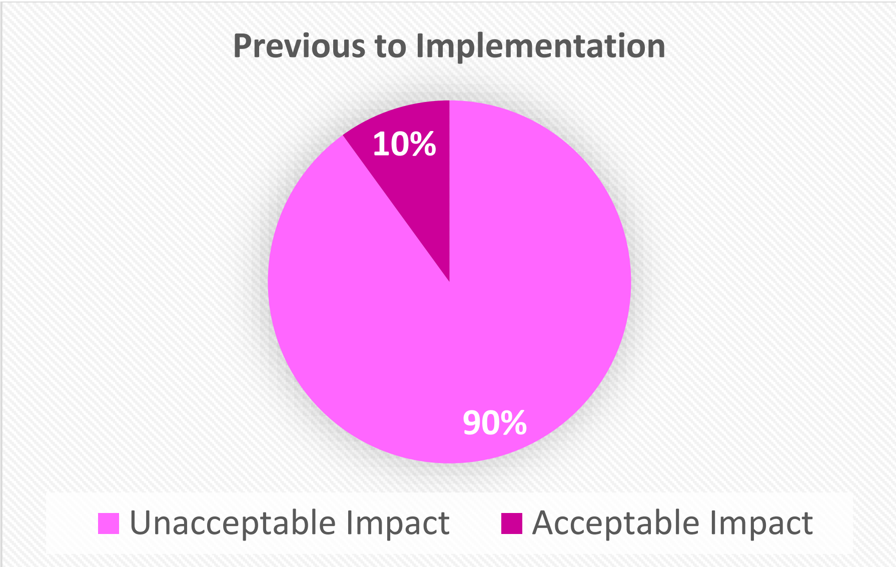

Figure 5.12 Case 3 characterization before implementation.

Correspondingly, the proportion of "Acceptable Impact" increased from 10% (Figure 5.12) to 80% (Figure 5.13).

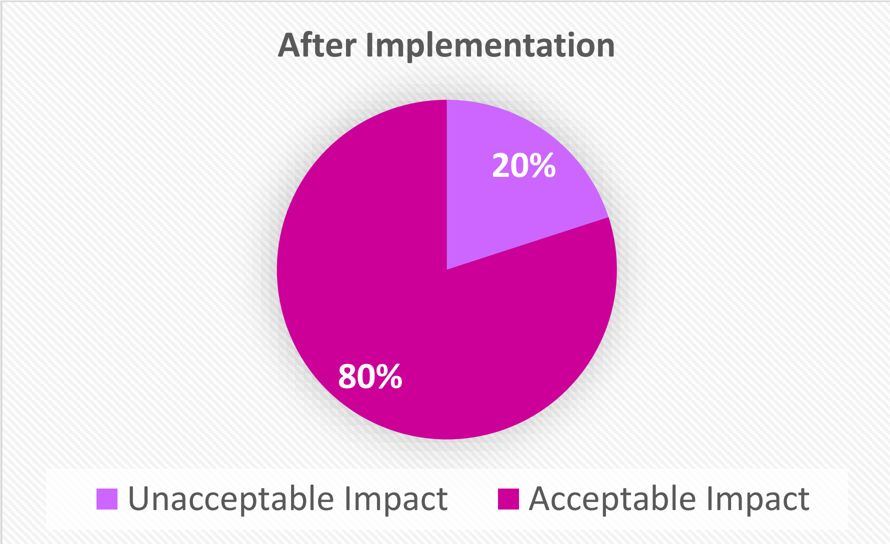

Figure 5.13 Case 3 characterization after implementation.

In general, the increase in the number of only quality knowledge assets characterized as "acceptable" indicates that the SIPAC-framework's suggested solution effectively supports the organizational behavior improvement from the fact better affecting how the knowhow of the organization impacts on strategic goal achievement.

Another prism to consider for testing organizational knowledge assets improvement is that one in which instead of observing the whole compound of knowledge assets of the audited companies observing each knowledge asset and it dynamically changed as a product of the digital solution that was implemented. For doing so, it is important to define that the following possible transitions would be considered beneficial:

- From Stable to Stable
- From Evolving to Stable
- From Replaceable to Stable
- From Warning to Stable
- From Evolving to Evolving
- From Replaceable to Evolving
- From Warning to Evolving
- From Warning to Replaceable
- From Acceptable Quality to Acceptable Quality
- From Unacceptable Quality to Acceptable Quality

- From Acceptable Impact to Acceptable Impact
- From Unacceptable Impact to Acceptable Impact

In the other hand, these other possible transitions would be considered harmful:

- From Stable to Evolving
- From Stable to Replaceable
- From Stable to Warning
- From Evolving to Replaceable
- From Evolving to Warning
- From Replaceable to Replaceable
- From Replaceable to Warning
- From Warning to Warning
- From Acceptable Quality to Unacceptable Quality
- From Unacceptable Quality to Unacceptable Quality
- From Acceptable Impact to Unacceptable Impact
- From Unacceptable Impact to Unacceptable Impact

The previous beneficial and harmful possible transitions regarding the implementation can also be represented as in Figure 5.14, with green background showing the beneficial and red background the harmful.

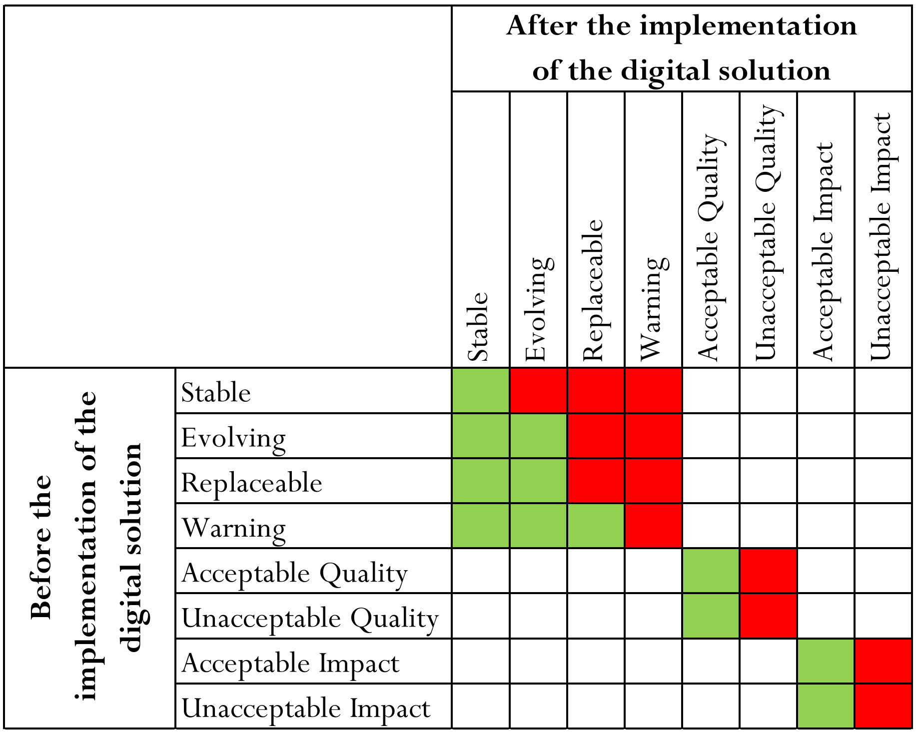

Figure 5.14 Beneficial and Harmful transitions for Knowledge Assets

The real results of the experimentation for the eleven cases is presented next in Figure 5.15.

As it may be seen, considering the previously defined rules of acceptance of beneficial or harmful transitions, in 80% of the recharacterization the transition was beneficial, which means that either maintained an acceptable good state of health or improved. In contrast, 20% of the characterization transitions were harmful

BUSINES CASE	CASE ID	ID of Knowledge Asset																		Total KA	Beneficial	Harmful	Quality Threshold	Impact Threshold
		1		2		3		4		5		6		7		8		9						
		Bef.	Aft.	Bef.	Aft.	Bef.	Aft.	Bef.	Aft.	Bef.	Aft.	Bef.	Aft.	Bef.	Aft.	Bef.	Aft.	Bef.	Aft.					
ISVA	1	UI	AI	E	E	W	E	UQ	UQ	UQ	UQ	UI	UI	S	S					7	4	3	-0.43	-0.86
EXA	2	E	E	R	S	E	E	S	S	S	S	W	E							6	6	0	-0.24	-0.5
ETIPS	3	W	W	E	E	R	S	R	W	S	S	E	E	R	R	R	R	W	S	9	5	4	-0.16	-0.15
VICMICRO	4	UI	AI	W	S	UQ	AQ													3	3	0	-0.16	-0.15
RUIZ	5	W	S	W	E	W	E	UI	AI											4	4	0	-0.16	-0.15
GROCHEL MARKeting	6	UI	AI	UQ	AQ	W	S	R	S	S	S									5	5	0	-0.16	-0.15
GROCHEL FORMATION	7	W	S	UQ	UQ	UQ	AQ													3	2	1	-0.16	-0.15
PYMECONSULT	8	AQ	AQ	UI	AI	AI	AI	UQ	AQ	W	E	R	E							6	6	0	-0.16	-0.15
MAFRA	9	E	E	W	E	R	S	W	W	W	W									5	3	2	-0.16	-0.15
CERAMA	10	E	S	W	R	W	R	S	S											4	4	0	-0.16	-0.15
URIX	11	UI	AI	UI	AI	UI	UI													3	2	1	-0.16	-0.36
																				Count	44	11		
																				%	80.00%	20.00%		

Figure 5.15 Results of characterization changes among audits

5.3.2.3. Hypothesis 3

H3: "*The SIPAC-framework is effective at predicting a company's' knowledge assets evolution, based on information about its effectiveness in previous experiences*"

Of special interest to this research was to test the predictive property of the SIPAC-framework regarding the characterization of an organization's knowledge assets. The following Figure 5.16 shows the initial, predicted and real subsequent characterization for a specific test case.

Impact Threshold	Quality Threshold							
0.1	0.15							
Digital Solution: Implementation of an open source web platform containing a cloud based knowledge repository, a knowledge sharing incentivation module and a private/public interface for web difussion.								
Real Pre-Implementation			**Estimation using SIPAC-framework**			**Real Post-Implementation**		
I-value	**Q-value**	**Characterization**	**I-value**	**Q-value**	**Characterization**	**I-value**	**Q-value**	**Characterization**
0.16	-0.2	Evolving	0.22	0.15	Stable	0.21	0.1	Evolving
-0.4	-0.1	Warning	0.21	0.1	Evolving	0.12	0.14	Evolving
-0.1	0.3	Replaceable	0.15	0.1	Evolving	0.18	0.12	Evolving
0.29	0.1	Evolving	0.23	0.25	Stable	0.18	0.21	Stable
0.3	-0.35	Evolving	0.215	0.2	Stable	0.32	0.18	Stable
-0.4 --		Unacceptable Impact	0.2 --		Acceptable Impact	0.32 --		Acceptable Impact
-0.36	0.18	Replaceable	0.12	0.21	Stable	0.03	0.23	Replaceable

Figure 5.16 Estimation vs. Real post implementation characterization results

As it may be seen, given the initial characterization, the SIPAC-framework allowed the prediction of the recharacterization to be done after the implementation of the digital solution/strategy proposed.

The initial characterization is shown in Figure 5.17.

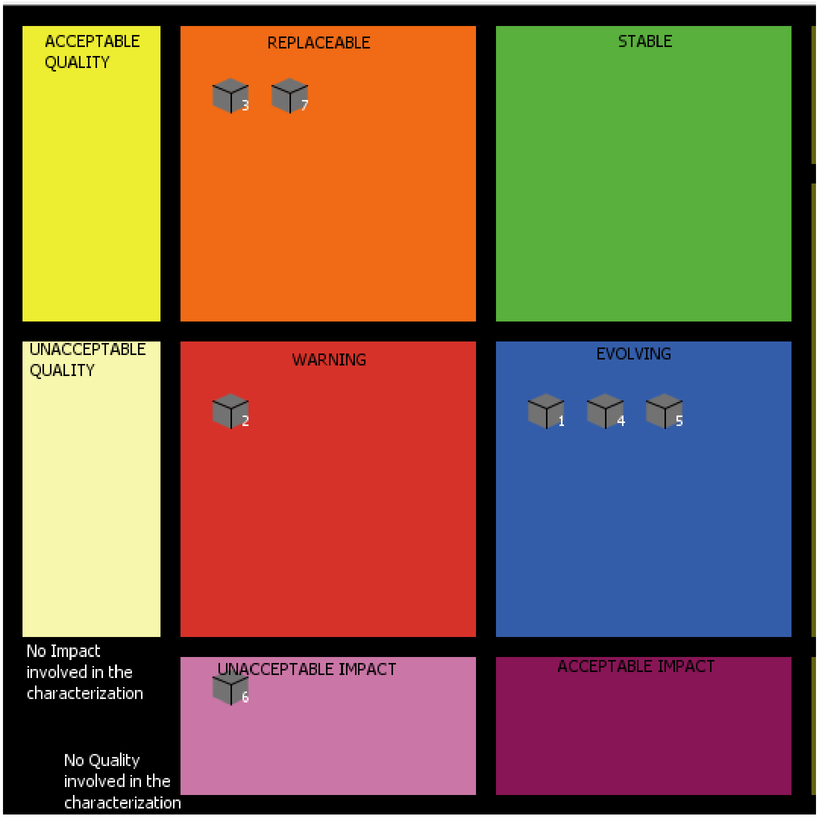

Figure 5.17 Real characterization before DS implementation.

As Figure 5.17 shows, 4 the knowledge assets 1, 4 and 5 have been characterized as "Evolving", 2 as "Warning", 3 and 7 as "Replaceable, and 6 as "Unacceptable impact".

The prediction generated by the SIPAC-framework simulation tool (Figure 5.18) shows that from the information of experiences with other companies, the tendency of this company's knowledge assets is to evolve as follows: knowledge assets 1, 4, 5 and 7 must evolve to be re-characterized as "Stable", 2 and 3 must evolve to be re-characterized as "Evolving", and finally the one with the number 6 must evolve to be recharacterized as "Acceptable Impact".

Considering that Stable is a state more desirable than Evolving, that Evolving is a little more desirable than Replaceable, and that Acceptable is better that Unacceptable; the predictions suggest improvement for knowledge assets 1, 2, 3, 4, 5, 6 and 7, as shown in Figure 5.18.

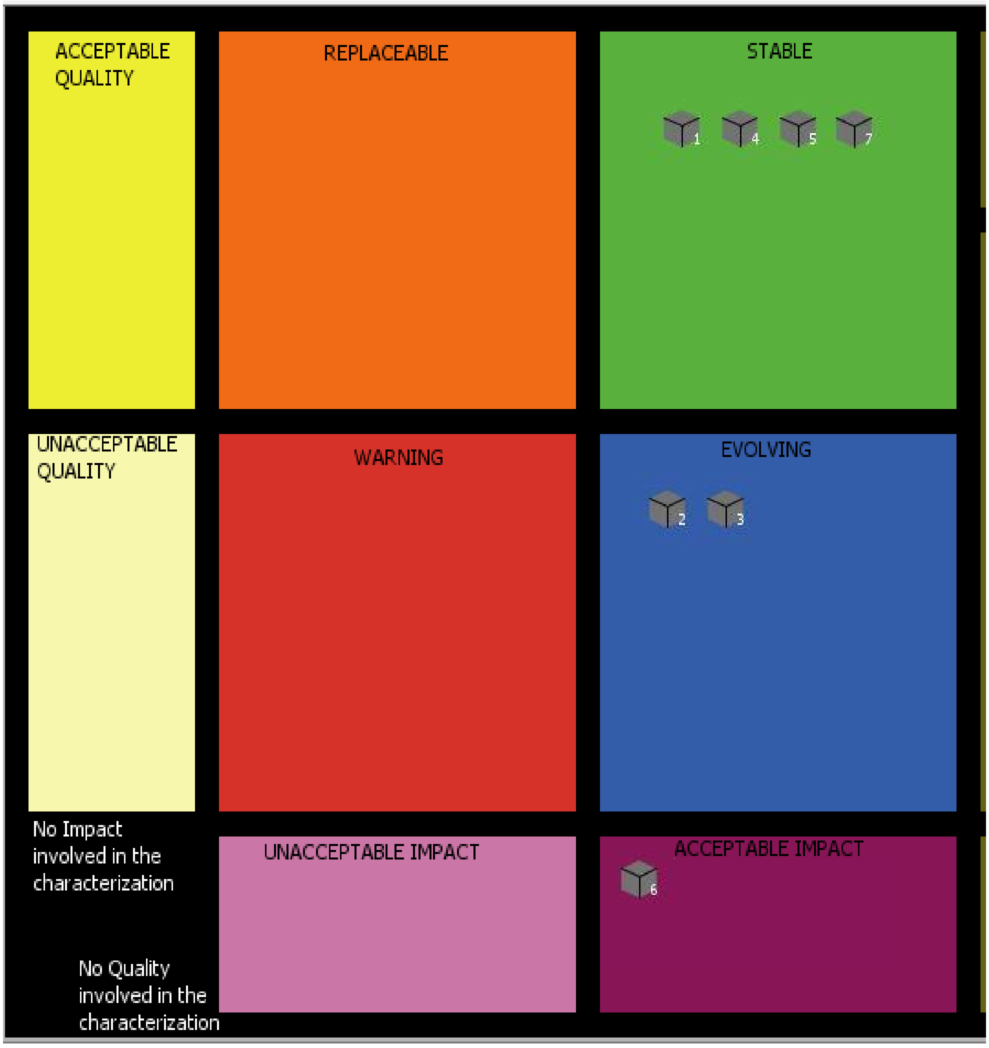

Figure 5.18 Predicted characterization after DS implementation.

In order to test the efficacy of the simulation, the prediction must be compared with the real results of the characterization for this specific case. The real characterization after the implementation of the digital solution is shown in Figure 5.19.

As it may be seen, in most of the characterizations performed (5 out of 7), the prediction coincided with the real characterization. Specifically, knowledge assets identified as 2, 3, 4, 5 and 6 recharacterized exactly as suggested by the simulation model.

In the case of the knowledge asset 1, the prediction failed, since it expected this asset to be recharacterized as “Stable” but it only achieved an “Evolving” state. This may be explained by the insufficient improvement in the quality assessment for such asset. There was a significant improvement in such quality, going from -0.2 to 0.1, however, this improvement needed to achieve a value higher than the defined quality threshold (0.15) to be characterized as “Stable”, so with the current conditions the re-characterization was not possible. However, the discussion is possible about how far the original quality valuation was, and the significant improvement achieved, which remains being a good indicator for the effectiveness of the SIPAC-framework suggested solution, which was the simulated scenario.

In the case of the knowledge asset identified as 7, the simulation predicted improvement in both the quality and the impact valuations, so that it may be re-characterized as Stable. However, the real re-characterization showed such asset still as Replaceable, with no change on characterization state. This may be explained by the extremely bad initial impact valuation that the knowledge asset has even before the implementation. The initial impact valuations of impact was -0.36, which is far from the stablished impact threshold of 0.1. Although there was an improvement in such impact, going from -0.36 to 0.03, this improvement was not enough to overcome the threshold which was established at 0.1, however, as in the previous case, it may be discussed the effectivity of the SIPAC-framework, given that the improvement occurred.

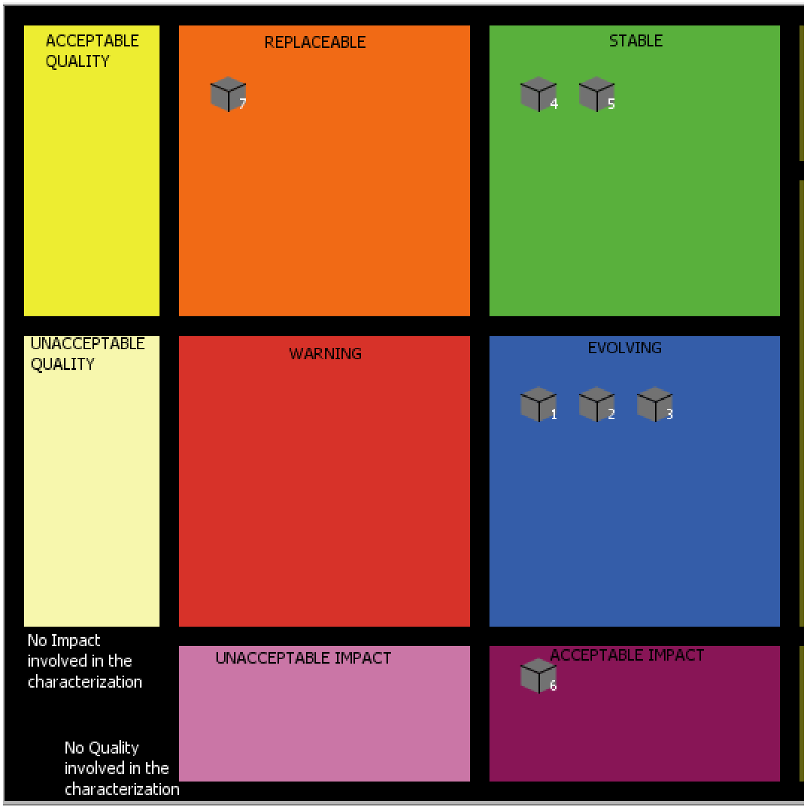

Figure 5.19 real characterization after DS implementation.

5.3.2.4. Hypothesis 4

H4: "*SW/IT professionals are satisfied with the process of deploying and experimenting with the SIPAC-framework in real organizational contexts*"

The fourth hypothesis was clearly stated to test the opinion of the users of the SIPAC-framework. A specific survey, which is shown in the Annex II, was designed to approach these professional's opinion.

Of special interest was to discover how easy was for them to deploy the whole framework. The results are promising, as shown in Figure 5.20, with a 73% giving the SIPAC-framework a 5 out of 5 in easiness for use. This is a very positive result given that the SIPAC-framework is innovative in the sense that introduces complex concepts to software engineers and IT professionals; concepts usually reserved for people with a clear formation in the business and intangible capital fields. Although these concepts are present, the SIPAC-framework has been designed to be helpful to the professionals using it, which according to the survey seems to be achieved with the remaining 27% giving a 4 out of 5, which remains being a positive result.

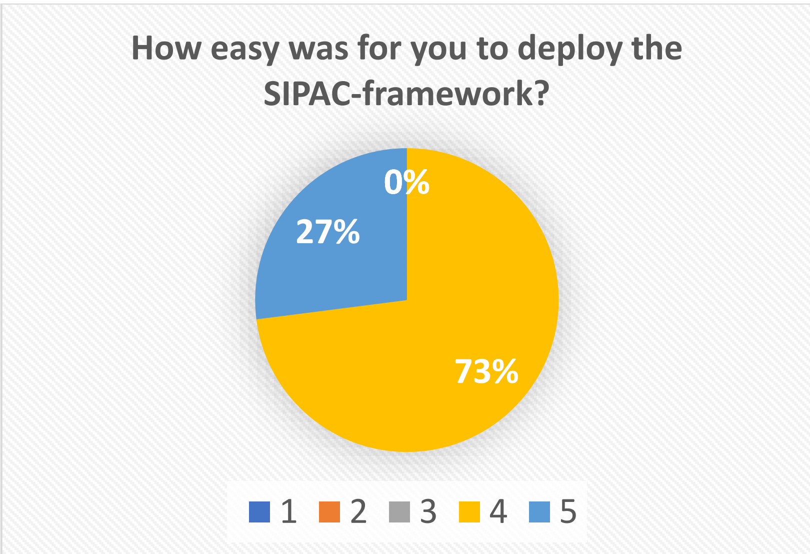

Figure 5.20 Ease of the SIPAC-framework deployment.

Following this, another question we made referred to the access these professionals had to the specific tool designed to simplify the approach between software engineers and the intellectual capital concepts: the spreadsheet for data collection tool. We explicitly asked about the usefulness of the sheet as a support for the deployment of the framework. As shown in Figure 5.21, we obtained a general positive valuation with 68% of them giving the sheet a 5 out of 5 in usefulness, and the remaining 32% giving a 4 out of 5.

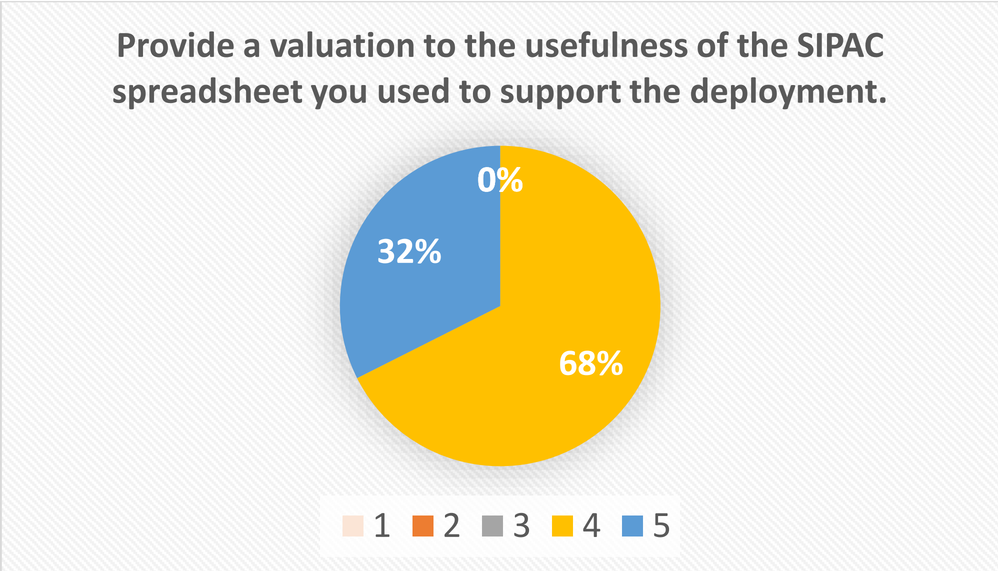

Figure 5.21 SIPAC-framework spreadsheet tool valuation.

The results are very significative for this research, given that one of the main goals from the beginning of research was to overcome the limitations given by the despaired connection among the software and the business language in practice. The general trend is to have available business people with insufficient software skills, and software people with insufficient business skills. With this tool, the idea was to reduce this gap by facilitating the IT/SW professionals the access and management of the (usually unknown) intellectual capital concepts and guarantee that they could perform the total assessment from the initial immersion to the final characterization of the knowledge assets. The results suggest a clear success regarding this, however we have continuously identified possible improvements mainly focused on easing the supporting tools management.

6. Conclusions and future work

In the software engineering and information technology professional practice, professionals have the responsibility to identify their clients' needs and design and propose the corresponding digital solution that will better fit with the client needs. Bearing this in mind, this work has presented a methodological and technological framework to improve the software engineering objective of better proposing digital solutions from the fact that a company's knowledge must be aligned with organizational business goal, so any strategy or digital solution implemented within the company must also be designed to pursue such alignment.

This methodological and technological framework was presented as a three-layer solution with distinguished functional parts.

The methodological layer presented a soft methodological guide to help the software consultant to transit among all the stages of identifying the client needs, identifying the knowledge assets, identifying the organizational business goals, selecting what is the organizational mission that better aligns business goals and knowledge assets, using such knowledge assets indicators information to characterize them and so being able to define an improvement plan that proposes the best aligned digital solution. Also, this framework helps the software and information technology professional to demonstrate the effect of implementing the proposed digital solution from the impact it has on organizational performance from the perspective of their knowledge assets behavior and the impact they have regarding the business goal.

The mechanisms layer proposes a conceptual framework that supports the methodological deployment of the first layer. Is has been defined a conceptual proposal for characterizing a company's knowledge assets based on their quality and impact on organizational business goals, for which a standard method for measuring and valuating knowledge assets is proposed. Also, a conceptual design of the process of decision-making is presented as the basis for simulating the process of decision making in regard to a software solution implementation decision. This decision-making model is based on the Instance-based learning model in which a memory existence is represented with several instances that are the reference to make better decisions from experiencing with all of them and using the most productive or rewarding ones. For such experiential learning, specific processes and concepts of the Instance-based learning model were used, such as blending, activation, etc.

The technological layer proposed the use of artifacts to better implement the general methodology of layer one. The more important artefact is an agents-based simulation model able to characterize knowledge assets using a graphical abstract representation, and able also to represent the decision-making process of deciding to implement or not the technological solution that the software engineer has defined, showing besides the effect that such a decision may have on the corresponding knowledge assets. There is also an artefact consisting on a web application to store, retrieve and export the information of a company's knowledge assets audit. A third artefact consist on a spreadsheet useful to manually save the information of a company at the time of interaction with a company information stakeholder.

All the three layers conform a whole framework that as a group of interconnected parts is definitely more than the sum of the parts if seen as separated and independent elements. This mix of the three layers give us a general guide to completely provide the service of guiding the client to improve from their knowhow identification and the better fit of the digital solution to implement.

6.1. Future work

6.1.1. Biomimetic analysis and exploration

One of the main paths of research to be followed from this research work is on the exploration of the biomimetic features that make a digital solution implementation to be less or more "smart", i.e. more similar to those behavioral patterns present in nature that show an intelligent behavior from a systemic perspective.

An initial attempt on identifying such behavioral patterns, specifically focused on honey-bees and ant colonies, was published on (Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2017), however a deeper work on validating and testing the personality traits that describe make an implementation smart is to be completed. This ongoing work is exploring the traits initially described by the interpersonal circumplex model, since besides merely human, these personality traits are useful for describing several animal species behavior (Zeigler-Hill & Highfill, 2017), which directly fits with the mentioned interest of thinking on the digital solutions proposed by the SIPAC-framework as smart solutions that from several factors can "wisely" mimic nature intelligence and focus on the supposed organic common systemic interest: achieving the strategic goal. Currently, research is being made considering both the intelligence implicit on the digital solutions and on the knowledge assets that the SIPAC-framework focused on identifying and exploiting for the digital solution proposal.

Trying to implement the biomimetic properties, some specific biomimetic indicators have been defined, which allow us to measure the behavior of assets, understanding them as members of a set of assets with a certain capacity of reaction to the environment, always aimed at ensuring their viability. These biomimetic features are being measured and tested, and directly comprehend the following biomimetic indicators:

- Age
- Extraversion
- Neuroticism
- Agreeableness
- Openness
- Conscientiousness

6.1.2. The SIPAC-framework expansion

Other branch of future research from this thesis is related to the exploration of changes in the SIPAC-framework when more than one strategic objective is considered. From the Systems Complexity perspective, this factor exponentially increases the complexity related to the whole system of knowledge assets of a company, however it is a matter worth for research since whereas a company can define a general strategic goal representing its mission, it is common to have several goals representative of several perspectives, which cannot be ignored from the systems thinking perspective. The addition of strategic goals implies the structuration of several weights of knowledge assets and indicators, which are different for each of the strategic goals. In its current form, the SIPAC-framework is prepared to audit a company knowhow and identify and simulate its knowledge assets behavior from the effect of digital solution decision-making, always in regard to an identified strategic goal. In the future, the incorporation of other strategic goals will enable to switch from a perspective to another and visualize how the knowledge assets of a company may be, for example, positively leveraging a strategic goal achievement while negatively affecting the achievement of the another.

Another aspect to be considered in future developments is the possibility of having collective indicators, i.e. indicators that may be used to measure more than one knowledge asset at a time. Until now, the SIPAC-framework guides in the process of identifying strategic goals, processes, knowledge assets and the indicators for such knowledge assets, however, one possibility to be discussed in future work is the inclusion of indicators that may be affecting more than only one indicator. This improvement shall imply several changes on all the layers constituting the SIPAC-framework, which is why it has been classified as a to-do for future developments. Among the changes to consider we can mention: changes on the data collection spreadsheet to duplicate indicators in field for different knowledge assets, changes on the database to update the entity-relation structure so that what used to be a 1-n relation for knowledge asset and indicators can transform to m-n, i.e. one knowledge asset may have several indicators, and one indicator may be used to measure several knowledge assets.

6.1.3. Formalize the conceptual model as an Intellectual Capital approach

Getting back to the intellectual capital field of knowledge, the SIPAC-framework has opened the possibility of exploiting the designed artefacts and models to support the formalization of a method for engineering the intellectual capital of a company. In chapter two we discussed on the several approaches for intellectual capital assets identification and classification, which constitutes a solid analytical framework to help a company in the process of unfolding its intangible side. However, using the SIPAC-framework's artefacts, it is possible to go beyond and help the company to make tangible, or at least have visibility, of its knowledge assets, their current state and whether they could be improved or not. We have considered in the SIPAC-framework artefacts the classification of knowledge assets as human, structural or relational capital, which is why we can also from this point and on estimate the maturity that each of the capital types has. This work is still to be made, however there are several artefacts ready to be used and there is even data of companies that could be exploited, so indeed a research proposal to continue this aspect of this research has been stablished.

Another aspect we had to think about was on how we were going to introduce the SIPAC-framework to strategist and decision-makers not specialized on engineering methods, methodologies, processes or digital solutions. That is why we though on correlating the SIPAC-framework with one of the most commonly used approaches for strategy analysis: The Business Model Canvas. We have started research on identifying the generic and ad-hoc relations that may exist between a company's knowledge assets and its business model canvas related parts, so that general strategist and decision makers can directly dilucidated the impact that good or bad knowledge asset may have on the business. To do so, we are leading a research work with two easily identifiable prisms: 1) The identification of existent relations between generic knowledge assets and a business model canvas elements, so that specific and ad-hoc relations can identified through a general guide; and 2) the construction of a simulation model, from the SIPAC-characterization model, that visually shows the effect of decisions regarding digital solutions implementation on the company's knowledge assets characterization and how these characterized assets affect specific areas of the business model canvas. This advance represents a potential input to real strategic decision making that can be used by both specialist and general decision makers since the main focus is on exploiting the strategic interpretation of the information of: the state of the knowledge assets and its effect on the business model canvas.

Regarding the target companies that could benefit from the SIPAC-framework, not only small and medium enterprises can audit their knowledge and explore the best digital solution that software engineers may propose, but also bigger companies could invest and empower the SIPAC-framework so that independently of the increasing complexity, through the use of technologies it may be adapted and deployed guaranteeing the correct focus on its *lait-motiv*: to empower from a company's knowhow to identify and propose the best digital solution for a best strategic goal achievement pursuit. In this work, the SIPAC-framework was used in small and medium enterprises, but the research team is highly convinced that as a bigger company commits to its implementation, the SIPAC-framework will perfectly fit, since its softness will allow the adaptation of the three layers: the methodological approach, the conceptual models and the use of the related artefacts.

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Annex I

Reviewed works

Table 27 Reviewed works and related scope list

Contribution	Systems Thinking	Cybernetics	Simulation	SW/IT Profession	Decision Making	Knowledge Management	Management/Business Strategy	Smart / Learning /Cognition	Digital Maturity	Business value creation	Intellectual Capital
(P. Checkland, 1993)	X						X				
(P. Checkland, 1999)	X						X				
(P. Checkland, 2000)	X						X				
(Winter & Checkland, 2003)	X						X				
(Beer, 1984)	X	X									
(Espejo, 1994)	X	X					X				
(Espejo & Gill, 1997)	X	X									
(Espejo & Kuropatwa, 2011)	X	X					X				
(Perez Rios, 2010)	X	X					X				
(Senge, 1990)	X						X				
(Ackoff, 2001)	X						X				
(Alter, 2019)								X			
(Medina-Borja, 2015)								X			
(Ebubekir, 2010)								X			
(Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, et al., 2017)			X	X		X		X			X
(Sanchez-Segura, Ruiz-Robles, Medina-Dominguez, et al., 2017)				X		X				X	X
(Sanchez-Segura, Dugarte-Peña, Medina-Dominguez, & García de Jesús, 2018b)	X		X	X		X				X	X
(Resnick, 1994)			X					X			
(Guo & Wilensky, 2014)			X					X			
(Seeley, 2010)								X			

Contribution	**Systems Thinking**	**Cybernetics**	**Simulation**	**SW/IT Profession**	**Decision Making**	**Knowledge Management**	**Management/Business Strategy**	**Smart / Learning /Cognition**	**Digital Maturity**	**Business value creation**	**Intellectual Capital**
(Yuce, Packianather, Mastrocinque, et al., 2013)								X			
(Zhang, Agarwal, Bhatnagar, et al., 2013)								X			
(Aboody & Lev, 1998)				X		X				X	X
(Blackler, 1995)						X	X				
(Hall, 1993)							X				X
(Kogut & Zander, 1992)				X			X				
(Martín de Castro, Delgado-verde, Amores-Salvadó, et al., 2013)						X	X				X
(P.M.I., 2013a)				X		X	X		X		
(Seleim, Ashour, & Bontis, 2007)							X				X
(Software Engineering Institute, 2010)				X		X			X		
(T. Stewart & Ruckdeschel, 1998)							X				X
(Verdun, Paguas, & Alberti, 2011)				X							X
(April & Laporte, 2009)				X			X				
(Nathan Baddoo & Hall, 2002)											
(Demartini & Paoloni, 2013)						X	X				X
(González & Dopico, 2017)							X				X
(Greco, Cricelli, & Grimaldi, 2013)							X				X
(Pike, Roos, & Marr, 2005)							X			X	X
(Iandolo, Barile, Armenia, et al., 2018)		X	X				X			X	
(Bourque & Fairley, 2014)				X		X	X				
(Khan, 2014)						X				X	X
(Tsai, Lu, & Yen, 2012)										X	X
(Ståhle & Ståhle, 2012)											X
(Abhayawansa & Guthrie, 2014)											X
(Marr, 2008)							X				X
(Axtle-Ortiz, 2013)						X					X
(Edvinsson, 1997)											X
(Roos, Roos, Dragonetti, et al., 1998)											X
(Aurum, Daneshgar, & Ward, 2008)				X		X					

Contribution	Systems Thinking	Cybernetics	Simulation	SW/IT Profession	Decision Making	Knowledge Management	Management/Business Strategy	Smart / Learning /Cognition	Digital Maturity	Business value creation	Intellectual Capital
(Buco, Jamjoom, Parsons, et al., 2010)				X		X					
(Caralli, Allen, Curtis, et al., 2016)				X		X					X
(García, Amescua, Sánchez, et al., 2011)				X		X					
(Heredia, Garcia-Guzman, Amescua, et al., 2013)				X		X					
(Dutta, 2007)						X				X	X
(Kaltio, 2001)				X		X					
(Leon, 2011)						X					
(OECD, 2011)											X
(Pagnozzi, Davis, Raco, et al., 2018)				X		X					
(Housel & Nelson, 2005)						X					X
(Nonaka, Toyama, & Konno, 2000)						X					
(Li, Tsai, & Lin, 2010)											
(Li & Tsai, 2009)						X	X				
(P.M.I., 2013b)				X		X					X
(N Baddoo, 2003)				X			X				
(Scacchi, 2002)				X							
(von Wangenheim, Hauck, Zoucas, et al., 2010)				X					X		
(Basili, Caldiera, & Rombach, 1994)							X				
(Basili, Lindvall, Regardie, et al., 2010)				X			X				
(García Guzmán, Mitre, Amescua, et al., 2010)				X			X				
(Plösch, Pomberger, & Stallinger, 2011)				X			X				
(Sun & Liu, 2010)				X			X		X		
(Akao & Mazur, 2003)							X				
(Kaplan & Norton, 1993)							X				
(Qian, 2010)											
(Saunders & Brynjolfsson, 2015)				X		X				X	
(Ghobakhloo, Azar, & Tang, 2019)				X			X			X	
(Kane, Palmer, Phillips, et al., 2019)				X			X		X	X	

Contribution	Systems Thinking	Cybernetics	Simulation	SW/IT Profession	Decision Making	Knowledge Management	Management/Business Strategy	Smart / Learning /Cognition	Digital Maturity	Business value creation	Intellectual Capital
(Plekhanov & Netland, 2019)						X	X			X	
(Burge, Carroll, McCall, et al., 2008)				X	X						
(M.-I. Sanchez-Segura, Jordan-Goñi, Medina-Dominguez, & Dugarte-Peña, 2016)	X	X		X	X						
(Mendes, Rodriguez, Freitas, et al., 2018)				X	X					X	
(Zaidan, Zaidan, Al-Haiqi, et al., 2015)				X	X						
(Wang, Huang, & Wang, 2018)					X		X			X	
(Moesgaard, 2014)					X			X			
(Gonzalez, 2017)					X			X			
(Gonzalez & Dutt, 2011)					X			X			
(Gonzalez, Lerch, & Lebiere, 2003)					X			X			
(Anderson & Lebiere, 1998)								X			
(Lebiere, 1998)					X			X			
(Gonzalez, Ben-Asher, Martin, et al., 2015)					X			X			
(Gonzalez, Best, Healy, et al., 2011)								X			
(Gonzalez & Dutt, 2010)					X			X			
(Lejarraga, Dutt, & Gonzalez, 2012)					X			X			
(Erev, Ert, Roth, et al., 2010)			X		X			X			
(Gonzalez, Dutt, & Lebiere, 2013)					X			X			
(Gonzalez, Dutt, & Lejarraga, 2011)					X			X			
(J. von Grabe & González, 2016)					X			X			
(Jörn von Grabe, 2017)					X			X			
(Soo & Rottman, 2018)					X			X			
(Govindarajan & Bajcsy, 2017)			X		X			X			
(Daniel, 2018)					X		X	X			
(G. A. Bell, Cooper, & Qureshi, 2002)	X			X							
(Gao, Li, & Nakamori, 2002)	X					X					

Contribution	Systems Thinking	Cybernetics	Simulation	SW/IT Profession	Decision Making	Knowledge Management	Management/Business Strategy	Smart / Learning /Cognition	Digital Maturity	Business value creation	Intellectual Capital
(Aurum, Daneshgar, & Ward, 2008)				X		X					
(Vahidi, Aliahmadi, & Teimoury, 2019)	X	X									
(Werner, 2017)	X	X									
(Ashby, 1956)		X									
(Beer, 1964)		X					X				
(Beer, 1972)		X					X				
(Beer, 1985)	X	X					X				
(Espejo & Reyes, 2011)	X	X					X				
(Espejo, Schuhmann, Schwaninger, et al., 1996)		X					X				
(Pérez Rios, 2008)	X	X					X				
(Schwaninger, 2009)	X	X					X				
(Espejo & Harnden, 1990)		X					X				

Annex II

Pre/Post experimentation - Survey results

Table 28 Pre vs. Post experimentation - Survey results

		Pre - Experimentation					Post - Experimentation				
Question ID	**About the methodology**	**No control**	**Low**	**Medium**	**High**	**Complete control**	**No control**	**Low**	**Medium**	**High**	**Complete control**
1	Think of a Knowledge Asset. How well do you know what it is, what is functional for?	15	19	3	0	0	0	0	13	24	0
2	Do you have clear what a KA is for?	27	10	0	0	0	0	5	15	14	3
3	How able are you for justifying the value given by the knowledge assets of a company?	27	10	0	0	0	0	0	15	22	0
4	Do you know what the Intellectual Capital is? Why is it important? Why does it affect your profession?	8	14	13	2	0	0	0	16	21	0
5	Do you know about the effect on society of the knowledge intensive industries from the value of their intellectual capital?	12	11	9	5	0	0	0	12	22	3
6	How clear are you about to what extent the software industry is knowledge intensive?	9	13	7	8	0	0	0	13	20	4
7	To what extent can you identify the intangible value that a software development process has within a software industry company?	14	17	6	0	0	0	0	12	19	6
8	To what extent can you estimate the intangible value of a company within the software and IT industry?	12	15	8	2	0	0	0	14	17	6
9	How prepared are you to demonstrate a company's direction board that your digital solution proposal better pursues organizational business goals based on the company's know-how?	11	13	12	1	0	0	3	8	22	4
10	Can you measure the knowledge management maturity level of an organization for which you are building a knowledge management digital solution?	22	10	5	0	0	0	0	12	20	5
11	How prepared are you to predict your client company's business goal evolution based on the state of its knowledge assets?	23	9	5	0	0	0	5	12	20	0

Annex III

Survey about the general use of the SIPAC-framework

Table 29 Survey about use of the SIPAC-framework

	Value from 1 to 5 (1 very poor - 5 very good)				
SIPAC-framework post-use survey	**1**	**2**	**3**	**4**	**5**
How easy was for you to deploy the SIPAC-framework?	0.00%	0.00%	0.00%	72.97%	27.03%
How do you value the adaptability of the SIPAC-framework to different enterprises, considering sector and size of the company?	0.00%	0.00%	0.00%	18.92%	81.08%
Provide a valuation to the usefulness of the SIPAC spreadsheet you used to support the deployment.	0.00%	0.00%	0.00%	67.57%	32.43%
As software engineer or similar, how useful was for you the SIPAC-framework as a support for your selection of the best digital solution to implement in your client company considering that you must adjust to the alignment between strategic goals and the company's knowhow?	0.00%	0.00%	2.70%	21.62%	75.68%