Universidad de Oviedo

Departamento de Explotación y Prospección de Minas

Programa de Doctorado en Minería, Obra Civil,

Medio Ambiente y Dirección de Proyectos

Tesis Doctoral

Mejora de la eficiencia en la gestión de carteras de proyectos en factorías software orientadas al sector financiero

César Álvarez Pérez

Directores
Francisco Ortega Fernández
Vicente Rodríguez Montequín

Tutor
Vicente Rodríguez Montequín

Oviedo, Abril de 2017

Justificación

Con fecha 20 de abril de 2017, la Comisión Académica del Programa de Doctorado en Minería, Obra Civil, Medio Ambiente y Dirección de Proyectos ha aprobado la tramitación del trabajo reseñado al entender que cumple con los requisitos exigidos para proceder a su lectura y defensa. El trabajo presentado por el doctorando se centra en el estudio de una factoría especializada en software financiero para la banca, que transforma su modelo de gestión en uno nuevo basado en el "balanced scorecard", con el objetivo de mejorar la eficiencia en la gestión de su cartera de proyectos y conseguir un modelo de negocio sostenible en el tiempo. Dado que la gestión de la cartera de proyectos representa la mayor parte de la carga de trabajo de estas factorías software, la información de gestión obtenida del seguimiento de su cartera de proyectos proporciona la información necesaria para valorar los indicadores del nuevo modelo, pudiendo mejorar la eficiencia gracias a la optimización de la toma de decisiones estratégicas en la gestión de la factoría. Para conseguir este objetivo, el modelo de gestión propuesto en la tesis, puede ser de gran utilidad. El autor incluye una serie de artículos, en los que el modelo de gestión inicial de la factoría software ha sido mejorado de manera sucesiva, hasta convertirse en un modelo de gestión basado en un "strategy map" ponderado, que vincula los indicadores de gestión con los objetivos estratégicos del negocio y permite conocer de antemano el efecto que la toma de decisiones tiene sobre los diferentes objetivos estratégicos del negocio. Esta propuesta definitiva de "strategy map" es una herramienta eficaz para la toma de decisiones en este tipo de factorías software orientadas al sector financiero, con el objetivo de conseguir un modelo de negocio sostenible para el desarrollo de software bancario.

Oviedo, 20 de abril de 2017

El Presidente de la Comisión Académica del Programa de Doctorado
Minería, obra civil, medio ambiente v dirección de proyectos

Fdo.: Jorge Loredo Pérez

Contra la presente resolución podrá interponer recurso de alzada ente el Excmo. Sr. Rector Magfco. de esta Universidad en el plazo de un mes a contar desde el siguiente a la recepción de la presente resolución, de acuerdo con lo previsto en el artículo 114 de la Ley 30/92, de 26 de noviembre, del Régimen Jurídico de las Administraciones Públicas y Procedimiento Administrativo Común (B.O.E. de 27 de noviembre), modificada por la Ley 4/1999, de 13 de enero (B.OE. de 14 de enero)

SR. PRESIDENTE DEL CENTRO INTERNACIONAL DE POSTGRADO

RESUMEN DEL CONTENIDO DE TESIS DOCTORAL

1.- Título de la Tesis	
Español/Otro Idioma: Mejora de la eficiencia en la gestión de carteras de proyectos en factorías software orientadas al sector financiero	Inglés: Improved efficiency in the project portfolio management in software factories oriented financial sector

2.- Autor	
Nombre: CESAR ALVAREZ PEREZ	DNI/Pasaporte/NIE: [redacted]
Programa de Doctorado: Minería, obra civil, medio ambiente y dirección de proyectos	
Órgano responsable: EXPLOTACION Y PROSPECCION DE MINAS	

RESUMEN (en español)

Las instituciones financieras y especialmente la banca se han caracterizado siempre por estar a la vanguardia en políticas de gestión innovadoras que permitiesen mejorar su rendimiento, y la banca es probablemente uno de los sectores que mide de manera más efectiva la productividad y costes de prácticamente todas las áreas de su negocio. Sin embargo, existe una en el que todavía falla: la valoración de la eficiencia de la gestión de la cartera de proyectos de sus desarrollos de software. Hasta hace pocos años, el plazo para la entrega de los proyectos software era más importante que la eficiencia con la que habían sido desarrollados, pero la última crisis económica obligó a las instituciones financieras a medir, revisar y mejorar la eficiencia con la que trabajan las empresas que desarrollan su software, con el objetivo de conseguir un modelo de trabajo sostenible y factible para el desarrollo de su software.

La literatura no ofrece una definición conceptual de modelo de negocio sostenible en el contexto de innovación tecnológica, organizativa y social, pero cambios en el modelo de gestión se reconocen como fundamentales para lograr su sostenibilidad. La gestión de un modelo de negocio identifica tres perspectivas que lo definen, basadas en: la tecnología, la organización (como herramienta de gestión estratégica para mejorar la cadena de valor de una empresa) y la estrategia (que relaciona la competitividad del mercado con la eficiencia). La noción de modelo de negocio sostenible está basada en el propio concepto de modelo de negocio y su combinación con aquellos otros conceptos que afectan, de manera importante, a la relación entre las personas y la gestión del negocio, a la creación de valor de negocio y a su continuidad en el tiempo. Los modelos de negocio sostenible son un tema en auge, pero actualmente son pocas las herramientas disponibles que permiten a las empresas la implantación de un negocio sostenible. El modelo de negocio sostenible propuesto en esta tesis fomenta la eficiencia operativa, la relación a largo plazo con los clientes y la satisfacción de sus necesidades, el incremento de la cartera de clientes y el compromiso de los empleados con la organización.

Esta tesis muestra el caso de estudio de una factoría software española, especializada en software financiero para la banca, que transformó su modelo de gestión estableciendo uno nuevo basado en el "balanced scorecard", con el objetivo de mejorar la eficiencia en la gestión de su cartera de proyectos y conseguir un modelo de negocio sostenible en el tiempo. La gestión de la cartera de proyectos representa la mayor parte de la carga de trabajo de estas factorías software. La información de gestión obtenida del seguimiento de su cartera de proyectos proporciona la información necesaria para valorar los indicadores del nuevo modelo, pudiendo mejorar la eficiencia gracias a la optimización de la toma de decisiones estratégicas en la gestión de la factoría software. Para conseguir este objetivo, el modelo de gestión propuesto en esta tesis, que ha sido publicado en una serie de artículos relacionados entre sí durante los últimos cuatro años y que forman parte de la propia tesis, puede ser de gran utilidad para lograrlo.

En estos artículos, el modelo de gestión inicial de la factoría software ha sido mejorado de manera sucesiva, hasta convertirse en un modelo de gestión basado en un "strategy map"

ponderado, que vincula los indicadores de gestión con los objetivos estratégicos del negocio y permite conocer de antemano el efecto que la toma de decisiones tiene sobre los diferentes objetivos estratégicos del negocio. Esta propuesta definitiva de "stratetgy map" es una herramienta eficaz para la toma de decisiones en este tipo de factorías software orientadas al sector financiero, con el objetivo final de conseguir un modelo de negocio sostenible para el desarrollo de software bancario.

RESUMEN (en Inglés)

Financial institutions and especially banks have always been at the forefront of innovation in management policies in order to improve their performance, and banking is probably one of the sectors that more effectively measures productivity and cost in virtually all aspects of its business. However, there is one area that still fails: the efficiency of the project portfolio management of its software developments. Up until a few years ago, the deadline for the delivery of the projects was more important than the efficiency with which they were developed, but the last economic crisis has forced financial institutions to measure, review and improve the software development efficiency related to their software factories to achieve a sustainable and feasible business model.

The literature does not offer a general conceptual definition of sustainable business models in the context of technological, organizational and social innovation, but changes to management business models are recognised as a fundamental approach to realise innovations for sustainability. A systematic overview of business model management identifies three perspectives related to this model focused on: technology, organizational (deals with the business model as a strategic management tool to improve a company's value chain) and strategy-oriented (adds the element of market competition to the efficiency). The notion of sustainable business models builds on the business model concept and combines it with the important concepts of stakeholder management, sustainable value creation, and a long-term perspective. Sustainable business model is an emerging topic, but only few tools are currently available to assist companies in sustainable business modelling. The sustainable business model outlined in this thesis encourages the operational efficiency, long-term relationship with customers and a focus on their needs, expanding the customer portfolio and employee engagement.

This thesis shows a case study in which a Spanish software factory oriented to financial sector opted to change its management system and establish a new framework based on the balanced scorecard and the strategy map with the aim of improve the efficiency in its project portfolio management and ensuring a new and sustainable business model. The project portfolio management represents the main part of the workload that these kind of software factories. The management information obtained from the control of their project portfolio management provides the necessary information to get the indicator measures which are needed in the proposed framework to improve the efficiency through improving its strategic management. To achieve this, the model proposed in this thesis, which have been published in several related articles as part of this thesis during the last four years, can be very useful in order to obtain this.

In these papers, the model initially proposed has been successively improved, and the management system has evolved into a novel weighted strategy map that links indicators and business goals and makes it possible to know in advance the effect that the decision making has on the different business strategies included in the strategy map. This proposal provides an effective assessment tool for financial software factory managers with the aim of develop financial software to guarantee the business sustainability model.

SR. PRESIDENTE DE LA COMISIÓN ACADÉMICA DEL PROGRAMA DE DOCTORADO EN MINERÍA, OBRA CIVIL, MEDIO AMBIENTE Y DIRECCIÓN DE PROYECTOS

Resumen

Las instituciones financieras y especialmente la banca se han caracterizado siempre por estar a la vanguardia en políticas de gestión innovadoras que permitiesen mejorar su rendimiento, y la banca es probablemente uno de los sectores que mide de manera más efectiva la productividad y costes de prácticamente todas las áreas de su negocio. Sin embargo, existe una en el que todavía falla: la valoración de la eficiencia de la gestión de la cartera de proyectos de sus desarrollos de software. Hasta hace pocos años, el plazo para la entrega de los proyectos software era más importante que la eficiencia con la que habían sido desarrollados, pero la última crisis económica obligó a las instituciones financieras a medir, revisar y mejorar la eficiencia con la que trabajan las empresas que desarrollan su software, con el objetivo de conseguir un modelo de trabajo sostenible y factible para el desarrollo de su software.

La literatura no ofrece una definición conceptual de modelo de negocio sostenible en el contexto de innovación tecnológica, organizativa y social, pero cambios en el modelo de gestión se reconocen como fundamentales para lograr su sostenibilidad. La gestión de un modelo de negocio identifica tres perspectivas que lo definen, basadas en: la tecnología, la organización (como herramienta de gestión estratégica para mejorar la cadena de valor de una empresa) y la estrategia (que relaciona la competitividad del mercado con la eficiencia). La noción de modelo de negocio sostenible está basada en el propio concepto de modelo de negocio y su combinación con aquellos otros conceptos que afectan, de manera importante, a la relación entre las personas y la gestión del negocio, a la creación de valor de negocio y a su continuidad en el tiempo. Los modelos de negocio sostenible son un tema en auge, pero actualmente son pocas las herramientas disponibles que permiten a las empresas la implantación de un negocio sostenible. El modelo de negocio sostenible propuesto en esta tesis fomenta la eficiencia operativa, la relación a largo plazo con los clientes y la satisfacción de sus necesidades, el incremento de la cartera de clientes y el compromiso de los empleados con la organización.

Esta tesis muestra el caso de estudio de una factoría software española, especializada en software financiero para la banca, que transformó su modelo de gestión estableciendo uno nuevo basado en el *balanced scorecard*, con el objetivo de mejorar la eficiencia en la gestión de su cartera de proyectos y conseguir un modelo de negocio sostenible en el tiempo. La gestión de la cartera de proyectos representa la mayor parte de la carga de trabajo de estas factorías software. La información de gestión obtenida del seguimiento de su cartera de proyectos proporciona la información necesaria para valorar los indicadores del nuevo modelo, pudiendo mejorar la eficiencia gracias a la optimización de la toma de decisiones estratégicas en la gestión de la factoría software. Para conseguir este objetivo, el modelo de gestión propuesto en esta tesis, que ha sido publicado en una serie de artículos relacionados entre sí durante los últimos cuatro años y que forman parte de la propia tesis, puede ser de gran utilidad para lograrlo.

En estos artículos, el modelo de gestión inicial de la factoría software ha sido mejorado de manera sucesiva, hasta convertirse en un modelo de gestión basado en un *strategy map* ponderado, que vincula los indicadores de gestión con los objetivos estratégicos del negocio y permite conocer de antemano el efecto que la toma de decisiones tiene sobre los diferentes objetivos estratégicos del negocio. Esta propuesta definitiva de *strategy map* es una herramienta eficaz para la toma de decisiones en este tipo de factorías software orientadas al sector financiero, con el objetivo final de conseguir un modelo de negocio sostenible para el desarrollo de software bancario.

Abstract

Financial institutions and especially banks have always been at the forefront of innovation in management policies in order to improve their performance, and banking is probably one of the sectors that more effectively measures productivity and cost in virtually all aspects of its business. However, there is one area that still fails: the efficiency of the project portfolio management of its software developments. Up until a few years ago, the deadline for the delivery of the projects was more important than the efficiency with which they were developed, but the last economic crisis has forced financial institutions to measure, review and improve the software development efficiency related to their software factories to achieve a sustainable and feasible business model.

The literature does not offer a general conceptual definition of sustainable business models in the context of technological, organizational and social innovation, but changes to management business models are recognised as a fundamental approach to realise innovations for sustainability. A systematic overview of business model management identifies three perspectives related to this model focused on: technology, organizational (deals with the business model as a strategic management tool to improve a company's value chain) and strategy-oriented (adds the element of market competition to the efficiency). The notion of sustainable business models builds on the business model concept and combines it with the important concepts of stakeholder management, sustainable value creation, and a long-term perspective. Sustainable business model is an emerging topic, but only few tools are currently available to assist companies in sustainable business modelling. The sustainable business model outlined in this thesis encourages the operational efficiency, long-term relationship with customers and a focus on their needs, expanding the customer portfolio and employee engagement.

This thesis shows a case study in which a Spanish software factory oriented to financial sector opted to change its management system and establish a new framework based on the balanced scorecard and the strategy map with the aim of improve the efficiency in its project portfolio management and ensuring a new and sustainable business model. The project portfolio management represents the main part of the workload that these kind of software factories. The management information obtained from the control of their project portfolio management provides the necessary information to get the indicator measures which are needed in the proposed framework to improve the efficiency through improving its strategic management. To achieve this, the model proposed in this thesis, which have been published in several related articles as part of this thesis during the last four years, can be very useful in order to obtain this.

In these papers, the model initially proposed has been successively improved, and the management system has evolved into a novel weighted strategy map that links indicators and business goals and makes it possible to know in advance the effect that the decision making has on the different business strategies included in the strategy map. This proposal provides an effective assessment tool for financial software factory managers with the aim of develop financial software to guarantee the business sustainability model.

Agradecimientos

Quiero dar las gracias a todos aquellos que han hecho posible la realización de esta tesis, desde el ámbito educativo al familiar, que siempre han hecho que los estudios sean uno de los valores fundamentales de mi vida.

Gracias a mis padres, Ángel Luis y Ofelia, por hacerme ver siempre la importancia de los estudios.

Gracias a Francisco, Joaquín y muy especialmente a Vicente, por vuestra ayuda y esfuerzo en sacar adelante esta tesis y los artículos que en ella se incluyen.

Pero sobre todo quiero dar las gracias a quienes más se vieron afectados por mi dedicación, durante estos últimos cuatro años, a la realización de esta tesis: Adriana y Valentina.

Glosario

Se presenta en este glosario la equivalencia entre la denominación en inglés y español de las palabras o expresiones a la que se refiere esta tesis en inglés. Se incluye también, en caso de haberse utilizado, su abreviatura.

Abreviatura	**English Full Form**	**Nombre Completo en Español**
AHP	Analytic hierarchy process	
BSC	Balanced scorecard	Cuadro de mando integral
BNP	Best non-fuzzy performance	
	Budgeting Error	Error de Presupuestación
	Build the Necessary Software	Desarrollar el Software Necesario
	Core Banking	Núcleo del sistema bancario
	Cost per Use	Coste por Uso
	Cost Structure	Estructura de Costes
	Customer Perspective	Perspectiva del Cliente
	Customers	Clientes
	Decrease Cost	Reducir los Coste
	Delay	Retraso
	Employee Productivity	Productividad del Empleado
	Employer Branding	Imagen de marca como organización que contrata y da empleo
	Experts	Experto
	Financial Perspective	Perspectiva Financiera
FSF	Financial software factory	Factoría software del sector financiero
FinTech	Financial Technology	
FAHP	Fuzzy analytic hierarchy process	
HLG	High-level goal	Objetivo de alto nivel
	Improve Cost HLG	Mejora de la Estructura de Costes - Objetivo de Alto Nivel
	Improve Productivity HLG	Mejora de la Productividad - Objetivo de Alto Nivel
	Improve the SW Development Processes	Mejora de los Procesos del Desarrollo de Software
	Improve the SW Quality and Innovation	Mejora de la Calidad e Innovación de los Desarrollos Software
	Increase Revenue	Incrementar los Ingresos
IT	Information Technology	Tecnologías de la información
	Intellectual Capital	Capital Intelectual
	Internal Business Processes Perspective	Perspectiva de los Procesos Internos de Negocio
KPI	Key performance indicator	Indicador clave de rendimiento
	Learning and Growth Perspective	Perspectiva de Aprendizaje y Crecimiento
	Middle Managers	Mandos intermedios
	Mission and Vision	Misión y Visión del Strategy Map
MCDM	Multi-criteria decision-making	Toma de decisiones multi-criterio
	Other employees	Otros empleados
	Reduction of Cost	Reducción de Costes
SLA	Service Level Agreement	Acuerdo a Nivel de Servicio
	Shareholder	Propietario o accionista
	Software Factory	Factoría Software
	Software Quality	Calidad del Software
	Stakeholder	Actores interesados, afectados o intervinientes
	Software Deliveries on Time	Entrega de los Proyectos Software a Tiempo
TIC		Tecnologías de la Información y la Comunicación
	Top Management	Alta dirección
TFN	Triangular fuzzy numbers	Número fuzzy triangular
	Useful Developments	Utilización de los Desarrollos
	User Satisfaction	Satisfacción del Usuario
	Work Performance	Rendimiento del Trabajo

Índice General

1

INTRODUCCIÓN

1. Introducción

El desarrollo de software para el sector financiero ha sido desde sus comienzos uno de los motores más importantes del sector de las tecnologías de la información y la comunicación (TIC). La evolución vivida en el sector ha dado lugar a que los grandes departamentos de informática con los que contaban las entidades financieras en los años ochenta y noventa se hayan transformado en empresas subsidiarias de estas entidades que operan, o intentan hacerlo, bajo el modelo de trabajo denominado s*oftware factory o factoría software*. Las entidades financieras han tendido a mantener el control de estas nuevas empresas dado el carácter estratégico que para ellas supone el software, en su mayoría desarrollos a medida. Durante muchos años estas empresas informáticas han trabajado casi en exclusiva para el grupo matriz propietario de la misma. Sin embargo, diversos motivos como la reducción de costes o las fusiones entre distintos grupos, han conseguido que se desligue cada vez su funcionamiento del grupo financiero, de manera que para subsistir deben ser cada vez más competitivas. Alcanzar esta competitividad pasa entre otras cosas por ofrecer sus servicios a entidades externas y explorar nuevos modelos de negocio y funcionamiento sostenibles.

Sin duda uno de los paradigmas que más intentan seguir este tipo de empresas es el de *factoría software*. Si bien la literatura existente define de manera distinta el concepto de factoría software, de manera general podemos entender por factoría software el centro de trabajo donde se desarrolla software aplicando técnicas y principios ligados a la producción industrial tradicional. Aunque el término de factoría software se utilizó por primera vez en el año 1968 y se considera a Hitachi Software Works como la primera factoría software, es en estos últimos años y ante las especiales condiciones socio-económicas, tecnológicas y de madurez de la ingeniería del software, cuando el término vuelve a cobrar notoriedad en la industria del software [1].

Al respecto de las factorías software que desarrollan software financiero para la banca, el desarrollo de proyectos representa la mayor parte de la carga de su trabajo. Por tanto, la información obtenida del seguimiento de su cartera de proyectos deberá proporcionar la información principal que sirva de base para los nuevos modelos de gestión, pudiendo mejorar la eficiencia gracias a la optimización de la toma de decisiones estratégicas en la gestión de la factoría software.

1.1. Motivación

El objetivo principal de esta investigación es establecer un modelo de gestión que, ligado al entorno específico de trabajo para una factoría software que desarrolla software para el sector financiero (*Financial Software Factory* – FSF), permita mejorar la eficiencia en la gestión de su cartera de proyectos software en base a la optimización de la toma de decisiones por parte de sus gestores.

Esta tesis se presenta como compendio de publicaciones [2–4], que se incluyen íntegramente en el Capítulo 4. Estas tres publicaciones reflejan el trabajo teórico-práctico realizado durante los últimos cuatro años, si bien previamente se han realizado otras publicaciones y exposiciones en congresos no incluidas en este compendio [5–8]. A día de hoy existe una cuarta publicación que se desearía incluir en el compendio de esta tesis, pero no se incluye debido que se encuentra en fase de revisión desde finales de 2016 [9].

1.2. Antecedentes

A mediados de 2010, Rafael de la Fuente Asprón, de la consultora LEDA MC especializada en productividad software, publicó en la revista *Financial Tech Magazine*, de tecnología para el sector financiero, el artículo *Medir la productividad de desarrollo de software en banca* [10]. En dicho artículo se hacía patente un problema que afectaba de lleno al desarrollo de software para la banca, y es que no se medía la productividad con la que ese software era desarrollado. Si bien se señalaba que la banca sea posiblemente el sector que más ha invertido en políticas de control, seguimiento y mejora de la eficiencia en cada una de los aspectos que forman parte de su propia organización, había un área en el que no se llevaban a cabo esas medidas de control y mejora, y estaban ligadas a los desarrollos

software que la banca encargaba para dar soporte a su núcleo del sistema bancario, o *core banking* como se le suele denominar en el sector, y a su negocio.

Se indica que, para la banca, el desarrollo de aplicaciones software de negocio representa más del 50% del presupuesto gestionado de las TIC. El sector bancario es tradicionalmente uno de los que más desarrollo de software requiere y uno de los que más se decanta por la externalización a la hora de abordar este tipo de proyectos. Sin embargo, a pesar de constituir una de las principales partidas de su presupuesto, la mayoría de las entidades bancarias todavía no mide la productividad de los desarrollos software. Una de las razones esgrimidas por la que no se analiza la productividad es que el modelo de producción del software bancario es absolutamente artesanal, y no se mide lo que se produce. Las entidades bancarias pagan por el tiempo que se tarda en producir y no por la cantidad de software producido, un modelo que en la mayoría de los casos termina redundando en el encarecimiento de los proyectos. Además, el artículo ponía de manifiesto que era más importante la fecha de entrega de los proyectos software que el coste que estos desarrollos suponían para la entidad financiera.

Desde finales de 2008, debido a la última crisis económica, las entidades financieras han optado por reducir el número de proyectos solicitados o bien por presionar al proveedor para que baje sus tarifas, con el fin de disminuir el gasto ligado a desarrollos software. En este punto es cuando empiezan a surgir las primeras preguntas referentes a la productividad y eficiencia con la que se estaban realizando los desarrollos entregados. La primera respuesta de los proveedores fue la de llevar las factorías software a otros países con mano de obra cualificada más barata, aunque esta solución reduce los costes pero no mejora directamente la productividad. Por definición, las factorías software se justifican con la idea de industrializar la producción de software, aplicando los principios y técnicas de la industria tradicional a la industria del software, con el fin de lograr mejoras en la producción que permitan incrementar la productividad y reducir los costes. Frente a la primera propuesta de deslocalización de la producción a terceros países, otras pocas de las factorías software especializadas en software financiero optaron por implantar nuevos modelos de gestión que permitiesen controlar la producción y su productividad [10], estableciendo métricas que favoreciesen medir la cantidad de software producido.

Con este planteamiento, a principios del año 2011, se contactó con una de las principales factorías software españolas especializadas en software bancario. Tras varias reuniones entre las partes, se decidió iniciar una colaboración mutua de intercambio de conocimientos que llevase a la propuesta de un nuevo modelo de gestión para la alta dirección de la factoría software que permitiese mejorar la eficiencia para su cartera de proyectos. Las propuestas realizadas, que han sido publicadas en varios artículos durante los últimos cinco años, conforman la línea de investigación de esta tesis, que está vinculada a un caso de estudio concreto para el que se propone un modelo de gestión sostenible para las FSF, en términos de mejora de la productividad y reducción de costes ligados al desarrollo de software financiero.

1.3. Estructura de la Tesis

Esta tesis se ha elaborado bajo el formato de tesis por compendio de publicaciones, e incluye tres artículos publicados bajo las reglas establecidas por la Universidad de Oviedo para dar validez a la presentación de una tesis bajo esta modalidad. Estos artículos presentan la totalidad del contenido relevante de la investigación de esta tesis.

La memoria de la tesis se ha estructurado de la siguiente forma:

1. Introducción
2. Objetivos
3. Desarrollo de la Investigación
4. Trabajos de Investigación
5. Discusión de los Resultados
6. Plan de Validación Preliminar

7. Conclusiones
8. Referencias

El Capítulo 1 de la tesis se corresponde con la *Introducción*. En esta parte de la tesis se presenta la *Motivación,* los *Antecedentes* del estudio, la *Estructura de la Tesis* y se enumeran todas las *Publicaciones Realizadas durante el Desarrollo de esta Tesis*. El Capítulo 2 hace referencia a los *Objetivos* de la investigación. Los objetivos de la tesis se van presentando en distintos sub-objetivos, relacionado cada uno de ellos con los objetivos expuestos en cada uno de los artículos publicados que forman parte del compendio de esta tesis. El Capítulo 3 de la tesis expone el *Desarrollo de la Investigación*. Está dividido en tres apartados, dedicados cada uno de ellos a uno de los artículos incluidos en la tesis. El Capítulo 4 de la tesis se corresponde con los *Trabajos de Investigación*, e incluye íntegros los tres artículos que forman parte de esta tesis en modalidad de compendio por publicaciones. Se hace constar además el informe de factor de impacto de las publicaciones. El Capítulo 5 ofrece una *Discusión de los Resultados* que analiza las propuestas realizadas y los resultados obtenidos de la investigación de la tesis. El Capítulo 6 presenta un *Plan de Validación Preliminar* del modelo, e incluye algunos ratios que permiten valorar la evolución de la productividad y costes de la factoría software estudiada en esta tesis. El Capítulo 7 expone las *Conclusiones* de esta tesis y motiva las nuevas líneas de trabajo e investigación que pueden desarrollarse fruto de esta tesis. El Capítulo 8 muestra las *Referencias* citadas en esta tesis por orden de mención. Se utiliza en la tesis el mismo estilo de referencias que se ha utilizado en las tres publicaciones que forman parte de la misma.

Para mantener la coherencia entre los artículos publicados que se incluyen en esta tesis, escritos en inglés, y el resto de la tesis, escrita en español, se ha decidido mantener durante toda la tesis la denominación en inglés de todos los nombres de indicadores, perspectivas, objetivos, y demás denominaciones que aparecen en las Tablas y Figuras de la tesis. El *Glosario* incluido al inicio de esta tesis muestra las equivalencias o traducciones Inglés-Español de las denominaciones incluidas en inglés en esta tesis.

1.4. Publicaciones Realizadas durante el Desarrollo de esta Tesis

Esta sección presenta cronológicamente las ocho publicaciones obtenidas durante el desarrollo de esta tesis. Las publicaciones número V., VI. y VIII. se corresponden con las publicaciones presentadas en esta tesis como compendio de artículos, incluidas íntegras en el Capítulo 4:

I. Álvarez, C.; R. Montequín, V.; Alba, C.; Fernández, L. Modelo de Cuadro de Mando para Factorías Software del Sector Financiero. *XVI Congreso Internacional de Ingeniería de Proyectos*; Valencia, 2012; pp. 2313–2323.

II. Montequín, V. R.; Álvarez, C.; Ortega, F.; Villanueva, J. Scorecard for Improving Software Factories Effectiveness in the Financial Sector. PRojMAN 2013 - International Conference on Project MANagement. Published in *Procedia Technology*: Lisbon, Portugal, 2013; Vol. 9, pp. 670–675.

III. Rodríguez Montequín, V.; Álvarez Pérez, C.; Ortega Fernández, F.; Villanueva Balsera, J. Scorecard and KPIs for monitoring software factories effectiveness in the financial sector. *International Journal of Information Systems and Project Management* 2013, 1, 29–43.

IV. R. Montequín, V.; Álvarez Pérez, C.; Ortega Fernández, F.; Balsera, J. V. Cuadro de mando para la gobernanza de factorías software del sector financiero. Published in *Gobernanza empresarial de tecnologías de la información*; Ed. Universidad de Cantabria, 2015; Vol. 210, pp. 51–62.

V. Álvarez, C.; Rodríguez, V.; Ortega, F.; Villanueva, J. A Scorecard Framework Proposal for Improving Software Factories' Sustainability: A Case Study of a Spanish Firm in the Financial Sector. *Sustainability* 2015, 7, 15999–16021.

VI. Álvarez Pérez, C.; Rodríguez Montequín, V.; Ortega Fernández, F.; Villanueva Balsera, J. Integrating Analytic Hierarchy Process (AHP) and Balanced Scorecard (BSC) Framework for Sustainable Business in a Software Factory in the Financial Sector. *Sustainability* 2017, 9, 486.

VII. Álvarez, C., Rodríguez, V., Ortega, F., Villanueva, J. Integrating fuzzy analytic hierarchy process and balanced scorecard framework for sustainable business in a software factory in the financial sector. *International Journal of Information Management*. (En revisión).

VIII. Pérez, C. Á.; Montequín, V. R.; Fernández, F. O.; Balsera, J. V. Integration of Balanced Scorecard (BSC), Strategy Map, and Fuzzy Analytic Hierarchy Process (FAHP) for a Sustainability Business Framework: A Case Study of a Spanish Software Factory in the Financial Sector. *Sustainability* 2017, 9, 527.

El orden cronológico con el que se muestran las publicaciones permite obtener una idea clara de cómo se ha realizado la evolución de la investigación, ya que el propio orden de realización y envío de las publicaciones va parejo al hilo conductor de la misma.

2

OBJETIVOS

2. Objetivos

El objetivo de esta tesis es el desarrollo de un modelo de gestión sostenible para las factorías software orientadas al sector financiero que permita incrementar la eficiencia en la gestión de su cartera de proyectos, en términos de mejorar su productividad y optimizar su estructura de costes (maximizando los ingresos y reduciendo los costes).

Este objetivo global se presenta en la tesis acotado en tres sub-objetivos, todos ellos directamente interrelacionados entre sí en la medida que cada uno de ellos aporta una mejora sobre el anterior. Cada sub-objetivo está relacionado con una de las tres publicaciones que forman parte de esta tesis.

El primer sub-objetivo responde a la propuesta de un modelo de gestión para las factorías software del sector financiero que incremente la eficiencia de los desarrollos software. El modelo propuesto está basado en el "marco del cuadro de mando integral" o *balanced scorecard (BSC) framework*. El segundo sub-objetivo revisa el planteamiento anterior y realiza una propuesta que, basada en el BSC de una FSF, logra valorar su rendimiento ligado al desarrollo de software. El tercer y último sub-objetivo hace frente a una propuesta definitiva para el modelo de gestión, que basada en el mapa estratégico o *strategy map* de una FSF, permite valorar el impacto de la toma de decisiones para la consecución de un modelo de negocio sostenible, actuando sobre la productividad y costes de la compañía.

3

DESARROLLO DE LA INVESTIGACIÓN

3. Desarrollo de la Investigación

Este tercer capítulo de la tesis está centrado en el desarrollo de la investigación, y se presenta dividido en tres apartados. Cada uno de ellos está dedicado a cada uno de los artículos que componen la tesis. Todos ellos presentan la situación inicial, repasan el estado del arte y de la literatura existente en relación con la parte tratada en la investigación, se abordan las propuestas y se exponen los resultados obtenidos. Se hace en definitiva un recorrido del trabajo realizado durante estos últimos años en forma de publicaciones.

El apartado 3.1 *Modelo de Gestión para las Factorías Software del Sector Financiero (FSF)*, dedicado a la primera de las publicaciones realizadas [2], aborda las características y el entorno de trabajo de las FSF, repasa el estado del arte y hace una propuesta de gestión para las FSF, en la que se incluye una propuesta de BSC y un *strategy map* para este tipo de compañías. El apartado 3.2 *Valoración del Rendimiento del Modelo de Gestión ligado al BSC*, dedicado a la segunda de las publicaciones [3], parte de la situación inicial y tras revisar el estado del arte aplicado ante situaciones similares de otros entornos de trabajo, hace una propuesta que integra el BSC de una FSF con *analytic hierarchy process* (AHP), para conseguir valorar el rendimiento global de la compañía. El artículo [9] que está en fase de revisión realiza una misma propuesta que el presentado en este apartado, pero introduciendo la teoría de números *fuzzy* en la aplicación del AHP, conocida como *fuzzy analytic hierarchy process* (FAHP), que permite obtener unas valoraciones de las alternativas que reflejan de mejor forma el valor del pensamiento humano, al reducir la incertidumbre y ambigüedad de las respuestas en la valoración de las alternativas. El apartado 3.3 *Un Modelo de Negocio Sostenible Basado en la Optimización de la Toma de Decisiones*, basado en la tercera de las publicaciones [4], toma como ejemplo las dos publicaciones previas y la que se encuentra en revisión para realizar una propuesta definitiva de modelo de negocio sostenible, que integra el BSC y el *strategy map* de una FSF con FAHP, para estudiar el peso que los indicadores, las perspectivas y *strategic goals* (objetivos estratégicos) tienen para la organización. Este enfoque permite conocer el efecto de la toma de decisiones en el modelo propuesto y valorar su impacto en las estrategia de negocio de una FSF.

3.1. Modelo de Gestión para las Factorías Software del Sector Financiero (FSF)

Los siguientes apartados centran el marco de la investigación, repasan el estado del arte y aportan la primera propuesta de modelo de gestión para las FSF.

3.1.1. Retos de la Banca Tradicional en un Entorno Tecnológico en Continua Evolución

Desde la aparición de Internet, y especialmente desde la generalización del uso de los teléfonos inteligentes o *smartphones*, que coincidió con la última crisis económica, la banca tradicional está tratando de reubicarse para mantener su posición dominante en el sector. Sin embargo, parece que no está bien adaptada al nuevo entorno y no logra mantenerse al día en un nuevo entorno digital y tecnológico en constante evolución, según un estudio de SAP e IBM [11]. La banca tradicional se enfrenta actualmente a importantes retos en distintas áreas, pero estos son los que destacan en dicho estudio:

- La banca tradicional no genera el suficiente beneficio: A pesar de que la gran banca sigue ganando cientos de millones de euros, el sector no está generando el retorno sobre la inversión que los accionistas requieren. Entre otras cosas, los tipos de interés actuales en Europa que se sitúan en el entorno del cero, o incluso negativos, golpean los márgenes del negocio bancario y dificultan el incremento de la rentabilidad del sector.
- Las expectativas de los consumidores: Cada vez se tiene más en cuenta la "experiencia del cliente" y la banca tradicional está sintiendo la presión porque no logra ofrecer el nivel de servicio que los consumidores están exigiendo, especialmente, en lo que respecta a tecnología.
- El incremento de la competencia ajena al propio sector: El aumento de la competencia de nuevas empresas que aúnan tecnología y finanzas (*FinTech*) haciendo uso del software para

proporcionar servicios financieros, está dañando la forma de negocio que mantenía la banca tradicional. La banca tradicional no logra adaptarse a las nuevas necesidades y cambios con la rapidez que lo hacen las *FinTech*, pero no solo en lo que se refiere a tecnología, sino también en la manera de operar, la cultura y otros aspectos propios en las relaciones bancarias.

- Presión regulatoria: los requisitos legales y normativos son cada vez más y mayores, lo que provoca que el sector bancario necesite invertir buena parte de su presupuesto de gastos en el cumplimiento normativo, destinando grandes cantidades de dinero al desarrollo de nuevos sistemas y procesos que permitan cumplir con el incremento de requisitos.

A día de hoy estos retos continúan creciendo, por lo que la banca tradicional necesita constantemente evaluar y mejorar su modelo de negocio para mantenerse al día, especialmente, en lo que se refiere a tecnología, en un entorno en el que la propia tecnología ligada al sector financiero no deja de evolucionar. Para hacer frente a todos estos retos, la banca requiere de nuevos proyectos y sistemas software, ya que buena parte de los existentes a día de hoy datan de principios de siglo y no pueden hacer frente a los retos actuales del sector, y por supuesto, a los futuros. Es por esto que las entidades financieras necesitan actuar en diferentes aspectos críticos y las empresas que desarrollan su software son, posiblemente, el pilar principal de esta acción.

3.1.2. Desarrollo de Software Bancario

La industria ligada al desarrollo de software es tremendamente exigente, caracterizada por una fuerte competencia, tiene gran dependencia del capital intelectual y necesita de una mano de obra en continua formación. Pese a esto, las restricciones económicas con las que han debido de convivir durante los últimos años, la industria del software ha visto cómo se han reducido tanto los proyectos destinados a investigación como el presupuesto destinado a mano de obra [12]. La industria del software no sólo necesita aumentar las capacidades de producción, sino que también necesita producir más con los recursos disponibles para conseguir aumentar la productividad [13].

El sector bancario es uno de los que requiere mayor cantidad de software para su funcionamiento [10]. Esta es la razón por la que las empresas especializadas en el desarrollo de software financiero necesitan transformarse realmente en una verdadera industria de desarrollo software, capaz de proporcionar los proyectos necesarios con la eficiencia, rapidez y calidad que los mercados financieros esperan hoy en día [14]. La primera necesidad a la que se enfrentan las instituciones financieras es la necesidad de que las empresas que desarrollan su software sean capaces de medir la cantidad de software que les están entregando, ya que en la mayoría de las situaciones no era así [10]. Existen varias maneras de medir la cantidad de software producido, como se explica en el trabajo de Fenton *et al.* [15] que permiten a las empresas saber lo que se está entregando y la productividad real con la que se está trabajando. Con esta información, se pueden crear estrategias que generen mejoras en los procesos y se puedan ligar los pagos por lo que realmente se está produciendo, en vez de hacerlo directamente con el tiempo dedicado a producirlo.

Una de las características de las fábricas de software especializadas en software bancario, y que suele darse en la mayoría de los casos, al menos en España y otros países europeos, es que han sido creadas por las propias entidades financieras con la intención de externalizar el desarrollo del software que necesitan para su negocio. Y es una situación difícil de gestionar, ya que es necesario satisfacer los intereses de un mismo grupo empresarial que es a la vez el propietario y el principal cliente. Durante años, el software que soporta el negocio bancario había sido desarrollado internamente en los propios departamentos de informática de las distintas entidades, pero a día de hoy se encuentra externalizado en factorías software especializadas. Estas factorías que han sido creadas en su mayoría durante los años 80 y 90 por las propias entidades financieras, y siguiendo la tendencia de externalización de servicios instaurada en el sector bancario, también han subcontratado parte del trabajo ligado al desarrollo de software. Una de sus particularidades es que han externalizado los procesos de desarrollo de software, pero mantienen otros sin externalizar por razones estratégicas [5], especialmente todo lo relacionado con el núcleo del sistema bancario (*core banking)* y las fases de análisis técnico y funcional de los desarrollos. A día de hoy, estas factorías software no trabajan exclusivamente para el grupo financiero al que pertenecen, ya que también

ofrecen sus servicios a otras instituciones financieras, operativa que va en aumento precisamente para reducir costes y hacerlas más competitivas.

El primero de los artículos incluidos en esta tesis [2] describe el caso en el que una FSF decidió revisar el concepto de industrialización del software con la intención de implementar los principios y elementos del *software factory approach* [16] y buscó un esquema de trabajo y organizativo que fomentase el incremento de la productividad en los diferentes equipos de desarrollo. Con la intención de cuantificar esta productividad se trabajó en el desarrollo de una métrica que permitiese expresar la productividad en términos de cantidad de software producido en un intervalo de tiempo, similar a como había descrito *de Vries* [17], de Microsoft, unos años antes. El equipo directivo de la factoría software tomó decisiones de alto nivel que afectaron a todas las áreas de la empresa, cumpliendo así con las directrices dadas por el grupo financiero, que como propietarios querían producir más y reducir el coste de la producción, y como clientes querían desarrollos más útiles, con mayor calidad, menores tiempos de entrega y que fuesen más baratos.

3.1.3. Esquema de una Factoría Software del Sector Financiero

Al igual que el resto de empresas, las dedicadas al desarrollo de software se han visto obligadas a reducir costes e ineficiencias, a la vez que se exigía mejoras en la calidad, reducir los tiempos de producción e incrementar la productividad y relevancia para los sectores a los que se ofrecen. Esta reestructuración de los procesos empresariales enfocados en la mejora de la eficiencia ha dado lugar a técnicas como el *lean manufacturing*, *supply chain management* y *product line engineering* [16]. La aplicación de estas ideas en la industria del desarrollo de software se conoce como el *software factory approach* [18,19]. La principal preocupación para una fábrica de software es la industrialización del desarrollo de software [20]. Una factoría software aplica, en el contexto del desarrollo de software, las mismas técnicas y principios de fabricación que la industria tradicional [21]: reutilización sistemática, ensamblaje de componentes, cadena de producción, procesos automatizados y guiados, entre otras características.

Nos referimos en esta tesis a aquellas factorías software orientadas al sector financiero como *financial software factories* (FSF), tal como se hace en los artículos que conforman esta tesis. Las características y el entorno de trabajo de la FSF estudiada en esta tesis no presentan diferencias significativas con el resto de ellas, al menos las que operan en España. Las FSF presentan unas características propias [7], derivadas en buena parte de su pertenencia a un grupo financiero:

- Trabajan prácticamente en exclusividad para un único grupo financiero, que es a la vez tanto el propietario como su principal cliente, aunque cada vez tienen mayor importancia los ingresos ajenos al grupo financieros.
- Tienen una gran demanda de proyectos, mayor que la que pueden atender.
- El cobro de los desarrollos está asegurado directamente por el grupo financiero.
- Parte del proceso de desarrollo del software suele estar subcontratado a varias compañías, a las que se les debe pagar en relación a las horas planificadas y no por el número de horas empleadas finalmente para realizar el proyecto.

Estas características propias de las FSF conllevan que siempre exista una gran demanda de proyectos, siendo necesario afrontar el mayor número de ellos en el menor plazo posible.

Por otro lado, la organización interna y el esquema típico de trabajo de las FSF no debe diferir sustancialmente del que se presenta a continuación, que incluye los siguientes procesos:

- *Demand Management* (Gestión de la Demanda): Recoge los requisitos de los usuarios y establece los métodos de priorización para el desarrollo de la cartera de proyectos.
- *Functional Analysis* (Análisis Funcional): Transforma los requisitos identificados en el nivel superior en requisitos funcionales.

- *Technical Analysis* (Análisis Técnico): Responsable de los aspectos técnicos de las especificaciones funcionales que deben ser implementadas.
- *Development* (Desarrollo): Realiza el desarrollo, construcción y montaje de los requisitos solicitados.
- *Testing* (Pruebas): Valida los proyectos realizados.
- *Production* (Puesta en Producción): que realiza la puesta en macha de los proyectos.
- *Quality* (Calidad): que evalúa la calidad de los procesos de desarrollo de software.

En el esquema explicado, el proceso de desarrollo de software es subcontratado con varias empresas, pero el resto de procesos están bajo el control directo de la FSF. La Figura 1 ilustra los procedimientos habituales seguidos en este esquema de trabajo, que son similares a los expuestos por Valderrama *et al.* [21] para las factorías software.

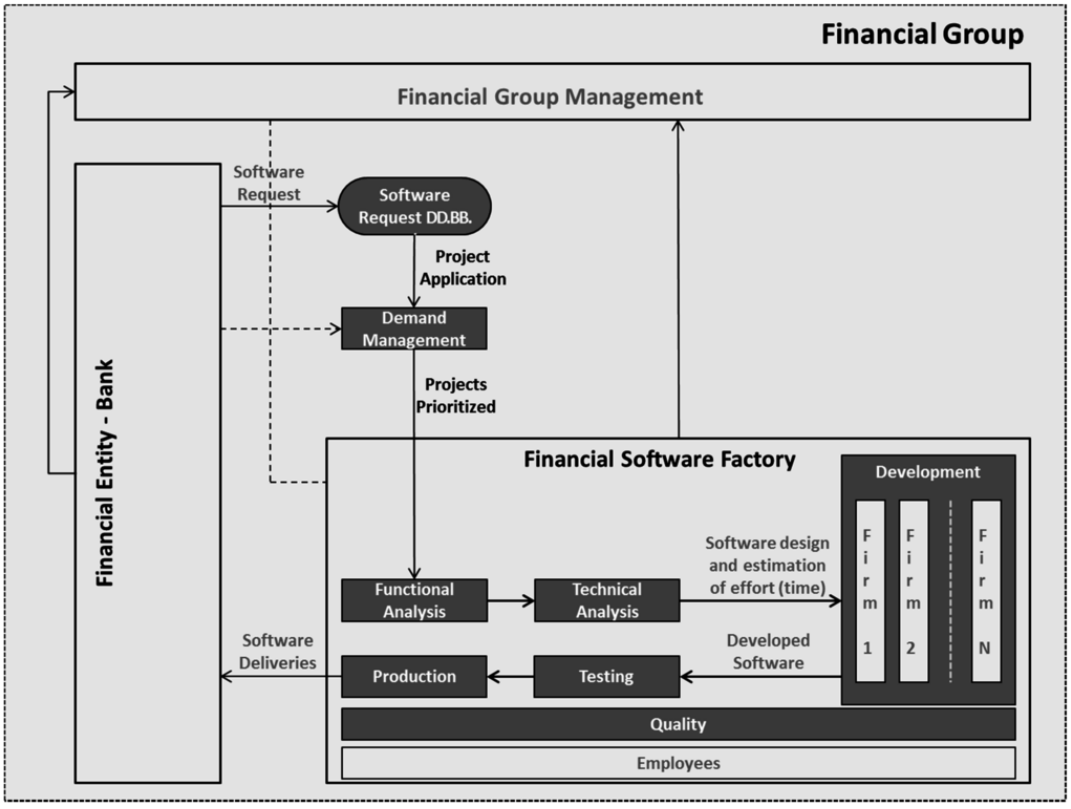

Figura 1. Modelo de mapa de procesos de una FSF [2].

3.1.4. Sistema de Gestión basado en el *Balanced Scorecard Framework*

El esquema de trabajo expuesto requiere de un sistema de gestión que incluya, de no ser todos, la gran mayoría de los aspectos de gestión de la organización. Así se consigue tener conocimiento de la productividad con la que se trabaja para mantener las ventajas competitivas de la organización. Sin embargo, la medida de la productividad en el desarrollo de software es más complicada que en otra clase de industrias, debido a la naturaleza intangible del software y la dificultad de medir lo producido [22]. Pese a esta dificultad, las FSF necesitan un sistema de control de la gestión que facilite el seguimiento de la producción y de respuesta a una serie de preguntas:

- ¿Cuál es la productividad de la FSF?
- ¿Cómo evoluciona la productividad a lo largo del tiempo?
- ¿Cómo evoluciona la planificación y coste de los proyectos?
- ¿Qué calidad tienen los proyectos entregados?

- ¿Cuál es el nivel de uso de los desarrollos por parte de los clientes?
- ¿Cuál es el grado de satisfacción de los clientes con los servicios y desarrollos de la FSF?
- ¿Cómo evolucionan la estructura de gastos de la FSF?
- ¿Qué posición ocupa la FSF en el mercado?
- ¿Cómo es la relación entre propietarios, empleados y clientes de la FSF?
- ¿Cuál es la sostenibilidad del modelo de negocio a medio y largo plazo?

Además de responder a estas preguntas, el sistema de gestión debe ayudar a tomar decisiones que mejoren la eficiencia, reduzcan los costes, controlen la cantidad de software desarrollado y aseguren la sostenibilidad del negocio. Es necesario integrar la estrategia de las tecnologías de la información (IT) de la FSF con la estrategia de negocio, y para lograrlo un sistema de gestión basado en el BSC puede ser de gran utilidad. El esquema de gestión que provee el BSC es probablemente la herramienta de gestión más conocida para una compañía.

En 1992, Kaplan y Norton, de la Universidad de Harvard, presentaron el BSC [23–25] como una herramienta para el control del rendimiento que permite a los gestores de las empresas valorar el negocio desde cuatro perspectivas distintas: *Financial* (financiera), *Customer* (clientes), *Internal Business Processes* (procesos internos de negocio) y *Learning and Growth* (aprendizaje y crecimiento). El BSC es utilizado por muchas empresas con la intención de evaluar su rendimiento en diversos aspectos, pero se trata únicamente de una plantilla que debe ser personalizada para ajustarla a los elementos específicos de cada organización, e incluso existen estudios [26] que sugieren que la ideología o cultura locales de cada sociedad deben ser tenidas en cuenta a la hora de personalizarlo, especialmente en aquellos casos en los que se utiliza en otra cultura diferente de la americana que lo ha ideado. Desde su introducción, muchos autores han propuesto modificaciones para adaptar el modelo inicial de BSC a diferentes tipos de entornos empresariales. Los estudios sobre el IT BSC [27,28] en el sector IT, el Sustainability BSC (SBSC) [29–31] en el marco de modelos de negocio sostenibles y otros estudios [32–34] en los que se utiliza el BSC para la valoración de la productividad en el sector financiero, y especialmente aplicado a la banca, son algunos de los ejemplos más conocidos de la utilización del BSC en relación a esta tesis.

En los siguientes años, Kaplan y Norton presentaron nuevos estudios que aportaron nuevos puntos de vista que mejoraron la versión inicial del BSC , uniendo las medidas de los indicadores incluidos en las cuatro perspectivas del BSC con los objetivos y la estrategia de negocio de la organización [35–37]. La idea de relacionar los objetivos con los indicadores incluidos en el BSC culminó con la creación del *strategy map* [38]. El *strategy map* proporciona una estructura robusta con las que las empresas pueden expresar sus objetivos estratégicos. Al mismo tiempo proporciona a los gestores de las empresas un marco de decisión basado en un sistema interactivo, que pueden diseñar y adaptar en base a la estrategia empresarial, haciendo del BSC y del *strategy map* el punto central del sistema de gestión con el que ejecutar la estrategia [39]. Además, los resultados de aplicar el BSC *framework* para vincular el desarrollo de software con la estrategia de negocio debería confirmar una mejora de la productividad, que permita alcanzar los objetivos de alto nivel definidos por la organización.

La principal contribución del *strategy map* es que incluye indicadores y medidas de rendimiento junto con objetivos estratégicos. Kaplan y Norton introdujeron tres principios que relacionan el BSC de una compañía con sus propia estrategia: relaciones causa-efecto; indicadores de rendimiento; y el enlace con los objetivos financieros [40]. El *strategy map* se construye acorde a las cuatro perspectivas del BSC, haciendo de interface entre la estrategia de negocio y el BSC. Proporciona una herramienta visual de gestión empresarial que ha sido utilizado por las empresas en prácticamente todas las áreas del negocio.

En relación con esta tesis es necesario resaltar las propuestas de utilización del BSC y el *strategy map* en el sector financiero [40,41], en el ámbito del desarrollo de software [42–44], en departamentos o empresas de IT [28,45,46] y en modelos de gestión sostenible [30,47]. Estos estudios son algunos ejemplos en relación al uso del *strategy map* con la intención de relacionar medidas, indicadores y objetivos estratégicos en una organización.

En organizaciones dedicadas al desarrollo de software intensivo, como una factoría software, es necesario vincular los objetivos ligados al desarrollo de software con los objetivos de alto nivel de la organización. Esta relación es importante, ya que permite justificar los esfuerzos realizados en la medición del software y contribuye en la toma de decisiones de alto nivel [43]. Además, vincular las actividades ligadas al desarrollo de software con los objetivos de negocio de alto nivel puede mejorar el rendimiento ligado a su desarrollo [48].

3.1.5. Las Factorías Software orientadas al Sector Financiero: un Caso de Estudio de una Compañía Española

La FSF estudiada en esta tesis es una compañía de IT bancaria que diseña, desarrolla y gestiona soluciones y servicios para entidades financieras, vinculada a un importante grupo financiero español. Este grupo financiero cuenta con más de 3.600 oficinas bancarias, 10.000 empleados, con más de ocho millones de clientes y unos activos totales superiores a los 60.000 millones de euros. Fundada a mediados de los años 80, es responsable de la definición e implantación de la estrategia tecnológica común en todo lo concerniente al tratamiento automatizado de la información del grupo empresarial al que pertenece. También ofrece sus servicios a otras compañías financieras de menor tamaño, ajenas al grupo empresarial, tanto en España como en el extranjero.

El objetivo de la FSF es operar, bajo un centro común de servicios informáticos, para las distintas entidades financieras que componen el grupo empresarial. Ha llevado a cabo en España la primera externalización (*outsourcing*) total de las aplicaciones bancarias a un entorno multi-entidad, en modalidad de pago por uso. Proporciona servicios a entidades financieras que van desde el desarrollo de su software a las plataformas que permiten su implementación y utilización. Esta software factory comercializa tanto desarrollos software a medida (*ad hoc*), como software en modalidad de pago por uso (*SaaS – Software as a Service*), en los que la FSF facilita los servicios de software de manera online al cliente, sin necesidad de inversión inicial y con un coste ligado al uso de los servicios. En este caso en concreto, los servicios de pago por uso se facturan según el número de transacciones o ejecuciones realizadas de los distintos módulos o componentes software.

Durante el año 2016 esta factoría software contó con más de 600 empleados, entre los propios y los subcontratados, con ingresos por ventas superiores a los 65 millones de euros, realizando más de 5.000 millones de transacciones económicas. Como empresa de *outsourcing* total para el sector financiero, llegó a contar con más de 82 clientes, pero, tras la crisis económica y financiera iniciada en 2008, el número de clientes se redujo a 40, debido a la fusión de entidades financieras y la desaparición de algunas de ellas. Superado el periodo de crisis y atendiendo a nuevas líneas de mercado, especialmente las conseguidas por la internacionalización de la empresa, ha llevado a cerrar el año 2016 con 49 clientes, teniendo presencia en España, Hispanoamérica y en varios mercados emergentes asiáticos. Durante los últimos años ha vuelto a crecer gracias a la incorporación de nuevos clientes y al crecimiento de los existentes, convirtiéndose sin duda, en un referente del *outsourcing* financiero para entidades bancarias.

La compañía cuenta actualmente con los medios necesarios para afrontar los retos que la economía digital supone para todo el sector. Proporciona la tecnología, servicios, procedimientos y capital humano que el sector financiero requiere de sus factorías software. Considera que la motivación y formación del capital humano es el mejor camino para conseguir crecer, ser eficientes, rentables y mantener la motivación de propietarios, empleados y clientes.

3.1.6. Propuesta de BSC Framework para una FSF

En un entorno muy restrictivo y con bajas tasas de crecimiento, esta FSF se propuso reducir los costes operativos, incrementar los ingresos y mejorar los servicios y aplicaciones ofertadas. Son conscientes de que necesitan proporcionar un servicio tecnológico maduro y estable, con la calidad y precio adecuados con los que satisfacer a los actuales clientes y poder atraer a otros nuevos. Deben desarrollar y mejorar sus servicios para seguir siendo el soporte necesario que el grupo financiero necesita para colaborar en su sostenibilidad y expansión. Ante estas circunstancias surgió la oportunidad de colaboración para el desarrollo de esta tesis y se optó por esta vía con el fin de

establecer un sistema de gestión empresarial para la factoría basado en el BSC *framework* que garantizase la sostenibilidad de la organización. Diferentes estudios confirman que las empresas que adaptan un modelo de gestión basado en el BSC tienden a lograr sus objetivos e incluso a superarlos [49]. El BSC es un "bien necesario" para las compañías, especialmente cuando es usado como un framework y como guía para el enfoque estratégico de la organización y de su correspondiente estructura [50].

Teniendo en cuenta estas necesidades, la dirección de las factoría software dio su aprobación al modelo propuesto, que las hizo llegar a toda la organización para transferirlas a la estrategia de la empresa. Se trabajó en el desarrollo de un conjunto de indicadores, en cómo medirlos y cómo realizar su seguimiento. Cada indicador o KPI cubre un área o departamento y alguno de ellos son un compendio de otros indicadores y diferentes medidas. Los KPIs fueron establecidos acorde a la mejor perspectiva estratégica y se evaluaron minuciosamente acorde a la planificación realizada. Las cuatro perspectivas estratégicas del BSC proporcionan una estructura robusta que permite expresar las necesidades de la organización y sus objetivos estratégicos (*strategic goals*) [39]. Se definieron también los objetivos del negocio (*business goals*), los objetivos de alto nivel (*high-level goals*) y la misión y visión global (*mission and vision*) de la organización. El sistema de gestión adoptado incluye además del BSC, el *strategy map* de la organización con sus *strategic goals*, la metodología de control de los indicadores y KPIs propuestos y las dependencias causa-efecto existente entre ellos.

Cada KPI y su valoración pueden influir en uno o más de los seis *business goals* que soportan los dos *high-level goals*. Estos *high-level goals* son a su vez los pilares de la estrategia que soportan directamente el logro de la *mission and vision* la organización [30]. Un buen *high-level goal* no es justamente un objetivo particular, sino que es un conjunto interrelacionado de objetivos que puede impactar en las cuatro perspectivas estratégicas del BSC. Estos objetivos interrelacionados cuentan la historia de la estrategia del negocio y constituyen la base para hacerla llegar a todos los actores relacionados o intervinientes (*stakeholders)* de una manera consistente [30]. Este sistema de gestión proporciona el entorno necesario para la toma de decisiones con el que satisfacer la estrategia de la organización. La Figura 2 muestra las diferentes capas o niveles de cómo se desarrolla una estrategia utilizando el BSC, comenzando en la parte superior con la m*ission and vision* de la organización hasta llegar en la parte inferior a la valoración de los indicadores. Con dicha valoración se deben tomar las iniciativas y correcciones que permitan alcanzar los objetivos establecidos.

Figura 2. Planificación y modelo estratégico utilizando el BSC framework. Adaptado de *The Balanced Scorecard Institute* [30].

La Figura 3 muestra el BSC desarrollado para una FSF [2], e incluye los KPIs escogidos con varios campos asignados a cada uno, según las recomendaciones de *The Advanced Performance Institute* [51]: código del KPI (*Code*), nombre del KPI (*KPI Name*), propietario o responsable (*KPI Owner*), frecuencia de medición (*Frequency Measurement*), valor de la medición (*Value Measurement*), tendencia objetivo (*Target Tendency*) y límites de control superiores e inferiores (*Upper and Lower Control Limits*) con los que gestionar la estabilidad de los procesos.

Los indicadores y KPIs derivan de los objetivos estratégicos de la FSF, a través de estas cuatro líneas estratégicas:

- Mejorar el rendimiento y productividad de la FSF.
- Los proyectos entregados deben ser de buena calidad para aumentar su uso por parte de los clientes.
- Optimizar y disminuir el coste y gastos de la FSF.
- Vender los desarrollos y comercializar servicios a compañías ajenas al grupo financiero para recuperar costes con ingresos externos.

BALANCED SCORECARD – FINANCIAL SOTWARE FACTORY

BALANCED SCORECARD – FINANCIAL SOTWARE FACTORY

STRATEGIC PERSPECTIVES	CODE	KPI NAME	KPI OWNER	FREQUENCY MEASUREMENT	VALUE MEASUREMENT	CONTROL LIMITS UPPER|LOWER	TARGET TENDENCY
FINANCIAL	F1	Cost Structure	Management Control	Quarterly	Ratio	Upper|Lower Values	Decrement
	F2	Reduction of Cost	Management Control	Monthly	Percentage	Upper|Lower Values	Increase
	F3	Useful Developments	Production & Man. Control	Quarterly	Ratio	Upper|Lower Values	Increase
CUSTOMER	C1	User Satisfaction	Marketing & Customers	Annual	Aggregate	Upper|Lower Values	Increase
	C2	Cost per Use	Management Control	Quarterly	Numeric Value	Upper|Lower Values	Decrement
	C3	SLA	Production & Man. Control	Monthly	Aggregate	Upper|Lower Values	Increase
INTERNAL BUSINESS PROCESSES	I1	Work Performance	Management Control	Monthly	Percetage	Upper|Lower Values	Increase
	I2	Employee Productivity	Human R. & Man. Control	Monthly	Percentage	Upper|Lower Values	Increase
	I3	Delay	Management Control	Monthly	Numeric Value	Upper|Lower Values	Decrement
	I4	Software Quality	Quality	Biannual	Aggregate	Upper|Lower Values	Increase
	I5	Budgeting Error	Planning & Man. Control	Biannual	Percentage	Upper|Lower Values	Decrement
LEARNING AND GROWTH	L1	Employer Branding	Human Resources	Biannual	Aggregate	Upper|Lower Values	Increase
	L2	Intellectual Capital	Organization &HR&Customers	Annual	Aggregate	Upper|Lower Values	Increase

Figura 3. BSC propuesto para una FSF. Adaptado de [2,3].

Los indicadores y KPIs fueron definidos durante varias sesiones de trabajo con la participación de diferentes roles de empleados. Algunos de los KPIs son simples de crear y sus mediciones fáciles de obtener, pero otros están formados por un compendio de otros indicadores y medidas y son complicados de obtener. Anualmente se revisa la validez de los KPIs, que pueden ser modificados o ajustados si fuese necesario. La Tabla 1 muestra una pequeña descripción y explicación de los

indicadores incluidos en el BSC de una FSF, los cuales están ampliamente desarrollados en el apartado *3.2 The proposed KPIs for the FSF* del Artículo 1 [2] de los que forman parte de esta tesis.

Tabla 1. Descripción y explicación de los KPIs incluidos en el BSC de una FSF [3].

Nº	KPIs	Description and explanation
1	Cost Structure	Cost evolution according to financial entity size. The costs of the software factory and the size of the financial entity are compared in such way that when the size of the matrix financial group decreases, the costs of the software factory should also decrease in a similar proportion. This indicator is in connexion with the third strategic line (optimization of cost).
2	Reduction of Cost	The ratio of cost that is covered by sales to companies outside the group. The purpose of this indicator is to assess the percentage of the structural cost of the software factory that is covered by income over the last year, whose source is the sale of software developments and services to companies outside the corporate group. Because of the huge cost of software development, sales revenue outside the financial group owner is generally seen as a reduction of costs. The indicator is derived from the fourth strategic line (sell the developments and services to other companies different from the owning financial group).
3	Useful Developments	Degree of use of the delivered software by the customers. In this particular case, the degree of use of the developments is indicated by the number of software executions and the indicator is calculated as the cumulative number of these executions in relation to the size of the financial institution over the last year. In this framework is understood that the greater use of the developments, the higher income should be achieved. The indicator is derived from the second strategic line (the level of use of the delivered software by the customers should be increased).
4	User Satisfaction	Degree of customer satisfaction concerning software developments and services given by the software factory. Customers are the users of these software developments and services. The indicator is connected to the second strategic line.
5	Cost per Use	The proportion between the cost paid by the customer and the degree of use of the delivered software, measured by means of the cumulative number of executions as in (F3). The indicator is connected to the third strategic line.
6	SLA	Level of service expected from the software factory as a service provider. The proposed SLA indicator to use in the BSC is a multi-indicator that joins and unifies all the agreements reached with the financial group, and more specifically between the financial institution and the FSF. The indicator is connected to the first and second strategic lines.
7	Work Performance	Efficiency level in terms of improving rates of software built. The indicator is calculated as ratio between budgeted hours and the performed hours and it is derived from the strategic line of improve the performance and productivity of the FSF.
8	Employee Productivity	Amount of software that an employee produces for each hour on the job. The ratio is connected with the improvement of performance and productivity of the FSF.
9	Delay	Average waiting time for delivery of software. This indicator shows the delay in hours when the software factory is delivering software developments. The indicator is connected with the improvement of performance and productivity of the FSF.
10	Software Quality	Aggregated indicator that assess the software quality, in connection with the second strategic line (delivery of software development must be good quality).
11	Budgeting Error	Accuracy of the estimates linked to software development. The indicator shows how good the estimations are over the last year and it is related with the third strategic line.
12	Employer Branding	Reputation of the software factory as an employer. Employees, and especially high-quality employees as a very important part of intellectual capital, must be attracted and retained by firms, and employer branding can help them to address the different needs and expectations of potential and existing employees. This indicator contributes to support all the strategic lines.
13	Intellectual Capital	Aggregated indicator that assess the intellectual capital as a compendium of human, structural and relational capital. This indicator contributes to support all the strategic lines.

Para desarrollar e implantar la estrategia de la compañía, la dirección de la factoría software se reunió en varias sesiones de trabajo con representantes de todos los niveles y áreas. En estas

reuniones se propuso un nuevo enfoque que permitiese plasmar la estrategia de la compañía, y entre las opciones posibles, optaron por el *strategy map* como el mecanismo más apropiado para relacionar la medición de los indicadores con los *strategic goals* de la factoría. Estos grupos de trabajo determinaron el conjunto de decisiones estratégicas, los *strategic goals* y la métrica e indicadores para medir el cumplimiento de dichos objetivos, de manera similar a como había expuesto Basili *et al* [43,44] en sus estudios sobre estrategias de negocio y desarrollo de software. Finalmente y acorde a todo lo expuesto, se definió el *strategy map* de la FSF que muestra las relaciones estratégicas de la factoría software. La Figura 4 muestra el *stragy map* de una FSF [2,4], explicado más ampliamente en el Artículo 1 y el Artículo 3 que forman parte de esta tesis.

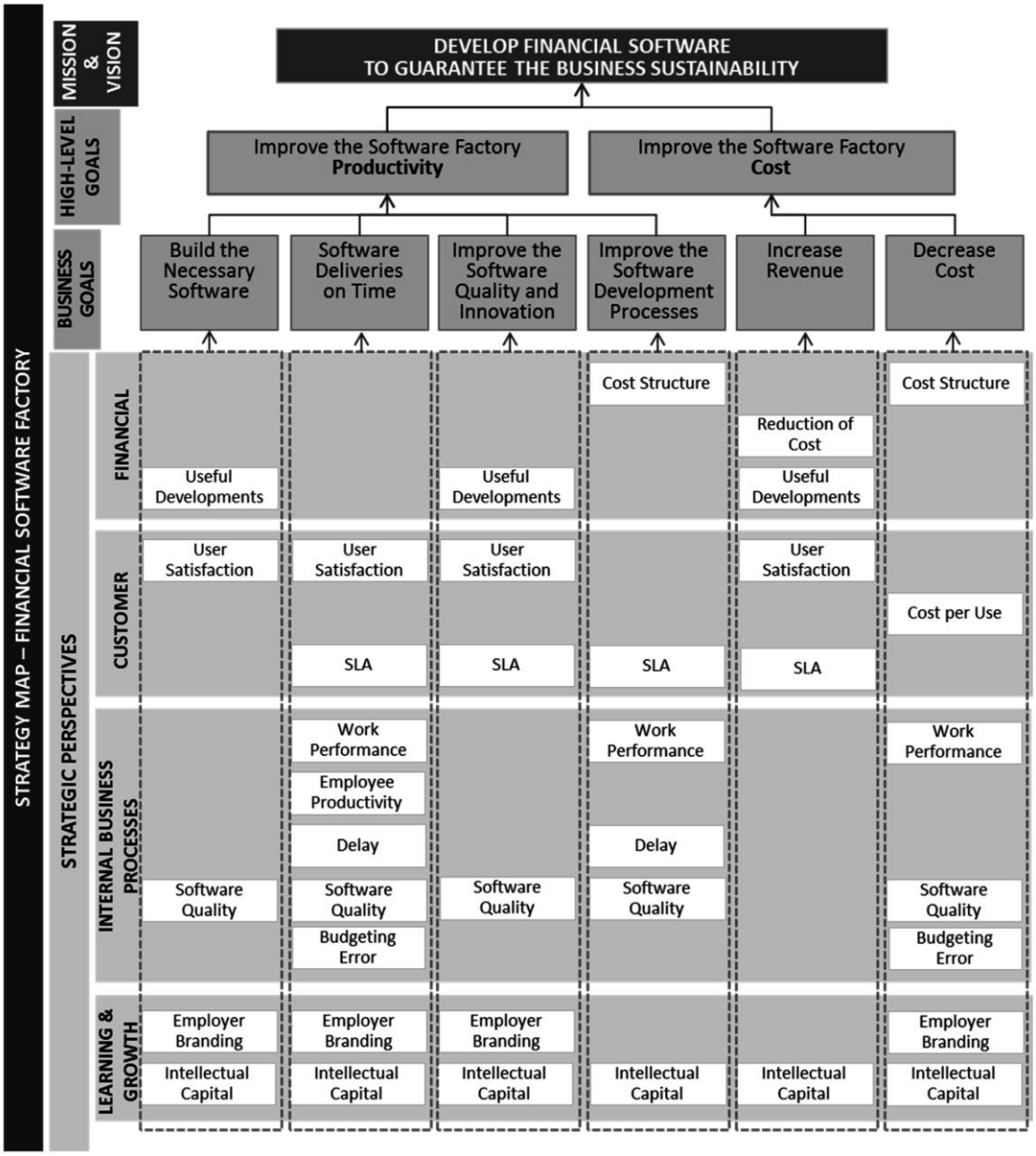

Figura 4. Strategy map para una FSF [2,4].

3.2. Valoración del Rendimiento del Modelo de Gestión ligado al BSC

Un problema que presenta esta propuesta inicial de BSC para una FSF es que no establece la importancia o los pesos de importancia de sus perspectivas y de los indicadores incluidos en ellas. El Artículo 2 [3] de los que forman esta tesis aborda este problema. Este artículo plantea una solución que permite asignar pesos de importancia a los distintos elementos del BSC, lo que permite valorar el rendimiento del modelo de gestión de una FSF basado en el BSC.

La integración del BSC con técnicas de toma de decisiones multi-criterio (*multi-criteria decision-making techniques* - MCDM), como el *Analytic Hierarchy Process* (AHP), ha resultado efectiva en numerosos estudios como un método de utilidad para calcular pesos y rankings de importancia, permitiendo establecer un sistema [52] y una métrica [53] para la evaluación del rendimiento. En esta tesis y como se ha hecho en el Artículo 2 de los que la conforman, el AHP ha sido propuesto para determinar los pesos de los indicadores incluidos en cada una de las cuatro perspectivas del BSC para una FSF, con el objetivo de valorar su rendimiento.

3.2.1. Analytic Hierarchy Process (AHP)

El AHP fue desarrollado inicialmente por Saaty en los años 70 [54,55] para resolver problemas de localización de recursos y planificación de necesidades en el ámbito militar. Desde su introducción, se ha convertido en uno de los métodos MCDM más utilizados para resolver problemas complejos no estructurados en diferentes áreas ligadas a las necesidades e intereses humanos [56]. En esta tesis el AHP ha sido utilizado para priorizar la importancia relativa de diferentes criterios (las perspectivas del BSC de una FSF) y sub-criterios (los indicadores y KPIs incluidos en cada una de las perspectivas del BSC de una FSF) mediante la comparación por pares de los criterios y sub-criterios entre si, utilizando la escala fundamental de Saaty [57], tal como se muestra en la Tabla 2.

Tabla 2. Escala de Saaty utilizada para la realización de juicios por parte de los expertos [57].

Intensity of Importance on an Absolute Scale	Definition	Explanation
1	Equally important	Two activities contribute equally to the objective
3	Weakly important	Experience and judgment strongly favour one activity over another
5	Essentially important	Experience and judgment strongly favour one activity over another
7	Very strongly important	An activity is strongly favoured and its dominance demonstrated in practice
9	Absolutely important	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate value between two adjacent judgments	When compromise is needed
Reciprocals	If activity *i* has one of the above numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	

La parte más creativa y clave del éxito en este tipo de planteamientos es el modelado del problema, en el que se debe identificar la jerarquía de los criterios y sub-criterios de decisión y las relaciones existentes entre ellos, para poder realizar la comparación por pares [58]. En este caso la estructura jerárquica utilizada para resolver el AHP se toma de la propia jerarquía establecida por el BSC de una FSF. La estructura jerárquica del BSC identifica el objetivo global (valoración del rendimiento), los criterios que definen las alternativas y que se encuentran en el medio de la jerarquía (perspectivas del BSC) y las alternativas competitivas (indicadores y KPIs incluidos en cada perspectiva) que están situadas en la parte inferior de la jerarquía, acorde a la jerarquía típica de este tipo de problemas [59]. El Apartado *2.2 AHP* del Artículo 2 de los que conforman esta tesis, amplía el estado del arte y repasa otros estudios ligados al AHP [60–65].

La Figura 5 muestra la estructura jerárquica utilizada para la valoración del rendimiento de una FSF.

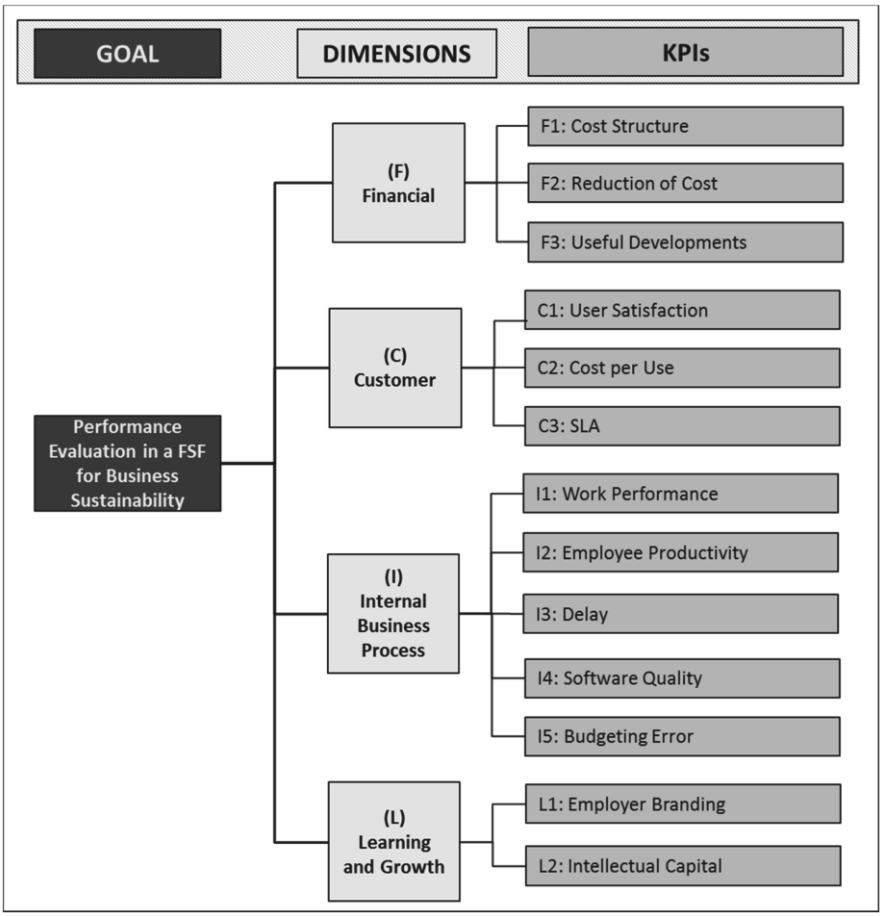

Figura 5. Estructura jerárquica del BSC para la evaluación del rendimiento de una FSF [3].

3.2.2. Integración del BSC con AHP para la Valoración del Rendimiento

Varios estudios han demostrado que un entorno de trabajo basado en el BSC es efectivo para evaluar el rendimiento de una organización [66]. Sin embargo, el BSC no establece los pesos de importancia de las perspectivas ni de los indicadores [67], lo que en la práctica significa que todas las perspectivas e indicadores tienen la misma importancia. Como herramienta para priorizar y consolidar métricas de rendimiento basadas en múltiples criterios, el AHP es muy adecuado para solventar estas limitaciones del BSC, adoptándose en numerosos casos esta integración del BSC y el AHP como método para el cálculo de pesos en un sistema de evaluación del rendimiento [65].

En ámbitos y sectores relacionados con esta tesis, el uso combinado del BSC y el AHP para valorar el rendimiento de una compañía, se ha utilizado en el sector IT [52,68], en el sector financiero [69,70] para la valorar el rendimiento de diferente bancos y para la valoración del rendimiento ligado a la sostenibilidad de las organizaciones [71,72] o de sus políticas de gestión sostenible [73].

3.2.3. Metodología Aplicada

La estructura analítica de la metodología utilizada en esta parte de la investigación está explicada gráficamente en la Figura 6. En la metodología utilizada, se han dados los siguientes pasos:

1. Analizar el BSC de una FSF (la organización estudiada).
2. Definir la estructura jerárquica relacionada con el BSC de una FSF.

3. Elaborar un cuestionario en formato AHP basado en la jerarquía establecida para obtener la opinión de los expertos en relación a la valoración de los indicadores y perspectivas del BSC, bajo el objetivo de la sostenibilidad del negocio.
4. Revisar y preparar las respuestas obtenidas para proporcionar el formato necesario para su tratamiento informático con software para cálculos AHP.
5. Calcular los pesos de manera global y por roles de *stakeholder* para todos los indicadores y perspectivas incluidas en el BSC.
6. Presentar los resultados y el análisis de los mismos para su discusión y formulación de las conclusiones.

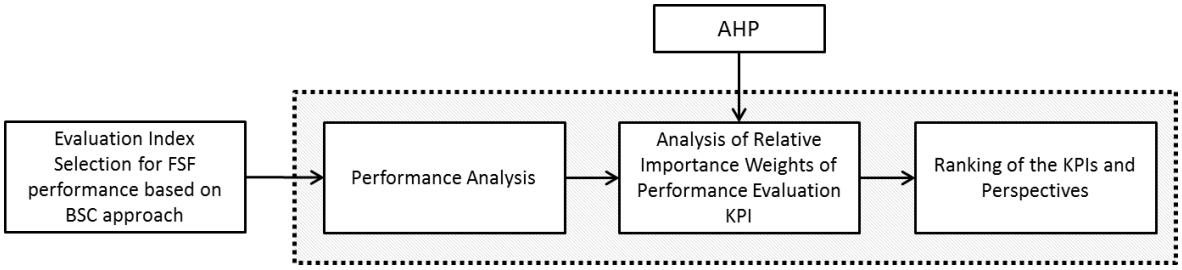

Figura 6. Marco de trabajo para la evaluación del rendimiento utilizado en la investigación [3].

3.2.4. Recolección de Datos

El cuestionario, elaborado con el formato convencional para su uso con AHP aplicando la escala presentada en la Tabla 2, se envió a diferentes expertos para una primera valoración de su contenido. Después de haberlo mejorado con las propuestas que estos expertos habían realizado, se hizo llegar a los distintos *stakeholders* de las FSF para recoger sus opiniones y juicios con los que valorar el rendimiento del BSC de una FSF. También se proporcionó un ejemplo de cómo rellenar el cuestionario y un conjunto de instrucciones. Se distribuyeron un total de 83 cuestionarios, por email y mediante encuesta online, a los propietarios (*Shareholders*) de la FSF, a la alta dirección (*Top Management*), responsables intermedios (*Middle Managers*), otros empleados (*Other Employees*), clientes (*Customers*) y expertos (*Experts*) en el campo de las factorías de software. La función de cada *stakeholder* en relación con la FSF se detalla en la Tabla 3.

Tabla 3. Distintos tipos de roles de *stakeholders* y su relación con la FSF [3].

Stakeholder Roles	Relation with the FSF
Shareholders	The shareholders are the owners of the company. They are usually top management of the financial entities involved in the same financial group.
Top Management	Top management are the highest ranking executives responsible for the entire FSF. They translate policy into goals and strategies for the future. Top management make decisions affecting everyone in the software factory.
Middle Managers	The middle managers are the employees of the FSF who manage at least one subordinate level of managers, and report to the top management in the organisation to ensure smooth functioning of the software factory.
Other Employees	Other employees are the lowest level of managers and the rest of the employees of the software factory, including analysts and developers.
Customers	Customers are the financial entities for which the software factory develops software and offers services to them.
Experts in Software Factories	Experts are a group of managers of other software factories from different sectors, professors and researchers in relation to software factories.

Finalmente se recibieron 61 cuestionarios (73.5% del total de los cuestionarios enviados); 3 fueron rechazados por llegar fuera de tiempo (3.6% de los cuestionarios enviados). De los restantes 19 (22.9%) no se ha recibido respuesta: el tiempo necesario para completarlo (entre 25 y 30 minutos), la fecha máxima de respuesta (una semana), o la falta de interés en este estudio (como pudo ser en el

caso de *Other Employees*, con un ratio de respuesta de solo el 46.1%), pueden ser las tres razones por la que no se ha recibido contestación.

Las respuestas recibidas fueron revisadas y adaptadas al formato adecuado para tratamiento mediante software AHP (en este estudio el paquete software utilizado para el tratamiento de los datos ha sido el paquete *FuzzyAHP of R* [74]). Las respuestas que no lograron pasar el test de consistencia (utilizado para valorar de manera directa la consistencia de las comparaciones a pares del cuestionario [75]), fueron revisadas y los valores de las matrices de comparación se chequearon. En los casos en los que los ajustes eran menores y no significativos, el procedimiento fue repetido [76]. El número definitivo de cuestionarios válido fue 44 (72.1% de los cuestionarios recibidos y un 53.0% de los cuestionarios enviados). La Tabla 4 muestra, según el rol de cada *stakeholder*, el número de cuestionarios enviados, recibidos y validados. Para finalizar, la aplicación software de AHP calculó lo pesos de los indicadores y de las perspectivas del BSC, generando como resultado los pesos de importancia de cada uno de ellos.

Tabla 4. Número y porcentajes de cuestionarios enviados, recibidos y válidos por roles [3].

Stakeholder Roles	Number of Sent Questionnaires	Number of Received Questionnaires		Number of Valid Received Questionnaires (Received/Sent)	
Shareholders	13	9	69.2%	6	66.7%/46.2%
Top Management	12	8	66.7%	6	75.0%/50.0%
Middle Managers	15	13	86.7%	8	61.5%/53.3%
Other Employees	13	6	46.1%	5	83.3%/38.5%
Customers	15	14	93.3%	10	71.4%/66.7%
Experts in Software Factories	15	11	73.3%	9	81.8%/60.0%
Total	**83**	**61**	73.5%	**44**	72.1%/53.0%

3.2.5. Resultados

Los resultados para la evaluación del análisis de rendimiento del BSC, muestra que las Perspectiva del Cliente (*Customer Perspective*), con una prioridad del 0.4586, es la más importante de las cuatro. La sigue la Perspectiva Financiera (*Financial Perspective*), con un peso del 0.2035. El peso de la Perspectiva de los Procesos Internos de Negocio (*Internal Business Processes Perspective*) es el 0.1712, y finalmente, la Perspectiva de Aprendizaje y Crecimiento (*Learning and Growth Perspective*) es la menos importante, con un peso de 0.1667.

El orden de prioridad para los 13 indicadores muestra que la Satisfacción del Usuario (*User Satisfaction*), con una peso de 0.2482, y los Acuerdos a Nivel de Servicio (*Service Level Agreements* – SLA), con un peso de 0.1319 (ambos incluidos en *Customer Perspective*), son los más importantes entre todos los indicadores incluidos en el BSC de una FSF. El tercer indicador más importante es el Capital Intelectual (*Intellectual Capital*), con un peso de 0.1049 (incluido en *Learning and Growth Perspective*), seguido de la Estructura de Costes (*Cost Structure*) con un peso de 0.0841 (incluido en *Financial Perspective*). El séptimo indicador más importante es la Calidad del Software (*Software Quality*), con un peso de 0.0633 (incluido en *Internal Business Processes Perspective*). La Figura 7 muestra la estructura jerárquica del BSC de una FSF con los resultados globales ordenados por pesos de importancia, y la Tabla 5 muestra los resultados por roles de *stakeholder*.

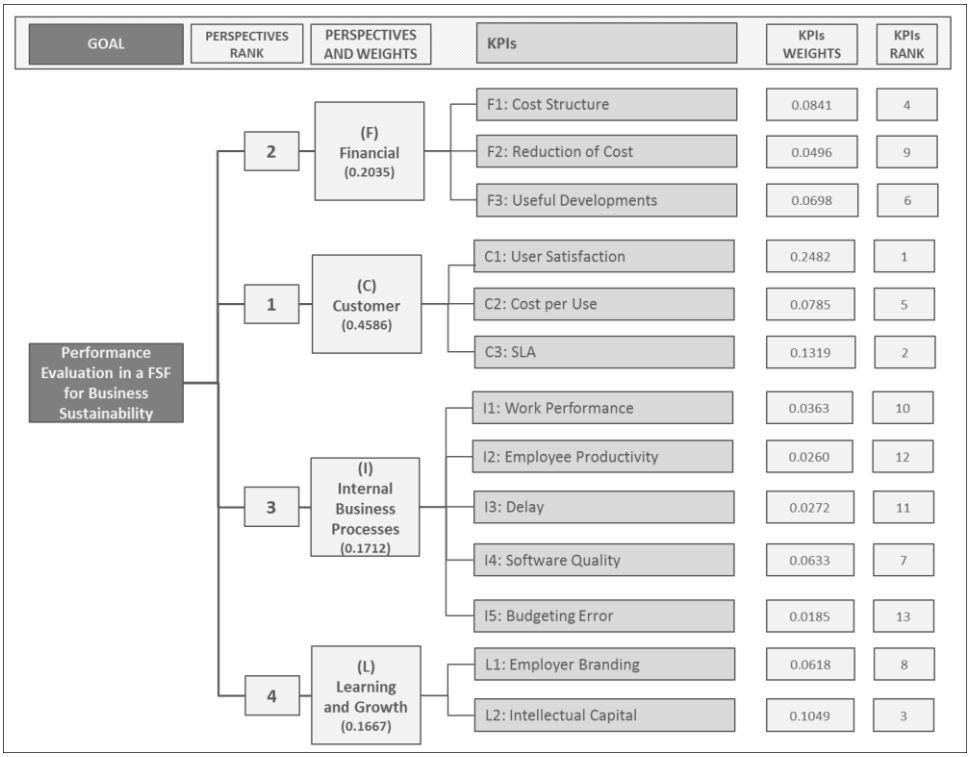

Figura 7. Pesos y ranking de la evaluación del rendimiento con AHP del BSC para una FSF [3].

Tabla 5. Pesos de la evaluación de rendimiento con AHP de las perspectivas e indicadores del BSC de una FSF según los distintos tipos de roles de *stakeholder* [3].

Criteria and Sub-Criteria / Roles of Stakeholders	Global	Share-Holders	Top Management	Middle Managers	Other Employees	Customers	Experts
(F) Finance	0.2035	0.2172	0.1536	0.2090	0.2914	0.1482	0.2407
(F1) Cost Structure	0.0841	0.1430	0.0446	0.0859	0.1051	0.0632	0.0825
(F2) Reduction of Cost	0.0496	0.0409	0.0430	0.0588	0.0522	0.0305	0.0684
(F3) Useful Developments	0.0698	0.0333	0.0659	0.0643	0.1340	0.0545	0.0898
(C) Customer	0.4586	0.5352	0.4933	0.4417	0.2829	0.4735	0.4628
(C1) User Satisfaction	0.2482	0.2263	0.2495	0.2284	0.1704	0.2508	0.2739
(C2) Cost per Use	0.0785	0.2041	0.0917	0.0446	0.0487	0.0646	0.0797
(C3) SLA	0.1319	0.1048	0.1522	0.1686	0.0638	0.1581	0.1093
(I) Internal Business Processes	0.1712	0.1403	0.2287	0.1992	0.2214	0.1510	0.1264
(I1) Work Performance	0.0363	0.0252	0.0381	0.0341	0.0508	0.0339	0.0320
(I2) Employee Productivity	0.0260	0.0178	0.0169	0.0219	0.0342	0.0364	0.0230
(I3) Delay	0.0272	0.0205	0.0455	0.0340	0.0348	0.0181	0.0198
(I4) Software Quality	0.0633	0.0580	0.0998	0.0906	0.0865	0.0527	0.0282
(I5) Budgeting Error	0.0185	0.0187	0.0285	0.0185	0.0151	0.0099	0.0234
(L) Learning and Growth	0.1667	0.1073	0.1244	0.1502	0.2043	0.2272	0.1700
(L1) Employer Branding	0.0618	0.0241	0.0459	0.0640	0.0473	0.1218	0.0591
(L2) Intellectual Capital	0.1049	0.0832	0.0785	0.0861	0.1570	0.1054	0.1110

3.3. Un Modelo de Negocio Sostenible Basado en la Optimización de la Toma de Desiciones

La primera de las tres publicaciones [2] que forman esta tesis presenta el caso de una factoría software española que decidió establecer un nuevo modelo de negocio, revisando el concepto de industrialización y aplicándolo al desarrollo de software, lo que se conoce como el *software factory approach*. Para conseguirlo se eligió un modelo de gestión del negocio basado en el BSC *framework*, con el que garantizar la sostenibilidad del modelo de negocio de la compañía.

3.3.1. Modelos de Gestión de Negocio Sostenibles

La literatura actual no ofrece una definición conceptual de modelo de negocio sostenible en el contexto de innovación tecnológica, organizativa y social [77], pero cambios en el modelo de gestión se reconocen como fundamentales para lograr su sostenibilidad [78]. El libro *Business Model Management. Design–Instruments–Success Factors* [79] de Wirtz, publicado en 2011, realiza una revisión sistemática y conceptual acerca del modelo de negocio. En dicha publicación, identifica tres perspectivas ligadas a la gestión del modelo de negocio, basadas en la tecnología, la organización (se ocupa del modelo de negocio como una herramienta de gestión estratégica para mejorar la cadena de valor de una compañía) y una tercera orientada a la estrategia (que añade el elemento de competencia de mercado a la eficiencia de la compañía).

La noción de modelo de negocio sostenible está basada en el propio concepto y definición de modelo de negocio, en combinación con otros conceptos importantes como la gestión de los *stakeholders* de la organización [80], la creación de valor sostenible [81] y la perspectiva de continuidad del negocio a largo plazo. Los modelos de negocio sostenibles son un tema en auge, pero actualmente son pocas las herramientas disponibles que permiten a las empresas su implantación [82].

El modelo de negocio sostenible propuesto en esta tesis fomenta la eficiencia operativa en la gestión de los proyectos software, la relación a largo plazo entre la organización y sus *stakeholders*, teniendo en cuenta las preferencias que cada uno de ellos espera de la gestión de la organización, busca la satisfacción de las necesidades específicas de cada tipo de tipo de *stakeholder* (valor económico para los propietarios, satisfacción para los clientes y mejoras en procesos internos y formativos para los empleados), el incremento de la cartera de clientes y el compromiso mutuo entre la organización y los empleados. Para desarrollar y evaluar todos estos aspectos se optó por una herramienta basada en un *strategy map* ponderado, donde los pesos son calculados gracias a la integración del BSC y el *strategy map* de la FSF con FAHP, y su gran objetivo estratégico es asegurar la sostenibilidad del modelo de negocio mediante la optimización de la toma de decisiones por parte de sus gestores. Para determinar los pesos que ponderan la relaciones del *strategy map* se utilizó el FAHP, un MCDM de utilidad para calcular la importancia de diferentes alternativas ligadas a un sistema de rendimiento [52].

3.3.2. Fuzzy Analytic Hierarchy Process (FAHP)

La evaluación de diferentes alternativas es un problema MCDM que incluye muchos atributos cuantitativos y cualitativos. El AHP es un método que ha sido ampliamente utilizado para seleccionar la mejor alternativa entre otras [83,84]. Sin embargo, debido a la vaguedad e incertidumbre que pueden presentar las opiniones inherentes al ser humano, se introdujo la lógica de los números *fuzzy* junto con el AHP, para así solventar esta deficiencia existente en el AHP convencional [85,86]. Buckey incorporó la teoría *fuzzy* en el AHP, denominando a esta nueva teoría FAHP. In 1996, Chang introdujo un nuevo enfoque en la aplicación del FAHP con el uso de los número *fuzzy* triangulares (*Triangular Fuzzy Numbers – TFN)* [87] para las representación de las comparaciones por pares.

Expresiones como “no muy claro”, “probablemente si” y “muy probable” son usadas con frecuencia en la vida cotidiana, pero añaden cierto grado de incertidumbre ligada al pensamiento humano. Para expresar estos casos, la noción de variable lingüística es vital. Las variables

lingüísticas son variables cuyos valores son palabras o expresiones de un lenguaje natural o artificial. En otras palabras, son variables con una expresión lingual como la de sus valores [88,89]. Esta tesis, y el Artículo 3 de los que la forman, usa cinco términos lingüísticos básicos para comparar la mejor opción en la evaluación de criterios, acorde a la escala de Saaty [57]. La función de pertenencia de un término lingüístico está definida por Mon *et al.* [90], de la forma en la que se muestra en la Tabla 6.

Tabla 6. Función de pertenencia de la escala lingüística [4].

Fuzzy Number	Linguistic Scale	TFN ($\tilde{a}_{ij}$)	Reciprocal of a TFN ($\tilde{a}_{ij}$)
$\tilde{1}$	Equally important	(1, 1, 3)	(1/3, 1, 1)
$\tilde{3}$	Weakly important	(1, 3, 5)	(1/5, 1/3, 1)
$\tilde{5}$	Essentially important	(3, 5, 7)	(1/7, 1/5, 1/3)
$\tilde{7}$	Very strongly important	(5, 7, 9)	(1/9, 1/7, 1/5)
$\tilde{9}$	Absolutely important	(7, 9, 9)	(1/9, 1/9, 1/7)
$\tilde{2}$, $\tilde{4}$, $\tilde{6}$, $\tilde{8}$	Intermediate value between two adjacent judgements		

Esta tesis incorpora en la investigación la teoría de conjuntos difusos en la valoración del rendimiento para evaluar las opiniones o juicios subjetivos de los *stakeholders* de la FSF. Se mejoran por tanto los datos obtenidos y expuestos en el apartado *3.2 Valoración del Rendimiento del Modelo de Gestión ligado al BSC* que habían sido obtenidos mediante la aplicación del AHP. Tras volver a ser recalculados aplicando FAHP, se ha logrado mejorar la precisión de los datos obtenidos de la automatización y tratamiento de las opiniones recibidas en el cuestionario.

El apartado *2.3 Fuzzy Theory and FAHP* del Artículo 3 de los que forman esta tesis, hace una amplia revisión del estado del arte de la teoría de números *fuzzy* y del FAHP, con las aportaciones de los estudios de Buckey, Zadeh y otros [89,91–94].

3.3.3. Integration of BSC and Strategy Map Framework with FAHP

Aunque la integración del BSC con técnicas de MCDM como AHP o FAHP han sido utilizadas como un método de utilidad para calcular pesos y poder establecer un sistema de evaluación del rendimiento, la integración del *strategy map* con AHP o FAHP para establecer los pesos de importancia de las relaciones causa-efecto definidas en el *strategy map* de una organización ha sido utilizada en pocos casos con una finalidad parecida. En otras ocasiones, se ha utilizado el *analytic network process* (ANP), cuya estructura es una red en vez de una jerarquía (como sucede con el AHP o FAHP), para resolver problemas de este tipo. En este estudio se ha optado por la solución de una integración entre los resultados del análisis de FAHP del BSC y del *strategy map*, ya que reduce sustancialmente el número de preguntas necesarias de comparación a pares para el posterior análisis. Además, el artículo que está en revisión y en el que se integró el BSC con FAHP para el cálculo de los pesos de indicadores y perspectivas, proporcionó diferencias de cierta importancia en algunas de las valoraciones frete a la integración del BSC con el AHP realizada en el Artículo 2. La existencia de estas diferencias y la mejor representación de los juicios de los expertos con la aplicación de la teoría de números *fuzzy*, nos llevó a la utilización del FAHP en vez de AHP en este último artículo.

En la mayoría de casos en los que se ha utilizado el AHP o el FAHP junto con *el strategy map*, ha sido para definir mediante la aplicación de estas técnicas los elementos o relación que debían formar parte del *strategy map*, pero no precisamente para valorar la importancia que esos elementos y relaciones ya definidas tienen dentro del *strategy map*. La revisión del estado del arte encontramos que Wu [40] presenta un metodología de evaluación estructural que permite relacionar y construir los indicadores y el *strategy map* de una entidad financiera. En el sector IT, Chen and Wang [95] proponen una combinación entre FAHP e indicadores con la intención de ayudar a las empresas del sector a definir sus estrategias de negocio y optar por la decisiones comerciales más apropiadas. Ren *et al.* [96] y Taticchi *et al.* [97] proponen mediante el uso de técnicas MCDM diferentes métricas de rendimiento con relación causa-efecto entre indicadores y estrategias de negocio. Varios estudios de Quezada *et al.* [98–100] presentan la utilización del AHP como soporte de la creación de un *strategy*

map en diferentes sectores. Lu *et al.* [31] proponen un análisis multi-criterio para establecer estrategias de desarrollo sostenible con las que fortalecer las ventajas competitivas del negocio.

Esta tesis propone la integración del BSC y del *strategy map* de una FSF con FAHP para determinar los pesos relativos de los indicadores y objetivos definidos en el *strategy map*, con la intención de valorar el impacto de la toma de decisiones sobre la misión y visión de la organización.

Como se ha explicado previamente en esta tesis, una parte muy importante en este tipo de planteamientos es la definición de la estructura jerárquica utilizada para resolver el problema. En este caso, y bajo un mismo objetivo global para ambas jerarquías, se adoptaron como jerarquías las definidas por la propia estructura jerárquica del BSC y del *strategy map* de una FSF, también acorde a la típica jerarquía de estos problemas [59], y que se muestran en la Figura 8 y la Figura 9.

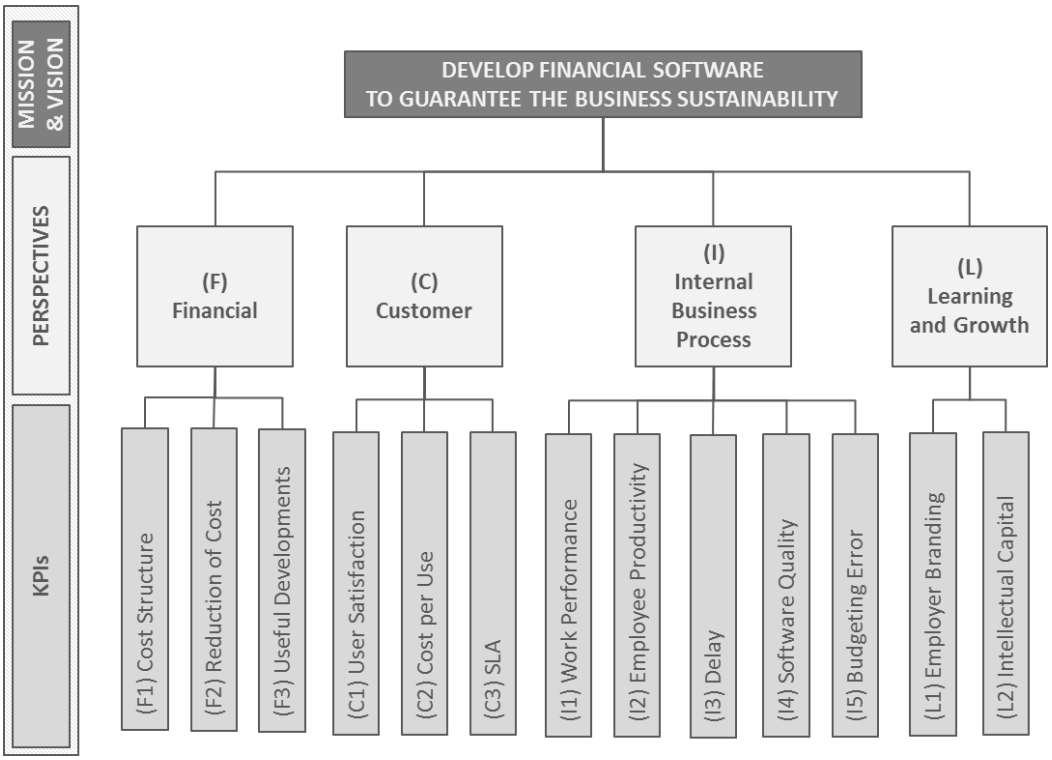

Figura 8. Estructura jerárquica del BSC de una FSF para análisis FAHP.

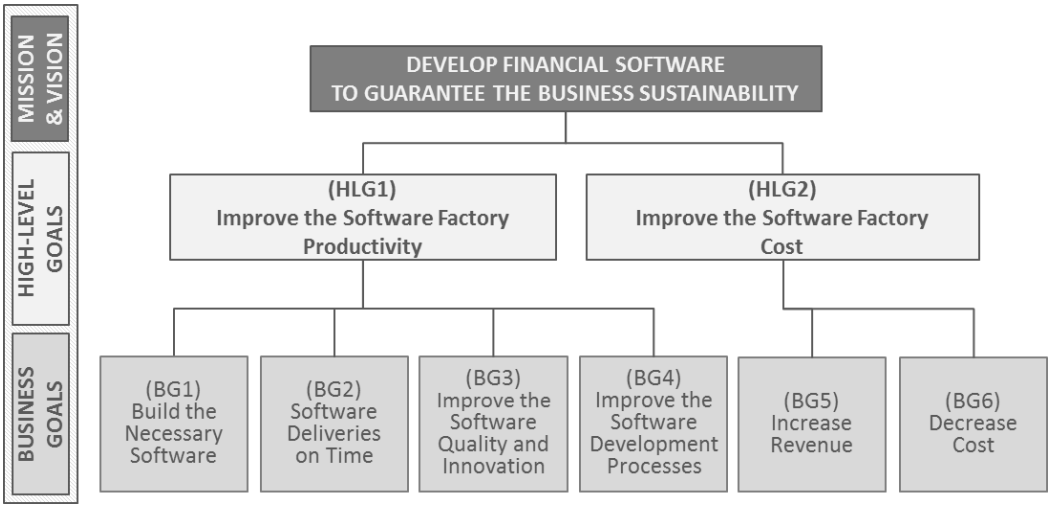

Figura 9. Estructura jerárquica del strategy map de una FSF para análisis FAHP.

3.3.4. Metodología Aplicada

En esta tesis se propone un entorno basado en el BSC y el *strategy map* de una FSF para establecer los pesos de los indicadores, perspectivas, *business goals* y *high-level goals* que forman parte del propio *strategy map*. La estructura analítica de esta investigación está explicada en el Figura 10.

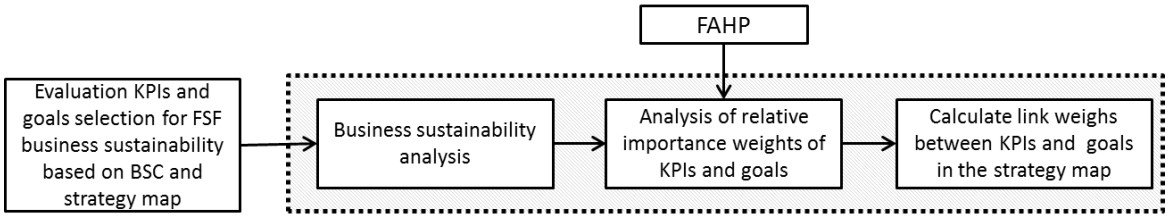

Figura 10. Marco de trabajo para la evaluación de rendimiento utilizado en la investigación [4].

En la metodología utilizada, se han dados los siguientes pasos:

1. Analizar el BSC y del *strategy map* de la FSF (la organización estudiada).
2. Definir la estructura jerárquica del BSC y del *strategy map*.
3. Elaborar un cuestionario en formato AHP basado en las dos jerarquías establecidas para obtener la opinión de los expertos en relación a la valoración de los indicadores, perspectivas y *strategic goals* definidos en el *strategy map* de la organización, bajo la premisa de "sostenibilidad del modelo de negocio".
4. Revisar y preparar las respuestas obtenidas de los expertos para darles el formato necesario para su posterior tratamiento informático con software para cálculo FAHP.
5. Calcular los pesos de manera global y por roles de *stakeholder* para todos los indicadores y perspectivas incluidas en el BSC.
6. Calcular los pesos de manera global y por roles de *stakeholder* para todos los *strategic goals* incluidos en el *strategy map*.
7. Con base en la relación existente entre los indicadores y los *strategic goals* definidos en el *strategy map*, calcular los pesos relativos de cada indicador sobre cada *business goal* concreto y al que afecta directamente. El total del peso del indicador se distribuye de manera proporcional a los pesos de los *business goals* a los que afecta.
8. Incorporar los pesos calculados al *strategy map*, lo que permite conocer el impacto que cada indicador tiene sobre todos los *strategic goals*, incluida la *Mission and Vision* definida en el *strategy map* de una FSF.

3.3.5. Recolección de Datos

La recolección de datos se llevó a cabo en el mismo cuestionario y de la misma forma explicada en el Apartado *3.2.4 Recolección de Datos* utilizada en el Artículo 2 de esta tesis. En este caso, además de las comparaciones por pares referentes a los indicadores y perspectivas incluidas en el BSC, se han realizado y tenido en cuenta las comparaciones por pares referentes a los *strategic goals* definidos en el *strategy map*.

3.3.6. Resultados Globales

En esta parte de la tesis se presentan los resultados obtenidos bajo el objetivo de sostenibilidad del modelo de negocio, utilizando en esta ocasión FAHP. En primer lugar se muestran por separado los resultados intermedios, que se corresponden con los de los pesos de los indicadores y perspectivas del BSC, en la Tabla 7, y con los de los *strategic goals* definidos en el *strategy map*, en la Tabla 8. Finalmente se muestran en la Tabla 9 y en la Figura 11 los resultados definitivos de esta parte de la investigación. Las diferencias existentes entre los resultados expuestos en el apartado 3.2.5 Resultados (análisis con AHP) y los aquí presentados en la Tabla 7 (análisis con FAHP) para los pesos de los mismos indicadores y perspectivas del BSC, se deben al ajuste sobre la ambigüedad e

incertidumbre que proporciona el uso del FAHP frente al AHP, tal como se ha explicado en esta tesis.

Como se observa en el análisis del BSC de la Tabla 7, *Customer Perspective*, con una prioridad de 0.4254, es la más importante de todas, seguida de la *Financial Perspective*, con una prioridad de 0.2134. *Learning and Growth Perspective* tiene un peso de 0.1808 mientras que *Internal Business Processes Perspective* es la de menor importancia con un peso de 0.1804. Referente a la importancia asignada a los trece indicadores incluidos en el BSC, *User Satisfaction*, con un peso de 0.2109, y SLA, con un peso de 0.1268, son los indicadores de mayor importancia. Ambos están incluidos en *Customer Perspective*. *Intellectual Capital* con un peso de 0.1053, incluido en *Learning and Growth Perspective,* es el tercer indicador en importancia, seguido de *Cost Structure*, incluido en *Financial Perspective*, con un peso de 0.0877. *Software Quality*, con un peso de 0.0633, es el octavo indicador en importancia y el más importante de entre todos los incluidos en *Internal Business Processes Perspective*.

La Tabla 8 muestra los resultados para los pesos de los *strategic goals* incluidos en el *strategy map*. El objetivo de alto nivel Mejora de la Productividad (*Improve Productivity HLG*) es el más importante de los dos *high-level goals*, con un peso de 0.7083, frente a Mejora de Costes (*Improve Costs HLG*), que tiene un peso asignado de 0.2917. En cuanto a la prioridad de los seis *business goals*, Desarrollar el Software Necesario (*Building the Necessary Software*) y Entrega a Tiempo de los Proyectos (*Software Deliveries on Time*) son las dos estrategias de negocio más importantes entre las seis evaluadas.

Tabla 7. Valores *fuzzy* para los pesos del BSC de una FSF para el análisis con FAHP de la sostenibilidad del modelo de negocio [4].

Criteria and Sub-Criteria (Perspectives and KPIs)	Local Weights TFN (*L, M, U*)	Overall Weights TFN (*L, M, U*)	BNP [1]	STD BNP [2]	Rank of Weights
(F) Financial	**(0.1148; 0.2035; 0.3518)**		**0.2234**	**0.2134**	**2**
(F1) Cost Structure	(0.2870; 0.4134; 0.5503)	(0.0329; 0.0841; 0.1936)	0.1036	0.0877	4
(F2) Reduction of Cost	(0.1568; 0.2438; 0.3741)	(0.0180; 0.0496; 0.1316)	0.0664	0.0562	9
(F3) Useful Developments	(0.2255; 0.3429; 0.4844)	(0.0259; 0.0698; 0.1704)	0.0887	0.0751	6
(C) Customer	**(0.2957; 0.4586; 0.5817)**		**0.4454**	**0.4254**	**1**
(C1) User Satisfaction	(0.3781; 0.5411; 0.6655)	(0.1118; 0.2481; 0.3871)	0.2490	0.2109	1
(C2) Cost per Use	(0.1090; 0.1712; 0.2881)	(0.0322; 0.0785; 0.1676)	0.0928	0.0786	5
(C3) SLA	(0.1745; 0.2876; 0.4568)	(0.0516; 0.1319; 0.2657)	0.1497	0.1268	2
(I) Internal Business Processes	**(0.1057; 0.1712; 0.2897)**		**0.1889**	**0.1804**	**4**
(I1) Work Performance	(0.1376; 0.2118; 0.3225)	(0.0145; 0.0363; 0.0934)	0.0481	0.0407	10
(I2) Employee Productivity	(0.0955; 0.1516; 0.2431)	(0.0101; 0.0260; 0.0704)	0.0355	0.0301	12
(I3) Delay	(0.0979; 0.1587; 0.2558)	(0.0103; 0.0272; 0.0741)	0.0372	0.0315	11
(I4) Software Quality	(0.2361; 0.3698; 0.5018)	(0.0250; 0.0633; 0.1454)	0.0779	0.0659	8
(I5) Budgeting Error	(0.0675; 0.1082; 0.1944)	(0.0071; 0.0185; 0.0563)	0.0273	0.0231	13
(L) Learning and Growth	**(0.1078; 0.1667; 0.2934)**		**0.1893**	**0.1808**	**3**
(L1) Employer Branding	(0.2644; 0.3708; 0.5154)	(0.0285; 0.0618; 0.1512)	0.0805	0.0682	7
(L2) Intellectual Capital	(0.4846; 0.6292; 0.7356)	(0.0522; 0.1049; 0.2158)	0.1243	0.1053	3

[1] BNP (Best non-fuzzy performance) = [(*U* - *L*) + (*M* - *L*)]/3 + *L*. [2] STD_BNP: standardised BNP.

Tabla 8. Valores *fuzzy* para los pesos de los *strategic goals* del *strategy map* de un a FSF para el análisis con FAHP de la sostenibilidad del negocio [4].

Criteria and Sub-Criteria (HLG and Business Goals)	Local Weights TFN (*L, M, U*)	Overall Weights TFN (*L, M, U*)	BNP [1]	STD BNP [2]	Rank of Weights
(HLG1) Improve Productivity	**(0.6243; 0.7156; 0.8180)**		**0.7193**	**0.7083**	**1**
(BG1) Build the Necessary SW	(0.1959; 0.2971; 0.4056)	(0.1223; 0.2126; 0.3318)	0.2222	0.2043	1
(BG2) SW Deliveries on Time	(0.1730; 0.2679; 0.3850)	(0.1080; 0.1917; 0.3149)	0.2049	0.1883	2
(BG3) Improve the SW Quality and Innovation	(0.1642; 0.2541; 0.3740)	(0.1025; 0.1818; 0.3059)	0.1967	0.1808	3
(BG4) Improve the SW Development Processes	(0.1197; 0.1810; 0.2881)	(0.0747; 0.1295; 0.2357)	0.1466	0.1348	5
(HLG2) Improve Cost	**(0.2099; 0.2845; 0.3946)**		**0.2963**	**0.2917**	**2**
(BG5) Increase Revenue	(0.4340; 0.5550; 0.6875)	(0.0911; 0.1579; 0.2713)	0.1734	0.1594	4
(BG6) Decrease Cost	(0.3602; 0.4450; 0.5821)	(0.0756; 0.1266; 0.2297)	0.1440	0.1323	6

[1] BNP (Best non-fuzzy performance) = [(*U* - *L*) + (*M* - *L*)]/3 + *L*. [2] STD_BNP: standardised BNP.

Los resultados finales se muestran en la Tabla 9. Esta tabla muestra los pesos de los enlaces entre indicadores y *business goals* en el *strategy map*. El peso global de cada indicador incluido en el BSC ha sido distribuido de manera proporcional al peso de cada una de las estrategias definidas en los *business goals* del *strategy map*. Finalmente, la Figura 11 muestra el *strategy map* ponderado de una FSF, e incorpora los pesos calculados para la relaciones causa-efecto existentes entre indicadores y *business goals*.

Tabla 9. Tabla con los pesos *fuzzy* de las relaciones causa-efecto entre los indicadores y business goals del strategy map de una FSF [4].

KPIs and Business Goals	KPI and Business Goal Overall Weights	Link Weights between KPIs and Business Goals
(F1) Cost Structure	**0.0877**	
(BG4) Improve the Software Development Processes	0.1348	0.0443
(BG6) Decrease Cost	0.1323	0.0434
(F2) Reduction of Cost	**0.0562**	
(BG5) Increase Revenue	0.1595	0.0562
(F3) Useful Developments	**0.0751**	
(BG1) Build the Necessary Software	0.2043	0.0282
(BG3) Improve the Software Quality and Innovation	0.1808	0.0249
(BG5) Increase Revenue	0.1595	0.0220
(C1) User Satisfaction	**0.2109**	
(BG1) Build the Necessary Software	0.2043	0.0588
(BG2) Software Deliveries on Time	0.1883	0.0542
(BG3) Improve the Software Quality and Innovation	0.1808	0.0520
(BG5) Increase Revenue	0.1595	0.0459
(C2) Cost per Use	**0.0786**	
(BG6) Decrease Cost	0.1323	0.0786
(C3) Service Level Agreements (SLA)	**0.1268**	
(BG2) Software Deliveries on Time	0.1883	0.0360
(BG3) Improve the Software Quality and Innovation	0.1808	0.0346
(BG4) Improve the Software Development Processes	0.1348	0.0258
(BG5) Increase Revenue	0.1595	0.0305
(I1) Work Performance	**0.0407**	
(BG2) Software Deliveries on Time	0.1883	0.0168
(BG4) Improve the Software Development Processes	0.1348	0.0120
(BG6) Decrease Cost	0.1323	0.0118
(I2) Employee Productivity	**0.0301**	
(BG2) Software Deliveries on Time	0.1883	0.0301
(I3) Delay	**0.0315**	
(BG2) Software Deliveries on Time	0.1883	0.0184
(BG4) Improve the Software Development Processes	0.1348	0.0131
(I4) Software Quality	**0.0659**	
(BG1) Build the Necessary Software	0.2043	0.0160
(BG2) Software Deliveries on Time	0.1883	0.0148
(BG3) Improve the Software Quality and Innovation	0.1808	0.0142
(BG4) Improve the Software Development Processes	0.1348	0.0106
(BG6) Decrease Cost	0.1323	0.0104
(I5) Budgeting Error	**0.0231**	
(BG2) Software Deliveries on Time	0.1883	0.0136
(BG6) Decrease Cost	0.1323	0.0095
(L1) Employer Branding	**0.0682**	
(BG1) Build the Necessary SW	0.2043	0.0197
(BG2) Software Deliveries on Time	0.1883	0.0182
(BG3) Improve the Software Quality and Innovation	0.1808	0.0175
(BG6) Decrease Cost	0.1323	0.0128
(L2) Intellectual Capital	**0.1053**	

(BG1) Build the Necessary Software	0.2042	0.0215
(BG2) Software Deliveries on Time	0.1883	0.0198
(BG3) Improve the Software Quality and Innovation	0.1808	0.0190
(BG4) Improve the Software Development Processes	0.1348	0.0142
(BG5) Increase Revenue	0.1595	0.0168
(BG6) Decrease Cost	0.1323	0.0139

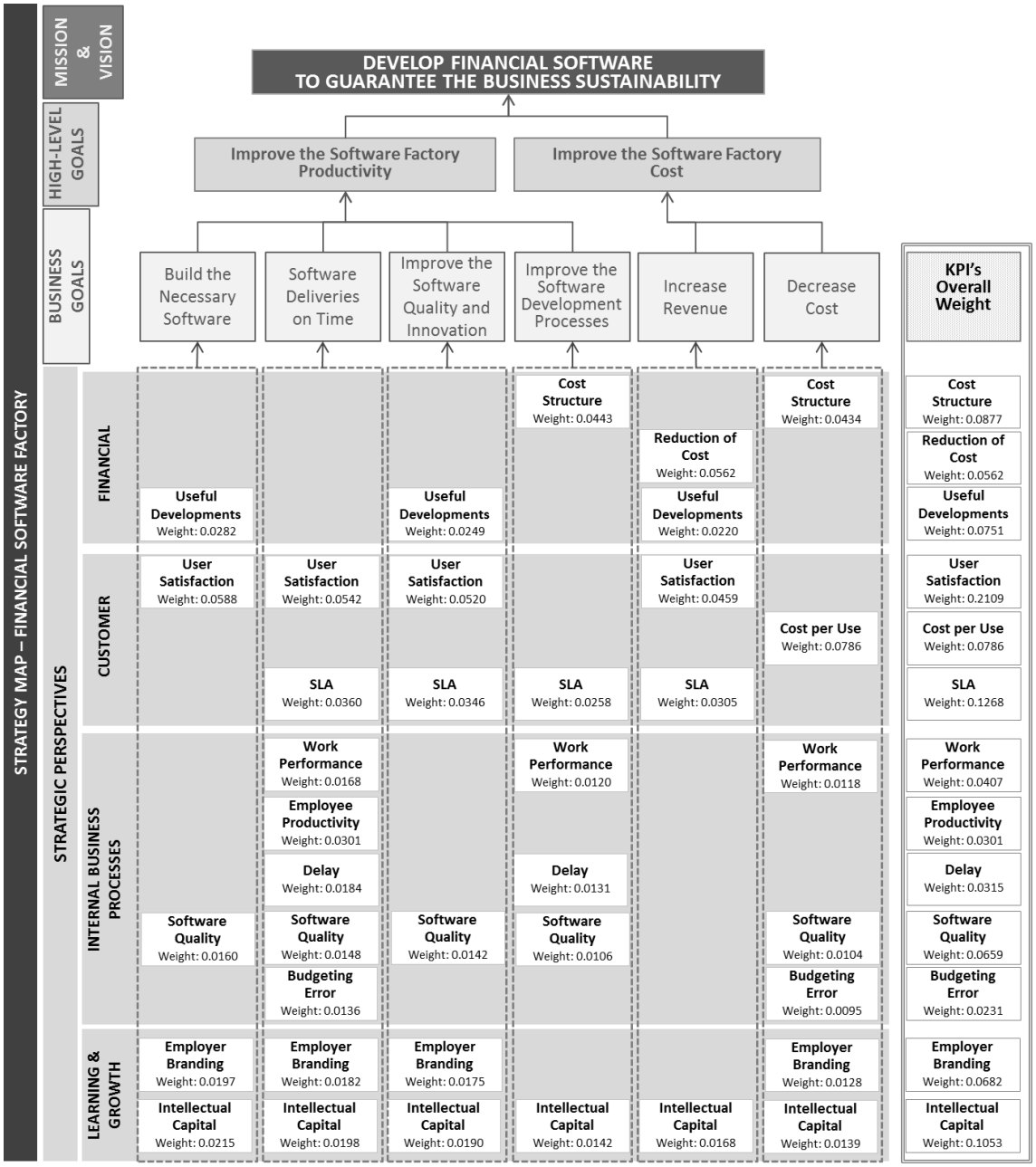

Figura 11. *Strategy map* ponderado para una FSF, con los pesos de las relaciones causa-efecto entre indicadores y *business goals*, y a la derecha, los pesos globales de cada indicador [4].

3.3.7. Resultados por Roles de *Stakeholder*

La Tabla 10 muestra los resultados de los indicadores y las perspectivas del BSC por roles de *stakeholder*. Los resultados por roles en el análisis de FAHP revelan que *Customer Perspective* es el foco principal de atención en el BSC, y *User Satisfaction* es el indicador más importante de entre todos los evaluados. *Customer Perspective* es la perspectiva más importante para todos los roles (salvo el de

Other Employees -Otros Empleados- que es la excepción), pero *User Satisfaction* es el indicador mejor valorado en todos los casos. El indicador SLA es globalmente el segundo más importante, y es siempre uno de los cuatro más importantes para los diferentes roles (*Other Employees* vuelve a ser de nuevo la excepción). El tercer indicador más importante es *Intellectual Capital*, que es siempre uno de los cinco más importantes en las valoraciones obtenidas.

La Tabla 11 muestra los resultados referentes a los *strategic goals* del *strategy map*. Estos resultados por rol muestran que *Improve Productivity* es el principal *high-level goal* para todos los roles, con un peso siempre superior al 0.6384. Los resultados por rol para los *business goals* muestran que ninguno de ellos es determinante para ningún rol.

Tabla 10. Pesos de los indicadores y perspectivas del BSC para una FSF del análisis de FAHP para la sostenibilidad del negocio, según los distintos roles de stakeholder [4].

Criteria and Sub-Criteria/ Stakeholder Roles	Global	Share-Holders	Top Management	Middle Managers	Other Employees	Customers	Experts
(F) Financial	**0.2134**	**0.2315**	**0.1733**	**0.2210**	**0.2809**	**0.1597**	**0.2471**
(F1) Cost Structure	0.0877	0.1386	0.0538	0.0916	0.1029	0.0686	0.0858
(F2) Reduction of Cost	0.0562	0.0487	0.0559	0.0655	0.0567	0.0363	0.0759
(F3) Useful Developments	0.0751	0.0414	0.0700	0.0725	0.1202	0.0615	0.0936
(C) Customer	**0.4254**	**0.4810**	**0.4415**	**0.4144**	**0.2780**	**0.4391**	**0.4254**
(C1) User Satisfaction	0.2109	0.1947	0.2009	0.2004	0.1437	0.2155	0.2223
(C2) Cost per Use	0.0786	0.1762	0.0914	0.0455	0.0570	0.0676	0.0801
(C3) SLA	0.1268	0.1037	0.1357	0.1552	0.0726	0.1494	0.1095
(I) Internal Business Processes	**0.1804**	**0.1620**	**0.2398**	**0.2000**	**0.2296**	**0.1635**	**0.1379**
(I1) Work Performance	0.0407	0.0333	0.0447	0.0388	0.0587	0.0392	0.0379
(I2) Employee Productivity	0.0301	0.0252	0.0214	0.0251	0.0416	0.0423	0.0278
(I3) Delay	0.0315	0.0276	0.0541	0.0376	0.0427	0.0230	0.0242
(I4) Software Quality	0.0659	0.0658	0.0977	0.0869	0.0883	0.0580	0.0346
(I5) Budgeting Error	0.0231	0.0273	0.0373	0.0241	0.0210	0.0134	0.0287
(L) Learning and Growth	**0.1808**	**0.1255**	**0.1455**	**0.1647**	**0.2115**	**0.2377**	**0.1896**
(L1) Employer Branding	0.0682	0.0304	0.0543	0.0697	0.0604	0.1200	0.0665
(L2) Intellectual Capital	0.1053	0.0872	0.0829	0.0872	0.1345	0.1053	0.1132

Tabla 11. Pesos de los *business goals* y de los *high-level goals* del *strategy map* para una FSF del análisis de FAHP para la sostenibilidad del negocio, según los distintos roles de *stakeholder* [4] .

Criteria and Sub-Criteria/ Stakeholder roles	Total/ Global	Share-Holders	Top Management	Middle Managers	Other Employees	Customers	Experts
(HLG1) Improve Productivity	**0.7083**	**0.6384**	**0.7209**	**0.6933**	**0.7906**	**0.7584**	**0.6590**
(BG1) Build the Necessary SW.	0.2043	0.1714	0.1722	0.1494	0.2732	0.2641	0.1886
(BG2) SW Deliveries on Time	0.1883	0.1670	0.2760	0.2295	0.1004	0.1515	0.2079
(BG3) Improve the SW. Q.&I.	0.1808	0.1973	0.1498	0.1706	0.1929	0.2244	0.1355
(BG4) Improve SW. Dev. Proc.	**0.1348**	**0.1027**	**0.1229**	**0.1438**	**0.2241**	**0.1185**	**0.1270**
(HLG2) Improve Cost	0.2917	0.3616	0.2791	0.3067	0.2094	0.2416	0.3410
(BG5) Increase Revenue	0.1594	0.1753	0.1473	0.1872	0.1266	0.1107	0.2052
(BG6) Decrease Cost	0.1323	0.1862	0.1318	0.1194	0.0828	0.1309	0.1358

4

TRABAJO DE INVESTIGACIÓN

4. Trabajos de Investigación

A continuación se detalla el factor de impacto (JCR) de los tres trabajos científicos que forman parte de esta tesis doctoral titulada *Mejora de la eficiencia en la gestión de carteras de proyectos en factorías software orientadas al sector financiero* y que lo hacen apto para la presentación de esta tesis doctoral como un compendio de publicaciones sobre una misma línea de investigación. Las tres publicaciones han sido publicadas con posterioridad al inicio de los estudios de doctorado en un medio incluido en el *Science Citation Index*.

El primero de los artículos [2], publicado a finales de 2015, presenta el modelo de gestión propuesto para las factorías software del sector financiero. Los otros dos artículos [3,4], publicados en marzo de 2017, amplían y mejoran la propuesta inicial hasta alcanzar una propuesta definitiva de modelo de gestión, que representa la aportación final de esta tesis.

4.1. Informe de Factor de Impacto de las Publicaciones

Las tres publicaciones que forman parte del compendio de la tesis han sido publicadas en la revista *Sustainability* (www.mdpi.com/journal/sustainability), de la editorial MDPI – Multidisciplinary Digital Publishing Institute (www.mdpi.com). En el portal web de la editorial encontramos la siguiente información en referencia al factor de impacto de la revista ***Sustainability***: "*Sustainability (ISSN 2071-1050) is an international and cross-disciplinary scholarly, open access journal of environmental, cultural, economic and social sustainability of human beings, which provides an advanced forum for studies related to sustainability and sustainable development. It publishes reviews, regular research papers, communications and short notes, and there is no restriction on the length of the papers.* ***Current Impact Factor (2015): 1.343****; WoS category rank: 146/225 (Q3) in 'Environmental Sciences'; 22/29 (Q4) in 'Green & Sustainable Science & Technology"*.

Con la finalidad de mejorar la difusión de los resultados de esta investigación, se ha seleccionado una revista bajo la modalidad *open access*. La publicación de los artículos ha sido financiada por el *Plan de Ciencia, Tecnología e Innovación del Principado de Asturias (Ref: FC-15-GRUPIN14-132)*, cuyo investigador principal del proyecto referenciado es el profesor Francisco Ortega Fernández.

4.2. Publicaciones que Forman parte del Compendio de la Tesis

Se incluyen a continuación íntegras las tres publicaciones que forman parte de esta tesis.

Publicación – Artículo 1
Álvarez, C.; Rodríguez, V.; Ortega, F.; Villanueva, J. A Scorecard Framework Proposal for Improving Software Factories' Sustainability: A Case Study of a Spanish Firm in the Financial Sector. Sustainability 2015, 7, 15999-16021. doi:10.3390/su71215800

Publicación – Artículo 2
Álvarez Pérez, C.; Rodríguez Montequín, V.; Ortega Fernández, F.; Villanueva Balsera, J. Integrating Analytic Hierarchy Process (AHP) and Balanced Scorecard (BSC) Framework for Sustainable Business in a Software Factory in the Financial Sector. Sustainability 2017, 9, 486. doi:10.3390/su9040486

Publicación – Artículo 3
Pérez, C.Á.; Montequín, V.R.; Fernández, F.O.; Balsera, J.V. Integration of Balanced Scorecard (BSC), Strategy Map, and Fuzzy Analytic Hierarchy Process (FAHP) for a Sustainability Business Framework: A Case Study of a Spanish Software Factory in the Financial Sector. Sustainability 2017, 9, 527. doi:10.3390/su9040527

4.2.1. PUBLICACIÓN – ARTÍCULO 1

Álvarez, C.; Rodríguez, V.; Ortega, F.; Villanueva, J. A Scorecard Framework Proposal for Improving Software Factories' Sustainability: A Case Study of a Spanish Firm in the Financial Sector. Sustainability 2015, 7, 15999-16021. doi:10.3390/su71215800

sustainability

MDPI

Article

A Scorecard Framework Proposal for Improving Software Factories' Sustainability: A Case Study of a Spanish Firm in the Financial Sector

César Álvarez †, Vicente Rodríguez †,*, Francisco Ortega † and Joaquín Villanueva †

Received: 15 September 2015; Accepted: 23 November 2015; Published: 2 December 2015
Academic Editor: Marc A. Rosen

Department of Project Engineering, University of Oviedo, C/Independencia 3, 33004 Oviedo, Spain; cesaralvarezcom@gmail.com (C.Á.); fran@api.uniovi.es (F.O.); balsera@api.uniovi.es (J.V.)
* Correspondence: montequi@api.uniovi.es; Tel.: +34-985-104-272
† These authors contributed equally to this work.

Abstract: Financial institutions and especially banks have always been at the forefront of innovation in management policies in order to improve their performance, and banking is probably one of the sectors that more effectively measures productivity and efficiency in virtually all aspects of its business. However, there is one area that still fails: the productivity of its software development projects. For years banking institutions have chosen to outsource their software projects using software firms created by them for this purpose, but up until a few years ago, the deadline for the delivery of the projects was more important than the efficiency with which they were developed. The last economic crisis has forced financial institutions to review and improve the software development efficiency related to their software factories to achieve a sustainable and feasible model. The sustainability of these software factories can be achieved by improving their strategic management, and the Balanced Scorecard (BSC) framework can be very useful in order to obtain this. Based on the concepts and practices of the BSC, this paper proposes a specific model to establish this kind of software factory as a way of improving their sustainability and applies it to a large Spanish firm specializing in financial sector software. We have included a preliminary validation plan as well as the first monitoring results. The adoption is still very recent and more data are needed to measure all the perspectives so no definitive conclusions can be drawn.

Keywords: software factory; balanced scorecard; financial software development; management; sustainability; productivity

1. Introduction

The software industry is a very demanding and challenging sector, characterized by vigorous competition, extensive dependence on intellectual capital and the need for continuous training in new technologies. Furthermore, many software companies are dealing with significant drops in revenue, and have been forced to reduce labor and cut research and development investments [1].

The banking sector traditionally requires the most software development and the most likely to opt for outsourcing when faced with these kind of situations. The development of business applications represents over 50% of the managed IT budget and in most cases it is outsourced [2]. However, despite being one of the largest IT budget items, some banks still do not measure the productivity of software and maintenance development. The reasons for not analyzing productivity are that the production software model is absolutely customized, and it is very difficult to measure what is produced, and furthermore it is due to the intangible nature of software. Banks pay for the time it takes to produce the software and not the amount produced, a model that in most

Sustainability **2015**, *7*, 15999–16021

cases includes the increase of the cost of the projects [2]. With the recent economic crisis, most of the financial institutions have chosen to reduce the number of projects or are pressing software developers to lower their rates. Their response to this situation has been to create offshore software factories with the aim of reducing costs. The creation of software factories is justified by the idea of industrializing the production of software, but this is not always the case. What they are really doing is hiring labor with a high level of training, but with lower rates, which causes costs to be reduced, but with no necessary improvement in development processes. The first thing that financial institutions must apply to software development firms, and especially to their software factories, is to measure the software they are delivering to them. Although it seems strange, the majority of software that is delivered is not measured [2]. There are several ways to measure the amount of software produced, as was explained by Fenton *et al.* [3], that allow companies to know what is being delivered and the real productivity. With this information they can create strategies for building improvements and payments can be linked to what is actually produced, and not the time taken to produce them. The financial software industry needs to transform itself into an industrialized software manufacturer, able to provide software projects that the financial markets expect today related to efficiency, fast delivery and quality [4].

One of the characteristics of these software factories, which occurs in most cases, at least in Spain and other European countries, is that they have been created by the financial institutions in order to outsource software development needed for their maintenance business. This is a difficult situation to manage because it is necessary to satisfy the interests of a business group, which in this case is both the owner and the main client. We refer in this study to this kind of software factories as *Financial Software Factories* (FSF).

Until approximately 2008, at the beginning of the last economic crisis that affected the whole of the financial sector, for such business groups of these software factories, the deadline for the delivery of projects was more important than the efficiency with which they were developed. There were times when the cost of development was not as important as ever before. In addition to its own business reforms, financial entities demanded internal changes in their FSF in order to make them more productive and able to manage the huge number of new software developments needed to comply with the regulatory changes and the always necessary core and commercial software. The ever-increasing demand for more software suggests the need not only to increase production capabilities but also to produce more with the resources available for production. In other words, software development productivity needs to increase, and needs to be sustainable [5].

This paper describes the case in which a FSF in Spain decided to review the concept of industrialization of the software to implement the principles and elements of the software factory approach [6] and searched for a scheme of work and organization that would increase the productivity of the different teams. In order to increase and quantify this productivity, it had established a metric that could be used to express productivity in terms of software product volume built in a span of time, similar to that described by de Vries and Microsoft a few years before [7]. The management team of this software factory took high-level decisions that affected all areas of the company to adopt the guidelines imposed by the financial group, who as owners wanted to produce more and reduce costs, and as customers wanted more useful, faster and cheaper software.

Based on the concepts and practices of BSC [8,9], this paper proposes a specific model for FSF as a way to improve their sustainability and validate it into a Spanish firm specialized in the financial sector software. This BSC is the tool adopted by the management of the software factory to assess its evolution, and it is used as a support for the identification of future problems and decision-making in order to form a sustainability business group. The BSC has been widely used in several sectors, although it has not been much used across the software development industry. Even though there are some variations of BSC for the software sector, with the IT BSC [10] probably the best known among them, most of them are more focused on treating it like an "IT department" instead of a company. As an example of this, Martinsons *et al.* [11] suggested that the IT department is typically an internal

Sustainability **2015**, *7*, 15999–16021

rather than external service supplier, and projects are commonly carried out for the benefit of both the end users and the organization as a whole, rather than individual customers within a large market. Although we can find some examples of BSC considering the software development company as a strategic business unit, this vision is the prevalent one. BSC is a "necessary good" for companies [12] when used as a framework and guideline for successful strategy communication and implementation, and a system for understanding what really creates value in the company, rather than when it is used as a pure performance measurement system [1]. BSC is a good strategy to support the sustainability of companies and it can be very useful to achieve the improvement of strategic management in order to achieve this sustainability.

This work aims to identify and define a collection of Key Performance Indicators (KPIs) that permit effectiveness to be improved in this context. The paper presents the developed framework, the strategy maps, the BSC and the KPIs, which are properly established and thoroughly evaluated taking a large Spanish software factory as a reference. The framework is especially tailored considering some particularities of this kind of company working for the financial sector. In the presented scenario, the challenge is to manage effectively and intelligently invested resources for the best results in an environment where competition is more complex and tougher.

2. Background and Literature Review

2.1. The Financial Software Factory Scheme

The characteristics and environment of working at the FSF studied in this work do not differ substantially from other software factories in the financial software sector. The software that supports the banking business had been traditionally developed in-house by the IT departments, but is now usually outsourced to IT firms, most of them created by the financial institutions at the beginning of the 1990s following the trend of externalization of services. Outsourcing and externalization of maintenance services has become a common practice in financial companies for years. One of the characteristics of this sector is that they have externalized the development processes, but they keep the top-level processes in place for strategic reasons [13], because of the extreme importance of the software for the core of the business. Despite this, these firms do not work exclusively for the matrix financial group, because they also offer their services to other financial institutions.

At the same time that all IT groups have been forced to lower operating costs and minimize waste and inefficiency, they must also improve quality, reduce time to market, and increase productivity and relevance to the business they serve [6,14]. This combination of business process restructuring and close focus on delivery efficiency has been seen in many business domains, and has resulted in techniques such as "lean manufacturing", "supply-chain management" and "product line engineering" [6]. The application of these ideas in the software development industry is known as the "software factory approach" [15,16]. The major concern for a software factory is the industrialization of software development [14]. A software factory applies, in the software development context, the same manufacturing techniques and principles as traditional manufacturing [17]: systematic reuse, development assembly, model-driven development and process frameworks.

The FSF that work under the software factories approach have to demonstrate they are more competitive than other firms [18]. To achieve this and also to adopt industrialization techniques in software development processes, this kind of software factories have some of their own features that influence their development habits in some way. Among other features, the main ones, in this study case, are [18]:

- They work almost exclusively for the financial group, which is both the owner and the principal customer.
- They usually have a greater demand for requests, more than is possible to complete. There is always a queue of software developments pending.

Sustainability **2015**, *7*, 15999–16021

- They have secured the payment of deliveries, which means that the more software developments that are built, the greater their income.
- Revenues are billed in relation to the use of developments.
- The software development process is usually outsourced to several software companies, but this does not apply to top-level processes such as functional specifications and project management. The payment to outsourced firms is made according to the number of hours budgeted and not by the number of hours it takes to achieve it.

All of these features mean that there is always a demand to produce as much as possible and in the shortest time. On the other hand, the usual organizational structure for a FSF should not differ substantially from what is presented below, which includes the following processes [13,18]:

- Demand Management, which aims to collect the top-level user requirements and establish methods for prioritizing demands.
- Functional Analysis, which transforms the identified top-level user requirements into functional requirements.
- Technical Analysis, which is responsible for the technical details of the functional specifications that must be implemented.
- Development, which performs the development, construction and assembling of the requested requirements.
- Testing, which has to validate everything that has been implemented.
- Production, which performs the customer deployment.
- Quality, which assesses the software development processes quality.

In the presented schema, the development process is outsourced to several software development firms, but the rest of the processes are under the software factory's control. Figure 1 illustrates the usual processes followed in this scheme of operation, which are similar to those explained by Valderrama *et al.* [17] for a software factory.

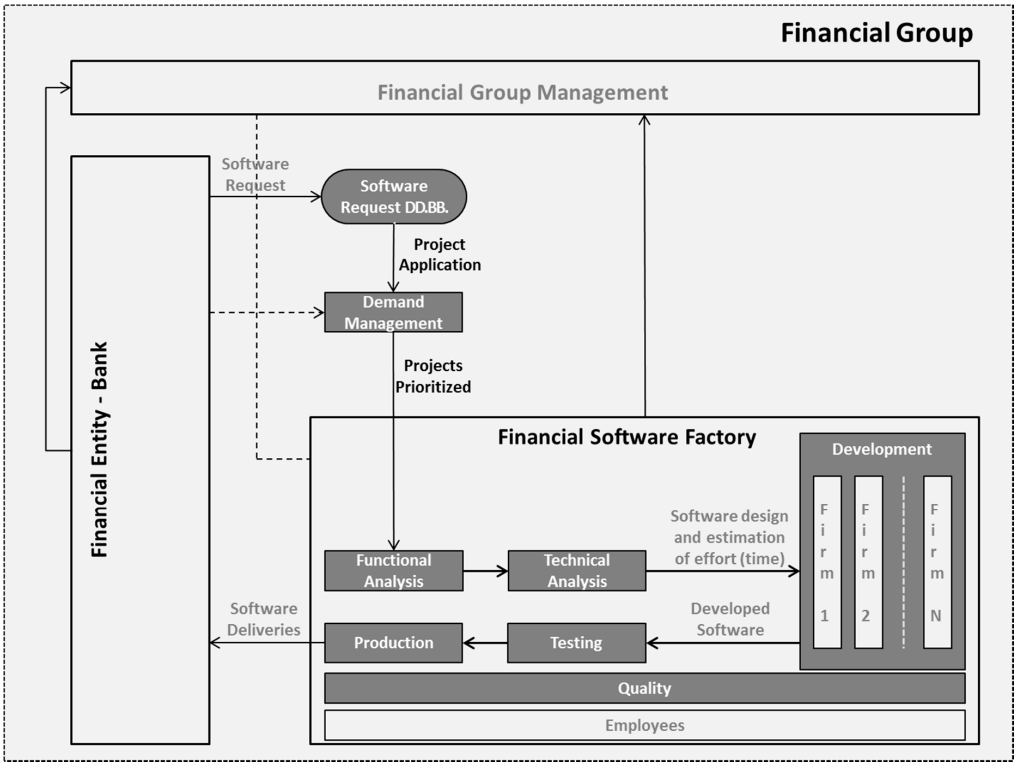

Figure 1. Map of processes of model for a software factory oriented financial sector.

Sustainability **2015**, *7*, 15999–16021

2.2. The BSC Framework as a Management System

The working scheme studied needs a complete management system that permits an awareness of the productivity with which it is working. Unfortunately, the performance measure in the production of software is not as simple as it is in other industries; but nevertheless, it is necessary that the management system can answer a series of questions:

- What is the productivity of the software factory?
- How does productivity evolve?
- How do the planning and cost of the projects evolve?
- What are the quality developments?
- What is the software factory's position in the market?
- How is the relationship between the shareholders, customers and employees with the software factory?
- Is the software factory a sustainable business in the medium to long term?

To answer these questions, the management system needs to control the production and the development processes. In addition, the management system should assist in making decisions to improve efficiency, reduce costs, control the amount of software developed and ensure the sustainability of the business. It is necessary to integrate the IT strategy to the business strategy, and placing it in the BSC framework can be very useful. The BSC approach is probably the best-known management tool for a company. In 1992 and the years that followed, Kaplan and Norton, of Harvard University, presented the Balanced Scorecard [8,19] as a corporate performance tool that allows managers to look at the business from four important perspectives: financial, customer, internal business and innovation and learning; and that provides answers to four basic questions referred to each perspective:

- How do we look to shareholders?
- How do customers see us?
- What must we excel at?
- Can we continue to improve and create value?

Kaplan and Norton argued that traditional financial measures offer a narrow and incomplete picture of the business, and they suggest that financial measures must be supplemented with other non-financial measures that reflect customer satisfaction, internal business processes and the ability to learn and grow [11]. In the following years, Kaplan and Norton presented new views and ways to improve the initial BSC approach, and linked it with measures and the business strategy [9,20]. The idea of linkages among objectives and measurements led to the creation of the strategy map [21]. This provides a robust structure to companies to express their strategic objectives and offers managers the framework for a generic interactive system. Managers can design a customized interactive system based on their strategy and use the strategy map and the scorecard as the cornerstone of their management system for executing the strategy [22]. Furthermore, the results adopting the BCS framework to link the software development with the business strategy should confirm the effective enhancement of productivity to reach the established high-level goals.

Since the BSC was introduced, many authors proposed some modifications to adapt the initial BSC to other scorecards that were specific for different areas or industrial environments. The IT BSC [10,11] in the information technologies sector and the SBSC [23] related to sustainable management are two of the best-known examples. The BSC framework is a performance management system that should allow enterprises to drive their strategies in measurement and follow-up to improve efficiency, reach their objectives and build a sustainable business model. To achieve this, companies need to "draw" the strategy map: the high level goal, the business objectives, the measurement goals and, finally, the strategic linking them all. When the complete goal hierarchy

Sustainability **2015**, *7*, 15999–16021

is defined, measurements can be taken and interpretations made to see if the goals at all levels have been achieved [24].

2.3. The Financial Software Factory, a Case Study

The FSF studied in this work is a software factory associated with an important financial group in Spain. The financial group has more than 2500 offices and 10,000 employees and total assets of more than 55,000 million euros. The FSF, founded in the 1980s, is responsible for the definition and implementation of the common strategy in all matters related to automatic processing of the financial information group. The purpose of the FSF is to operate a common center of computer services for the financial institution of the group and has carried out the first implementation of "total outsourcing of banking applications" held in Spain, and it provides services to financial institutions comprising software development and platforms for their implementation and use. Currently, besides the financial group, it also serves other smaller financial institutions, both public and private. During 2014, the FSF employed about 700 people, including their own and outsourced employees, with a sales revenue of over 65 million euros, and it has made more than 5000 million economic transactions.

In a very restrictive economic environment and low growth rates, the FSF works to reduce costs, increase revenue and improve software developments and services. They are aware that they need to provide a mature and stable technological service, with quality and an appropriate price to satisfy their customers. They must develop and improve their services to remain the technological support of the financial group and collaborate with its sustainability and expansion. Given these circumstances, the top management of the FSF opted to establish an efficient management business system that offers BSC framework.

3. Results and Discussion

3.1. The Proposed BCS Management Framework

In this case study, the BSC framework was established for the higher management of the software factory as the preferred management system to guarantee organization sustainability. Studies show that companies that implement BSC tend to accomplish their goals or even outperform them [25]. Based on these ideas and principles, the software factory management gave its approval to this approach and explained to the whole organization their needs and their proposed ideas for transferring them into strategies. A set of fifteen KPIs was selected and a system of measurement for each KPI was adopted. Every KPI covers an area or department, and some KPIs are a compendium of other different indicators and measures. The KPIs were established with the best strategic perspective and thoroughly evaluated according to a planning timetable. The four perspectives of the BSC provide a robust structure to express the organization needs and their strategic objectives [22]. The adopted management system includes the *Strategic Map* and the KPI measures. Each KPI and its value measurement may influence one or more of the six *Strategic Business Goals*, which support the two *Strategic High-Level Goals*. The Strategic High-Level Goals are "pillars" of the strategy that directly supports achievement of the mission and vision of the organization. A good Strategic High-Level Goal is not just a particular objective, but a linked set of objectives that can impact on all of the four BSC perspectives. These linked objectives tell the story of the strategy, and form the basis for communicating the business strategy to everyone in a consistent manner [23]. This management system provides the necessary environment for making decisions in order to achieve the strategy of the company. Figure 2 shows the different layers of how a strategy using the BSC is developed, starting at the top with the company high-level strategy (Mission and Vision) and linking it, layer to layer, to KPI measures and the control of the objectives using the BSC.

Sustainability **2015**, *7*, 15999–16021

Figure 2. Strategic thinking and planning using the BSC framework, adapted from *The Balanced Scorecard Institute* [23].

The proposed BSC framework, including the KPI description, the adopted BSC and the established strategic map, are described and explained below.

3.2. The Proposed KPIs for the BSC

The higher management of the software factory addressed the creation and selection of a set of KPIs according to the new needs transmitted by the financial group. KPIs are directly linked to business success, but defining an effective KPI is not always easy to do [26]. The KPIs defined were made in several work sessions with the participation of high and intermediate management staff, and they worked to choose a set of KPIs to ensure the business sustainability in the medium and long term. Some of the KPIs were simple to create and easy to obtain, since previous data and measurements existed that facilitated their preparation. On the other hand, there are other indicators that did not previously have measurements related to them, and these are being developed presently.

A set of fifteen KPIs are presented below, and for each of them, the following fields are described, according to the specifications published by the *Advanced Performance Institute* [27]:

- *KPI Name*: All KPIs need a name which should clearly explain what the indicator is about.
- *Strategic BSC Perspective*: Each KPI is aligned to one of the four BSC strategic perspectives.
- *KPI Owner*: Identifies the areas or departments that are responsible for controlling each indicator and establishes the system to capture, store and retrieve the data related to this indicator.
- *KPQ*: Identifies the key performance question (KPQ) that the indicator is helping to answer, and provides the context of why this indicator is being introduced.
- *Formula*: Identifies how the data will be captured, if it is possible to create a formula, and if the KPI is a simple indicator or if it is composed of other indicators.
- *KPI justification and description*: In this field the importance of KPI for the organization is justified, how the data needed to measure the indicator are obtained is described and all those relevant facts that should be known about the KPI are explained.

Furthermore, during the explanation of KPIs, there are usually several words or expressions used that need to be clarified for understanding:

Sustainability **2015**, *7*, 15999–16021

- *Transactions*: "Transactions" are those events that trigger the execution of a program, object, feature or section of code. Transactions can be triggered by a user request or by calling another transaction previously executed.
- *Total Software Factory Cost*: We refer to "Total Software Factory Cost" as all costs incurred to make a business model work, including staff cost.
- *Total Financial Group Assets*: In the banking sector, "Total Assets" are all that a bank owns, including loans, reserves, investment securities and physical assets. "Average of Total Assets" is a usual measurement to identify the size of a bank.
- *Total Executed Transactions*: "Total Executed Transactions" is the number of times that a transaction is triggered during a predetermined fixed span of time.
- *Cost Charged to the Client*: "Cost Charged to the Client" is the cost that the customer pays to use the software developments and services offered by the software factory. In this case, the customer is the bank's business group, and the amount of this cost is related to the number of total transactions executed.
- *Budgeted Hours*: In the proposed model, a "Budgeted Hour" is the amount of software that the software factory should build in an hour of real time. During the estimating process, the estimates of the size are transformed into hours. We use these hours to monitor the projects.
- *Performed Hours*: In the proposed model, "Performed Hours" is the amount of software that the software factory had built in an hour of real time.

3.2.1. KPIs for the Financial Perspective

In general, the aim of the financial perspective is to provide a vision of the business to the shareholders, and usually answer the question: "to succeed financially, how should we appear to our shareholders?" [22], and shows plans for growth, handling risk and making a profit. It evaluates how well a strategy is being developed and executed in order to improve profits. KPIs in this perspective indicate whether the company's strategy, implementation, and execution are contributing to bottom-line improvements [8]. Typical financial goals have to do with profitability, growth, and shareholder value. However, in this case and as it was explained before, one of the features of these software factories in the financial sector is the fact that the owner and the client are in both cases the same financial group. This means that typical KPIs from a financial perspective of BSC such as *ROI* (Return On Investment, measures the benefit to the investor resulting from an investment of some resource), *ROA* (Return On Assets, measures how profitable a company's assets are in generating revenue) or *ROE* (Return On Equity, measures the relation by dividing the profit before tax, or net profit, compared to equity (capital and reserves)) are not appropriate for this particular case study, as the improved profits of the software factory are not important for the group, and also the fact that the improved result could be caused by the increase in customer invoicing, an undesirable situation of its own accord. Furthermore, KPIs related to sales revenue of software can be easily modified for the purpose of altering their values. In addition these changes do not provide improvements in the software factory's productivity or efficiency. Other typical indicators of the financial perspective such as the growth of the company do not seem appropriate, since in this case the size of this FSF should vary in proportion to the financial institution of the group.

The needs and interests of the financial group that must be evaluated for improvement and optimization into the financial perspective of the software factory BSC are:

- Reduction and optimization of the expenses of the software factory.
- Sell the developments and services to other companies different from the owning financial group, to recover the development costs with external revenues.
- Delivery of software development must be good quality and useful for the customer. The use of software increases customer loyalty and promotes business sustainability.

Sustainability **2015**, *7*, 15999–16021

According to these premises, the following three KPIs were proposed for assessing the financial perspective of the software factory BSC, under the interests of the financial group as owner.

KPI Name: Cost Structure

- Strategic BSC Perspective: Financial
- KPI Owner: Management Control
- KPQ: How to evolve the costs of the software factory?
- Formula:

$$Cost\ Structure = \frac{Total\ Software\ Factory\ Cost}{Total\ Financial\ Group\ Assets} \quad (1)$$

KPI justification and description: This indicator allows us to assess the evolution of the costs of the software factory. To do this, compare the costs of the software factory with the size of the financial entity, expressed as its total average assets over the last year. The financial group wants to have a contained cost structure, so the costs should vary according to the size of the financial institution. It is desirable that when the size of the bank decreases, the cost of software factory should decrease, at least as much as the bank does. On the other hand, when the size of the bank increases, the cost of the software factory could also increase, but without reaching the growth rates of the bank. Furthermore, this KPI should be aligned with the sector.

KPI Name: Reduction of Cost

- Strategic BSC Perspective: Financial
- KPI Owner: Management Control
- KPQ: What is the ratio of costs that are covered by sales to companies outside the group?
- Formula:

$$Reduction\ of\ Cost = \frac{External\ Sales\ Revenue}{Total\ Software\ Factory\ Cost} \times 100 \quad (2)$$

KPI justification and description: The purpose of this indicator is to assess the percentage of the structural cost of the software factory that is covered by income over the last year, whose source is the sale of software developments and services to companies outside the corporate group. Because of the huge cost of software development, sales revenue outside the financial group is generally seen as a reduction of costs associated with development, making it a sustainable factor linked to the software factory. Revenues from sales to companies outside the financial group are gaining increasing importance because other small financial groups choose to hire or rent the use of software development, as they find it impossible to deal, either temporally or economically, with needs originated by new software developments.

KPI Name: Useful Developments

- Strategic BSC Perspective: Financial
- KPI Owner: Production and Management Control
- KPQ: How useful are the developments for the financial group?
- Formula:

$$Useful\ Development = \frac{Total\ Executed\ Transactions}{Total\ Financial\ Group\ Assets} \quad (3)$$

KPI justification and description: The purpose of this indicator is to assess the use of the delivered software developments. To compensate for the lack of traditional financial indicators linked to sales revenue in the BSC, this indicator can assess the extent of use by the group companies of (both older and more recent) software developments. It is understood that the greater use of the developments, the higher income should be achieved. The use of the developments is measured by

Sustainability **2015**, *7*, 15999–16021

the number of transactions executed in relation to the size of the financial institution over the last year. The increased ratio gives assurance to the financial group that developments are useful and, therefore, do their job well. Otherwise, a decrease in the use of development and services would generate uncertainty, casting doubt on their usefulness and the need to find alternatives for software developments outside the financial group. Business sustainability will be increased then, the higher the development and use of services offered and the greater the availability of the financial group to invest more resources in the software factory.

3.2.2. KPIs for the Customer Perspective

In general, the aim of the financial perspective is to assess customer satisfaction, in terms of satisfying and resolving customer needs. This perspective usually answers the question: "to achieve our vision, how should we appear to our customer?" [8,22]. Measures in this perspective are necessary because sustainability and financial success is achieved by solving the needs (products and services) demanded by customers. The BSC, as a description of a company's strategy, should identify the customer objectives in each targeted segment [9].

The needs and interests of the financial group that must be evaluated for improvement and optimization into the customer perspective of the software factory BSC are:

- To have covered the needs of software.
- Software development must be delivered on time.
- Services prices must be assumed by the client to be equal to the rest of the companies in the sector.

According to these premises, the following three KPIs were proposed for assessing the customer perspective of the software factory BSC, under the interests of the financial group as customer.

KPI Name: User Satisfaction

- Strategic BSC Perspective: Customer
- KPI Owner: Marketing and Customers
- KPQ: What is the level of customer satisfaction?
- Formula:

$$User\ Satisfaction = \Sigma \left(\frac{Satisfaction\ Aspects\ Value}{Maximun\ Satisfaction\ Aspects\ Value}\ x\ Satisfaction\ Aspects\ Weight \right) \quad (4)$$

KPI justification and description: Most companies are becoming more aware of the importance of user satisfaction with the service provided. Universal end user computing in banking needs a reliable and valid instrument that measures satisfaction in this environment and evaluates its success when used in improving user performance [28]. User satisfaction KPI is defined as "the overall level of compliance with the user expectations, measured as a percentage of really met expectations" [29]. The level of satisfaction is, therefore, an aggregate measure of user satisfaction with various aspects of the service [30]. In this study, User Satisfaction KPI tries to measure the satisfaction of the financial entity concerning software developments and services given by the software factory. In order to measure financial institutions' user satisfaction it can be used on an online survey in order to determine the strong and weak points of the services offered. According to the survey results, and the criteria for its evaluation, actions must be taken in order to improve user satisfaction and the quality of the services provided.

KPI Name: Cost per Use

- Strategic BSC Perspective: Customer
- KPI Owner: Management Control
- KPQ: What is the relative cost of software development?

Sustainability **2015**, 7, 15999–16021

- Formula:

$$Cost\ per\ Use\ = \frac{Cost\ Charged\ to\ the\ Client}{Total\ Executed\ Transactions} \tag{5}$$

KPI justification and description: The financial entity, as a customer of the software factory developments and services, wants the costs to be as low as possible. This indicator relates the cost paid by the customer for the use, measured by the number of Executed Transactions, of the services contracted over the last year.

KPI Name: Service Level Agreements (SLA)

- Strategic BSC Perspective: Customer
- KPI Owner: Management Control
- KPQ: What is the level of compliance with the SLA?
- Formula:

$$SLA\ = \Sigma \left(\frac{SLA\ Provided\ Value}{Operative\ Level\ Agreed\ for\ SLA}\ x\ Indicator\ Weight \right) \tag{6}$$

KPI justification and description: In the software development sector the business provides critical application services for customers, which need effective mechanisms to manage and control them. SLAs are agreements signed between a service provider and another party such as a service consumer, broker agent, or monitoring agent [31]. Customers and companies need a method to maintain and identify the trust and reliability between each of the parties involved in the negotiation process. A well-structured SLA KPI has significant positive influence on the various aspects of relational governance in information technology outsourcing relationships. Overall, the findings support the proposition that well-developed SLAs not only provide a way to measure the service provider's performance, but also enable effective management of outsourcing engagements through the development of partnership-style relationships with high levels of trust and commitment [32].

The proposed SLA indicator to use in the BSC is a multi-indicator that joins and unifies all the agreements reached with the financial group, and more specifically between the financial institution and the software factory. For each SLA established between the FSF and the financial institution, there are two values related to itself: the value of the agreed service and the provided value for this SLA. The value offered for the SLA KPI is an aggregated value based on the relationship (agreed and provided value) of each SLA and the weight established between the FSF and the financial institution for this relationship.

3.2.3. KPIs for the Internal Business Process Perspective

In general, the aim of the internal business process perspective is to achieve the shareholders' and customers' objectives, and usually to answer the question: "what business processes must we excel at?" [22]. Here, the managers identify the processes that are most critical for achieving the company objectives, and measures provide managers with information focus on internal operations and emphasize how a company delivers software products and services to its customers. Typical financial goals have to do with productivity, efficiency, performance, quality, schedule and planning cost and time, and other different and specific goals related to different companies.

In this case and as it was explained previously, one of the features of the FSF studied in this paper, is the fact that the software size is expressed in terms of the number of hours budgeted or estimated for its development, and also the cost of these software developments is based on these budgeted hours of work. This means the concepts of *Budgeted Hours* and *Performed Hours* to control and monitor the evolution of the developments in terms of size, time and cost can be unified around only one KPI.

The needs and interests of the financial group that must be evaluated for improvement and optimization into the internal business process perspective of the software factory BSC are:

Sustainability **2015**, *7*, 15999–16021

- Improve the efficiency and productivity related to software developments.
- Identify cost and time deviations to avoid future problems.
- Improve the quality of software developments.

According to these premises, the following seven KPIs were proposed for assessing the internal business process perspective of the software factory BSC, under the interests of the financial group.

KPI Name: Work Performance

- Strategic BSC Perspective: Internal Business Process
- KPI Owner: Management Control
- KPQ: What is the Software Factory performance?
- Formula:

$$Work\ Performance\ = \frac{Budgeted\ Hours}{Performed\ Hours} \times 100 \tag{7}$$

KPI justification and description: The production performance and efficiency of firms is a major concern of many individuals, including policymakers, consumers, economists, and managers of the firms themselves. Consumers think firms that produce more efficiently tend to produce at lower prices and higher production levels. Firms desire to provide quality products at the lowest cost in order to maximize revenues for any given cost structure, which is facilitated by efficient production [33]. The most common measure used to determine the status of performance is productivity.

Obviously, one of the aspects of software development that needs to be improved is productivity. However, to quantify productivity a metric is needed that we can use to express productivity in terms of software product volume built in a span of time. When we are able to predict the size of the system and to measure product-size growth during development, the time required to complete the project can be better predicted, and productivity in terms of hours spent per unit of product size can be measured. By measuring the growth and size, we are able to identify differences between the actual and planned values and to start analyzing and managing the differences when they become apparent [7].

In this study, to construct an index of productivity to assets for the software development performance, a KPI structure needs to be implemented to measure the difference between the size of software budgeted (Budgeted Hours) and the size of software performed (Performed Hours) over the last year. The Work Performance KPI represents a comparison of the productivity level in terms of improving rates of software development and is defined as the number of budgeted hours divided by the number of hours performed for software development. This KPI can assess the labor productivity of the software factory. It also shows the degree of actual implementation against the estimated development projects, because of the duality between size and hours spent per unit of product size. Higher values for the indicator up to 100% indicate that performance and development productivity is higher than budgeted, and that the development will be completed with an advance equal to the percentage of improvement noted by the indicator. On the other hand, indicators below 100% indicate that productivity is not at the desired level and that the time schedule is not being met.

The value of the KPI is the development size (and hours) earned by the software factory production model.

KPI Name: Employee Productivity

- Strategic BSC Perspective: Internal Business Process
- KPI Owner: Human Resources and Management Control
- KPQ: What is employee productivity?

Sustainability **2015**, *7*, 15999–16021

- Formula:

$$Employee\ Productivity\ = \frac{Budgeted\ Hours}{Labor\ Work\ Hours}\ \times 100 \tag{8}$$

KPI justification and description: This KPI measures the software product volume built in Budgeted Hours per labor hour of employees. This indicator, following the proposed scheme, shows the amount of software that an employee produces for each hour on the job. This ratio is interpreted as the percentage of employee productivity over the last year.

KPI Name: Delay

- Strategic BSC Perspective: Internal Business Process
- KPI Owner: Management Control
- KPQ: What is the waiting time for software development deliveries?
- Formula:

$$Delay\ = \frac{Time\ to\ Finish\ Hours}{Budgeted\ Hours} \tag{9}$$

KPI justification and description: Furthermore to know if Performed Hours for development is in line with planning, it is necessary to know the average waiting time for deliveries of software developments. This indicator shows the delay in hours when the software factory is delivering software developments, and it relates the amount of software that is developed in a budgeted hour with the number of hours from the financial entity requesting the developments until these developments have been delivered to the customer. The value offered by this indicator shows the average waiting time for delivery of software built in one budgeted hour over the last year.

KPI Name: Request Queue Evolution

- Strategic BSC Perspective: Internal Business Process
- KPI Owner: Management Demand and Management Control
- KPQ: How does the size of pending software deliveries evolve?
- Formula:

$$Requst\ Queue\ Evolution\ = \frac{Finish\ Budgeted\ Hours}{Required\ Budgeted\ Hours}\ \times 100 \tag{10}$$

KPI justification and description: This indicator shows the size of product volume that is being delivered against the software product volume that has been requested over the last year. The scheme proposed by this FSF means that there is always software to develop, so it is necessary to know this ratio for taking decisions if required, because it shows if the request queue of pending developments increases or decreases in time.

KPI Name: Software Reuse

- Strategic BSC Perspective: Internal Business Process
- KPI Owner: Development and Production
- KPQ: What is the level of software reuse?
- Formula:

$$Software\ Reuse\ = \frac{Number\ of\ No\ First\ Time\ Executed\ Transactions}{Number\ of\ First\ Time\ Executed\ Transactions} \tag{11}$$

KPI justification and description: Some of the benefits of an effective reuse of software are: accelerated development, reduced development cost, increased quality, decreased software test time and enhanced customer satisfaction [34,35]. The FSF studied in this work is specialized in developing a specific family of financial products with known characteristics, not just arbitrary software applications, which allows the software factory approach [7,36] and the software reusability

Sustainability 2015, 7, 15999–16021

principles to be applied. The proposed Software Reuse KPI allows assessing the amount of software code that is effectively reused. This amount is determined by the number of transactions that are executed by the call of other transactions previously executed. When a transaction triggers the execution of another transaction, it means that the code executed had previously been developed, and, therefore, is reused code. An important event in the definition of this indicator is that the KPI values are obtained which provide post-processing developments, so that it is a dynamic measurement data obtained during execution of the software. It not only values the amount of reused code during the development process, but also assesses the number of times that reused code is executed by the daily activity of the financial institution. The Software Reuse KPI shows the calculated value of reusability code ratio according to these factors over the last year.

KPI Name: Software Quality

- Strategic BSC Perspective: Internal Business Process
- KPI Owner: Quality
- KPQ: What is the quality of software development?
- Formula:

$$Software\ Quality\ =\ SubSet\ (Quality\ in\ Use;\ Product\ Quality\ Model) \tag{12}$$

KPI justification and description: Software Quality KPI offers to the managers the possibility of controlling the quality of software developments. In this model, we proposed that this KPI will be compounded taking standard metrics like those proposed in ISO 25010:2011 [37], Software Quality in Use (Effectiveness, Efficiency, Satisfaction, Freedom from Risk and Context Coverage) and Product Quality Model (Functional Suitability, Performance Efficiency, Compatibility, Usability, Reliability, Security, Maintainability and Portability).

The proposed Software Quality KPI works under the ISO 25010 standard, although this metric has been chosen in this model because it is one of the best known. To develop this KPI, each organization can choose the standard that seems most appropriate to establish its own metric related to software quality. The Software Quality KPI should offer a quality assessment of the developments according to ISO 25010, and in this study it has been chosen to use a subset of aggregated metrics in the project portfolio such as: efficiency, usefulness, functional correctness, functional appropriateness, time behavior, interoperability, others related to security, modifiability and adaptability.

KPI Name: Budgeting Error

- Strategic BSC Perspective: Internal Business Process
- KPI Owner: Planning and Management Control
- KPQ: What is the budget error in software development deliveries?
- Formula:

$$Budgeting\ Error\ =\ \frac{\Sigma\left[ABS\left(Budgeted\ Hours\ -\ Performed\ Hours\right)\right]}{Performed\ Hours}\ \times 100 \tag{13}$$

KPI justification and description: This indicator measures the accuracy of the estimates linked to software development, and should be analyzed together with other indicators of Internal Business Perspective, especially the Work Performance KPI. The estimating process has different steps: previously an estimation of software size is done using technical sizing figures as Function Points, Lines Of Code and others linked to "Transactions", and then, these estimates of the size are transformed into hours and are used to monitor the projects.

If the differences between Budgeted and Performed Hours are due to estimation errors rather than improvements in production processes, the methodology for budgeting (size, time and cost

Sustainability **2015**, *7*, 15999–16021

developments in hours) should be revised in order to reduce cost. It is necessary to emphasize the importance to have a very good system or tool for budgeting, because the estimation accuracy affects most KPIs into the Internal Business Process Perspective. The Budgeting Error KPI shows how good the estimations are over the last year, and its value is the planning error degree.

3.2.4. KPIs for the Learning and Growth Perspective

In general, the aim of the Learning and Growth perspective is to provide a vision about the continuity of the business. A company needs well-trained, highly skilled employees if it is to excel in the other perspectives in the BSC. This perspective usually answers the question: "can we continue to improve and create value?" [8]. The other three perspectives on the BSC identify the parameters that the company considers most important for competitive success, but investments in intellectual capital and employee capabilities make it possible to achieve them.

The software industry is a very demanding and challenging sector, characterized by vigorous competition, extensive dependence on intellectual capital and the need for continuous training in new technologies for competitive success. Other factors like quality of workforce, management capabilities and environmental conditions of a software organization also affect software development productivity [38]. A company's ability to innovate, improve and learn ties directly in with the company's value and sustainability of the business model. Typical goals in this perspective have to do with innovation, intellectual capital and more recently employer branding, including the most important features in human resources orientation.

The needs and interests of the financial group that must be evaluated for improvement and optimization into the Learning and Growth perspective of the software factory BSC are:

- Ensure the presence of the best personnel for the company.
- Improve the intellectual capital of the company in order to improve its sustainability.

According to these premises, the following two KPIs are proposed for assessing the Learning and Growth perspective of the software factory BSC, under the interests of the software factory.

KPI Name: Employer Branding

- Strategic BSC Perspective: Learning and Growth
- KPI Owner: Human Resources
- KPQ: What is the employer branding of the company?
- Formula:

$$Employer\ Branding\ =\ SubSet\,(Employer\ Branding\ Indicator\ Measures) \tag{14}$$

KPI justification and description: Employer Branding, a relatively new concept, is a new branch of enterprise brands. From conceptual understanding, like a product brand, it is an image given by the company to potential employees in the human resources market. With the growing competition among enterprises, many senior managers recognize talent as the key factor for an enterprise to succeed. The employer brand does not exist in a static market environment and it must be dynamically or organizationally shaped. Thus, enterprises need to build an employer brand with their own characteristics, and establish a series of internal and external evaluation and feedback systems [39].

In order to create a sustainable management of human resources, an attractive employer brand is necessary that can address the different needs and expectations of potential and existing employees, which can result in a sustained competitive advantage. Employees, and especially high-quality employees as a very important part of intellectual capital, must be attracted and retained by firms, and employer branding can help them to address the different needs and expectations of potential and existing employees [40]. Firms can use their brands to promote the value of sustainability to their

Sustainability **2015**, *7*, 15999–16021

industrial customers, consumers, and other stakeholders. This may be achieved through branding activities that emphasize the firm's sustainability practices and their impact on stakeholders [41]. All sectors, but especially the software development sector where human capital is the most important factor in the process, must understand the importance and benefits of developing an employer brand to attract, engage and retain talent. A good employer branding strategy is crucial, and in this case it is necessary to know the software factory business objectives to guide the efforts to the interested audience [42]. There are employer branding measures with a high degree of accuracy and, according to the statistics in a study published in 2014 [43], there are several different possible metrics to use related to employer branding, but the most important are: employee satisfaction, employee engagement and loyalty, quality of hire, time and cost per hire, job acceptance rate of candidates, number of applicants, employee turnover, increased level of employee referrals, decreased absenteeism, promotion readiness rating, external/internal hire ratio, performance ratings of newly promoted managers and manager/executive failure rate. A subset of these employer branding indicators must be measured, established and merged into a specific Employer Branding KPI into the Learning and Growth perspective in the BSC.

KPI Name: Intellectual Capital

- Strategic BSC Perspective: Learning and Growth
- KPI Owner: Organization and Human Resources
- KPQ: What is the intellectual capital level of the company?
- Formula:

$$Intellectual\ Capital\ =\ SubSet\ (Human\ Capital,\ Structural\ Capital;\ Relational\ Capital) \quad (15)$$

KPI justification and description: The concept of intellectual capital was revealed firstly by Kenneth Galbraith in 1969. Intellectual capital is usually defined as the combination of three main factors: *Human Capital*, *Structural Capital* and *Relational Capital*. When these factors are compatible with each other, this increases creativity, stimulates innovation and facilitates feedback [44].

The most important assets in the software industry are their employees, and their knowledge is the pillar of human capital. A business like this, with strong direct intellectual capital with innovative business behavior can survive for longer periods and obtain competitive advantage. A good information system to measure the intellectual capital of this software factory may well be strategic and can be used to leverage structural resource differences among firms, including differences in resource integration, diversification, and quality. Thus, an information system attempts to develop proprietary organizational capabilities for linking to firm performance [45]. An Intellectual Capital KPI that measures a subset of the intangible assets of human capital (knowledge, skills, abilities), structural capital (processes, procedures, organization, information systems, common repository) and relational capital (customers, suppliers, contributors) is included in the proposed BSC to assess this essential part of the assets of the company that develop the business and make it sustainable. A remarkable fact about structural capital and software companies is that they often adapt their processes to improvement frameworks that guide them in high-performance operations, as in CMMI® [46] or PRINCE2® [47].

3.3. The Proposed Financial Software Factory Balanced Scorecard

This study has opted to choose the classic BSC originally proposed and developed by Kaplan and Norton [8], although being a business IT company, it might seem more appropriate to have adopted the IT-BSC introduced by Van Grembergen [10] and widely studied later [48,49]. The second is better for an IT department in a company, but in this study the software factory is treated as a whole company and not as an internal IT department.

Sustainability **2015**, *7*, 15999–16021

Figure 3 shows the *Balanced Scorecard* proposed for this FSF. The BSC includes the proposed KPIs, each of them situated in their corresponding strategic perspective. The BSC is completed with various fields assigned to each KPI: Code (every indicator should have a unique identification number that makes it easier to keep track of indicators [27]; here, "Code" refers to corresponding numbers of the equations in this article), KPI Name, KPI Owner, Frequency Measurement, Value Measurement, Target Tendency and the Upper and Lower Control Limits to manage the processes stability. By linking the financial and non-financial KPIs exposed in this study with the strategy, and using the BSC as a management support, we have the necessary management system in order to ensure medium- and long-term sustainability.

BALANCED SCORECARD – FINANCIAL SOTWARE FACTORY

BALANCED SCORECARD – FINANCIAL SOTWARE FACTORY

STRATEGIC PERSPECTIVES

	CODE	KPI NAME	KPI OWNER	FREQUENCY MEASUREMENT	VALUE MEASUREMENT	CONTROL LIMITS UPPER|LOWER	TARGET TENDENCY
FINANCIAL	(1)	Cost Structure	Management Control	Quarterly	Ratio	Upper|Lower Values	Decrement
	(2)	Reduction of Cost	Management Control	Monthly	Percentage	Upper|Lower Values	Increase
	(3)	Useful Developments	Production & Man. Control	Quarterly	Ratio	Upper|Lower Values	Increase
CUSTOMER	(4)	User Satisfation	Marketing & Customers	Annual	Aggregate	Upper|Lower Values	Increase
	(5)	Cost per Use	Management Control	Quarterly	Numeric Value	Upper|Lower Values	Decrement
	(6)	SLA	Production & Man. Control	Monthly	Aggregate	Upper|Lower Values	Increase
INTERNAL BUSINESS PROCESSES	(7)	Work Performance	Management Control	Monthly	Percetage	Upper|Lower Values	Increase
	(8)	Employee Productivity	Human R. & Man. Control	Monthly	Percentage	Upper|Lower Values	Increase
	(9)	Delay	Management Control	Monthly	Numeric Value	Upper|Lower Values	Decrement
	(10)	Request Queue Evolution	Man. Demand & Man. Control	Monthly	Percentage	Upper|Lower Values	Decrement
	(11)	Software Reuse	Develpment & Production	Quarterly	Ratio	Upper|Lower Values	Increase
	(12)	Software Quality	Quality	Biannual	Aggregate	Upper|Lower Values	Increase
	(13)	Budgeting Error	Planning & Man. Control	Biannual	Percentage	Upper|Lower Values	Increase
LEARNING & GROWTH	(14)	Employer Branding	Human Resources	Biannual	Aggregate	Upper|Lower Values	Increase
	(15)	Intellectual Capital	Organization & HR & Customer	Annual	Aggregate	Upper|Lower Values	Increase

Figure 3. The Balanced Scorecard proposed for the Financial Software Factory.

3.4. The Strategy Map of the Financial Software Factory

Software development is becoming increasingly a pervasive element in many business areas, and furthermore, linking software activities to an organization's higher-level business goals can improve its performance [50].

In software-intensive organizations, as in this work, it is necessary to link software measurement goals to higher-level goals. This linkage is important, as it helps to justify software measurement efforts and allows measurement data to contribute to higher-level decisions [24].

Sustainability **2015**, *7*, 15999–16021

To develop and implement the strategy map of the software factory studied in this work, the financial group, led by top management, met in working sessions with representatives from different levels and areas. In these meetings, they proposed a new approach to plan and implement the business strategy, and they decided on one of the options, the most appropriate mechanisms for linking the measurement goals to higher-level goals for the software factory. These working groups determined the right set of strategy decisions, the business goals, the software goals and the metric for measurement of goals, similar to that proposed by Basili *et al.* in some of their studies published in 2007 [24] and 2010 [51], concerning both software development and business strategy. Finally, and according to all of these, they created a strategy map that effectively shows the linkages of the software factory objectives to the whole financial group.

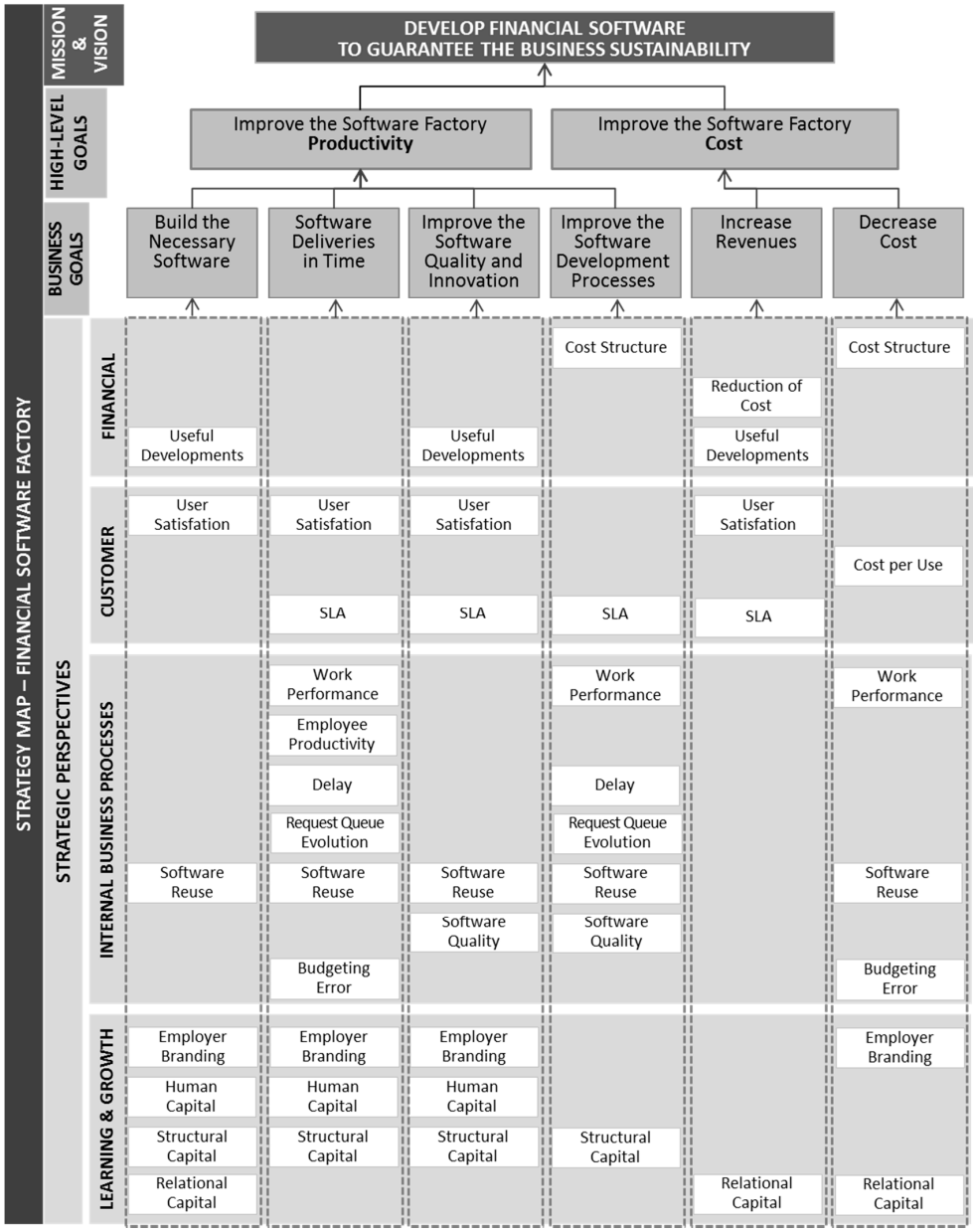

Figure 4. The strategy map proposed for the Financial Software Factory.

Figure 4 shows the *Strategy Map* proposed for this Software Factory. At the top of the Strategy Map are the *Strategic Goals*: the *Strategic Mission* and *Vision*, the *Strategic High-Level Goals* and the

Sustainability **2015**, *7*, 15999–16021

Strategic Business Goals. Under each Strategic Business Goal a set of KPIs is situated. This set includes the KPIs that are directly related and have and influence in each specific Strategic Business Goal. Every Strategic Business Goal has its own set of KPIs and every KPI can influence more than one Strategic Business Goals, as it is represented in Figure 4. KPIs do not have a specific influence to each other into the strategy map.

3.5. Preliminary Validation Plan

A validation plan provides an opportunity to build and improve the trust in a new model. In this case, the software factory management will need to use the model effectively in decision making in order to improve the software development processes. An effective validation plan requires a consistent approach across all validation features of the BSC framework. To make this the management must to consider all about software development processes. An effective validation plan requires time and efforts to reach and prove the different steps or phases: Planning, Execution, Review and Scoring and, finally, Analysis and Reporting [52]. Furthermore it will be necessary a tool that support these steps. Validation plan is an important role in framework improvement and it will help to understand and identify weaknesses, strengths and limitations. Finally it will be the key towards approval to use this proposed model for a FSF and as result a validation report will show the scope of the validation.

The FSF studied in this work has already provided us with the first monitoring data that are necessary for the validation of the proposed model. Until now, we only have data for some indicators from 2012 to 2014, but they allow us to draw some conclusions that should be endorsed with the data obtained for the following years. Table 1 shows the values of the data for some of the main indicators of the company and their influence on some of the KPIs proposed in this model, during 2012 (the last year working with the old framework) and 2014 (the first complete year working with the framework proposed). The KPIs presented show positive values associated with lower costs and improved performance and productivity. In contrast, the Budgeting Error KPI needs more corrective actions for improvement.

Table 1. Data and KPIs values obtained during 2012 and 2014.

Data/Year	**2012**	**2014**	**Var.%**
Finished Software Request	338	424	25.44%
Budgeted Hours	251,019	257,951	2.76%
Performed Hours	354,722	339,847	−4.19%
Group Revenues	60,418,000 €	54,681,000 €	−9.50%
Core Transactions	1,296,439,281	1,276,054,739	−1.57%
KPIs/Year	**2012**	**2014**	**Var.%**
Cost per Use	0.0466	0.0429	−8.05%
Work Performance	70.77	75.90	7.26%
Employee Productivity	0.56	0.65	15.93%
Budgeting Error	29.23	24.10	−17.57%

Over the next few years, new data will be collected and new indicators will be assessed in order to confirm the performance and productivity improvements observed during 2014.

4. Conclusions

Over the past 25 years, many articles have been written that proposed the BSC as a business management tool for improving business. Assessing the productivity and performance of software development industries is not easy, due to the intangible nature of the final product, but they need to know and control the production to establish policies and strategies that can achieve the desired goals.

In this paper a management system for controlling the productivity of a FSF is proposed, and for this aim, a specific framework based on the BSC is defined in order to answer the questions that the

Sustainability **2015**, *7*, 15999–16021

managers need to be satisfied. For this purpose and in a working environment based on the software factory approach, we have adopted a set of management objectives that applied to this type of FSF allowing them to establish measurements that are linked to the internal business process that can value the software development quality and productivity, and its evolution over time. The proposed relationship between size, budgeted hours, the cost of software deliveries, and the specific indicators designed to control it, facilitate the difficult task of controlling the deployment and deviations of the software projects. This knowledge is necessary for making corrections and initiatives to guide the production process to the desired performance. The indicators included in the financial perspective provide insights into the economic viability of the FSF and allow comparing it with other similar FSF. The assessment of the indicators included in the other two perspectives provides information about the relationships amongst the company, customers and employees. This information values the availability of customers to remain so and checks if human resources planning promotes the continuity and growth of the business.

The BSC is a "necessary good" for companies, especially when is used as a framework and guideline for a strategy approach of the organization and its corresponding structure [12]. According to our knowledge, this work is the first to propose the BSC framework to be used in this specific kind of IT firm whose mission is to develop financial software adapted to the banking sector. The special features discussed in this study on the FSF, result in other proposals from typical indicators for BSC not fitting properly for this type of management system, arising therefore, the need for new proposals. The described model is limited to use in this kind of FSF, although it could be apply in other different software factories that fit the presented framework.

Although the framework has being implemented in a real context with beneficial results, as shown in Table 1, the adoption is still very recent so no definitive conclusions can be drawn.

The proposed BSC, design of the indicators and their relationship with the business goals set, provide a management system that allows production control, facilitates the needs of management and allows them to take appropriate decisions for the sustainability of the software development business in a specific FSF.

Likewise and in relation to this work, we expect to launch new studies linked to the optimization of demand management systems for project portfolios of this type of software factory.

Acknowledgments: This work has been subsidized through the Plan of Science, Technology and Innovation of the Principality of Asturias (Ref: FC-15-GRUPIN14-132). The authors also thank anonymous referees who reviewed and gave important comments to this paper.

Author Contributions: Vicente Rodríguez and Francisco Ortega contributed in developing the conception of the research design; data interpretation; and writing. César Álvarez contributed in the development and execution of the research approach; literature review; data collection and integration; validation and writing. Joaquín Villanueva contributed in enhancing the research approach and data collection.

Conflicts of Interest: The authors declare no conflict of interest.

References and Notes

1. Papalexandris, A.; Ioannou, G.; Prastacos, G.P. Implementing the Balanced Scorecard in Greece: A Software Firm's Experience. *Long Range Plan.* **2004**, *37*, 351–366. [CrossRef]
2. De la Fuente Asprón, R. Medir la Productividad del Desarrollo de Software en Banca. Available online: www.financialtech-mag.com (accessed on 22 June 2013).
3. Fenton, N.; Bieman, J. *Software Metrics: A Rigorous and Practical Approach*; CRC Press: Boca Raton, FL, USA, 2014.
4. Emaldi Abasolo, M. The Software Factories. *Dyna (Bilbao)* **2007**, *82*, 330–333.
5. Murphy, G.C. What is software development productivity, anyway? (keynote). In Proceedings of the 10th Working Conference on Mining Software Repositories (MSR), San Francisco, CA, USA, 18–19 May 2013; IEEE Press: San Francisco, CA, USA, 2013; p. 1.
6. Brown, A.W.; Lopez Mancisidor, A.; Reyes Oliva, L. Practical Experiences with Software Factory Approaches in Enterprise Software Delivery. In Proceedings of the Sixth International Conference on

Software Engineering Advances, ICSEA, Barcelona, Spain, 23–29 October 2011; pp. 465–470. Available online: http://www.thinkmind.org/index.php?view=instance&instance=ICSEA+2011 (accessed on 26 November 2015).
7. De Vries, M. Measuring Success with Software Factories. Available online: https://msdn.microsoft.com/en-us/library/bb245774.aspx (accessed on 26 November 2015).
8. Kaplan, R.S.; Norton, D.P. The Balanced Scorecard—Measures That Drive Performance. *Harv. Bus. Rev.* **1992**, *70*, 71–79. [PubMed]
9. Kaplan, R.S.; Norton, D.P. *The Balanced Scorecard: Translating Strategy into Action*; Harvard Business Press: Boston, MA, USA, 1996.
10. Van Grembergen, W. The Balanced Scorecard and IT Governance. *Inf. Syst. Control J.* **2000**, *2*, 40–43.
11. Martinsons, M.; Davison, R.; Tse, D. The balanced scorecard: a foundation for the strategic management of information systems. *Decis. Support Syst.* **1999**, *25*, 71–88. [CrossRef]
12. Mooraj, S.; Oyon, D.; Hostettler, D. The Balanced Scorecard: A Necessary Good or an Unnecessary Evil? *Eur. Manag. J.* **1999**, *17*, 481–491. [CrossRef]
13. Rodríguez Montequín, V.; Álvarez, C.; Ortega, F.; Villanueva Balsera, J. Scorecard for Improving Software Factories Effectiveness in the Financial Sector. *Procedia Technol.* **2013**, *9*, 670–675. [CrossRef]
14. Djotio Ndie, T.; Tangha, C.; Ekwoge Ekwoge, F. MDA (Model Driven Architecture) as a Software Factory Industrialization Pattern: An Approach for a Pragmatic Software Factories. *J. Softw. Eng. Appl.* **2010**, *3*, 561–571. [CrossRef]
15. Poppendieck, M.; Poppendieck, T. *Lean Software Development: An Agile Toolkit*; Addison Wesley: Boston, MA, USA, 2003.
16. Hotle, M.; Landry, S. Application Delivery and Support Organizational Archetypes: The Software Factory. Available online: https://www.gartner.com/doc/980919/application-delivery-support-organizational-archetypes (accessed on 26 November 2015).
17. Peredo Valderrama, R.; Canales Cruz, A.; Peredo Valderrama, I. An Approach toward a Software Factory for the Development of Educational Materials under the Paradigm of WBE. *Interdiscipl. J. E-Learn. Learn. Objects* **2011**, *7*, 55–67.
18. Rodríguez Montequín, V.; Álvarez Pérez, C.; Ortega Fernández, F.; Villanueva Balsera, J. Scorecard and KPIs for monitoring software factories effectiveness in the financial sector. *Int. J. Inf. Syst. Project Manag.* **2013**, *1*, 29–43.
19. Kaplan, R.S.; Norton, D.P. Putting the Balanced Scorecard to Work. *Harv. Bus. Rev.* **1993**, *71*, 134–140.
20. Kaplan, R.S.; Norton, D.P. Using the Balanced Scorecard as a Strategic Management System. *Harv. Bus. Rev.* **2007**, *85*, 150–161.
21. Kaplan, R.S.; Norton, D.P. *Strategy Maps: Converting Intangible Assets into Tangible Outcomes*; Harvard Business School Press: Boston, MA, USA, 2004.
22. Kaplan, R.S. Conceptual Foundations of the Balanced Scorecard. *Handb. Manag. Account. Res.* **2008**, *3*, 1253–1269.
23. Rohm, H.; Montgomery, D. *Link Sustainability to Corporate Strategy Using the Balanced Scorecard*; The Balanced Scorecard Institute: Cary, NC, USA, 2011.
24. Basili, V.; Heidrich, J.; Lindvall, M.; Münch, J.; Regardie, M.; Rombach, D.; Seaman, C.; Trendowicz, A. Bridging the Gap between Business Strategy and Software Development. Available online: aisel.aisnet.org/icis2007/25/ (accessed on 26 November 2015).
25. Chi, D.-J.; Hung, H.-F. Is the BSC really helpful for improving performance? Evidence from software companies in China and Taiwan. *Afr. J. Bus. Manag.* **2011**, *5*, 224–239.
26. Eckerson, W.W. Creating Effective KPIs. Available online: http://www.information-management.com/issues/20060601/1056305-1.html (accessed on 26 November 2015).

27. Marr, B. *How to Design Key Performance Indicators, Management Case Study*; The Advanced Performance Institute: Buckinghamshire, UK, 2010.
28. Etezadi-Amoli, J.; Farhoomand, A.F. A structural model of end user computing satisfaction and user performance. *Inf. Manag.* **1996**, *30*, 65–73. [CrossRef]
29. Tyrinopoulus, Y.; Antoniou, C. Public transit user satisfaction: Variability and policy implications. *Transp. Policy* **2008**, *15*, 260–272. [CrossRef]
30. Del Castillo, J.M.; Benitez, F.G. A Methodology for Modeling and Identifying Users Satisfaction Issues in Public Transport Systems Based on Users Surveys. *Procedia-Soc. Behav. Sci.* **2012**, *54*, 1104–1114. [CrossRef]
31. Alhamad, M.; Dillon, T.; Chang, E. Conceptual SLA framework for cloud computing. In Proceedings of the 4th IEEE International Conference on Digital Ecosystems and Technologies (DEST), Dubai, United Arab Emirates, 13–16 April 2010; pp. 606–610.
32. Goo, J.; Kishore, R.; Rao, H.R.; Nam, K. The Role of Service Level Agreements in Relational Management of Information Technology Outsourcing: An Empirical Study. *MIS Q.* **2009**, *33*, 119–145.
33. Morrison, C.J. *A Microeconomic Approach to the Measurement of Economic Performance: Productivity Growth, Capacity, Utilization, and Related Performance Indicators*; Springer Science & Business Media: Berlin, Germany, 2012.
34. Sommerville, I. *Software Engineering (9th Edition)*; Pearson Addison Wesley: Boston, MA, USA, 2004.
35. Huda, M.; Arya, Y.D.S.; Khan, M.H. Quantifying Reusability of Object Oriented Design: A Testability Perspective. *J. Softw. Eng. Appl.* **2015**, *8*, 175–183. [CrossRef]
36. Fuller, T. A Foundation for the Pillars of Software Factories. *ACSIJ* **2012**, *1*, 10–17.
37. Joint Technical Committee ISO/IEC JTC 1/SC7 ISO/IEC 25010:2011 Systems and Software Engineering–Systems and software Quality Requirements and Evaluation (SQuaRE)–System and Software Quality Models 2011.
38. Yilmaz, M.; O'Connor, R.V. An Empirical Investigation into Social Productivity of a Software Process: An Approach by Using the Structural Equation Modeling. In *Systems, Software and Service Process Improvement*; Springer: Berlin, Germany, 2011; Volume 172, pp. 155–166.
39. Chunping, Y.; Xi, L. The Study on Employer Brand Strategy in Private Enterprises from the Perspective of Human Resource Management. *Energy Procedia* **2011**, *5*, 2087–2091. [CrossRef]
40. App, S.; Merk, J.; Büttgen, M. Employer Branding: Sustainable HRM as a Competitive Advantage in the Market for High-Quality Employees. *Manag. Rev.* **2012**, *23*, 262–278.
41. Kumar, V.; Christodoulopoulou, A. Sustainability and Branding: An Integrated Perspective. *Ind. Market. Manag.* **2014**, *43*, 6–15. [CrossRef]
42. Nagy, I. How to Measure your Employer Branding ROI. Available online: http://www.social-hire.com/social-recruiting-advice/2151/how-to-measure-your-employer-branding-roi (accessed on 7 July 2015).
43. Minchington, B. *2014 Employer Branding Global Trends Study Report*; Employer Brand International—EBI: Torrensville, Australia, 2014.
44. Örnek, A.Ş.; Ayas, S. The Relationship between Intellectual Capital, Innovative Work Behavior and Business Performance Reflection. *Procedia* **2015**, *195*, 1387–1395. [CrossRef]
45. Wu, I.-L.; Chen, J.-L. A stage-based diffusion of IT innovation and the BSC performance impact: A moderator of technology-organization-environment. *Technol. Forec. Soc. Change* **2014**, *88*, 76–90. [CrossRef]
46. Software Engineering Institute. Capability Maturity Model Integration (CMMI®) Version 1.3. Available online: http://cmmiinstitute.com/ (accessed on 15 September 2015).
47. Office of Government Commerce. PRINCE2®:2009 (Projects IN Controlled Environments). Available online: https://www.axelos.com/best-practice-solutions/prince2 (accessed on 15 September 2015).
48. Van Grembergen, W.; de Haes, S. Measuring and Improving IT Governance through the Balanced Scorecard. *Inf. Syst. Control J.* **2005**, *2*, 35–42.
49. Van Grembergen, W.; Saull, R.; de Haes, S. Linking the IT Balanced Scorecard to the Business Objectives at a Major Canadian Financial Group. *J. Inf. Technol. Case Appl. Res.* **2003**, *5*, 23–50. [CrossRef]
50. Kathuria, R.; Joshi, M.P.; Porth, S.J. Organizational alignment and performance: past, present and future. *Manag. Decis.* **2007**, *45*, 503–517.

Sustainability **2015**, *7*, 15999–16021

51. Basili, V.; Heidrich, J.; Lindvall, M.; Münch, J.; Regardie, M.; Rombach, D.; Seaman, C.; Trendowicz, A. Linking Software Development and Business Strategy Through Measurement. *IEEE Comput.* **2010**, *43*, 57–65. [CrossRef]
52. Towers Watson. Effective Model validation—Embedding Trust. Available online: https://www.towerswatson.com/en/Insights/IC-Types/Ad-hoc-Point-of-View/Insights/2013/Insights-Model-validation (accessed on 26 November 2015).

4.2.2. PUBLICACIÓN – ARTÍCULO 2

Álvarez Pérez, C.; Rodríguez Montequín, V.; Ortega Fernández, F.; Villanueva Balsera, J. Integrating Analytic Hierarchy Process (AHP) and Balanced Scorecard (BSC) Framework for Sustainable Business in a Software Factory in the Financial Sector. Sustainability 2017, 9, 486. doi:10.3390/su9040486

sustainability

MDPI

Article

Integrating Analytic Hierarchy Process (AHP) and Balanced Scorecard (BSC) Framework for Sustainable Business in a Software Factory in the Financial Sector

César Álvarez Pérez, Vicente Rodríguez Montequín *, Francisco Ortega Fernández and Joaquín Villanueva Balsera

Department of Project Engineering, University of Oviedo, C/Independencia 3, 33004 Oviedo, Spain; cesaralvarezcom@gmail.com (C.Á.P.); fran@api.uniovi.es (F.O.F.); balsera@api.uniovi.es (J.V.B.)
* Correspondence: montequi@api.uniovi.es; Tel.: +34-985-104-272

Academic Editor: Fabio Carlucci
Received: 5 January 2017; Accepted: 22 March 2017; Published: 24 March 2017

Abstract: A balanced scorecard (BSC) framework for a factory that develops software for banking was proposed by us at the end of 2015 to ensure its sustainability, and was focused on improving its productivity and cost. Based on this framework, the aim of this study is to construct an approach using the analytic hierarchy process (AHP) and BSC for evaluating a factory's performance in order for it to become a sustainable business. In this study, AHP is proposed to prioritise and determine weights for the perspectives and indicators included in the BSC for a financial software factory (FSF). The combination of these weights with different indicator measures produces a model that provides an effective assessment tool for FSF managers. The results of the study, which are shown both globally and disaggregated according to the different roles of FSF stakeholders, show that user satisfaction is the main pillar for making decisions. In addition, the result considering roles shows differences according to the relationship of each stakeholder with the software factory. The current study has been validated in a Spanish factory that develops software for several financial entities.

Keywords: balanced scorecard; analytic hierarchy process; software factory; performance evaluation; financial software development

1. Introduction

Since the advent of the internet, and especially since the emergence of smartphones, which coincided with the last financial crisis that significantly hit the banking sector, banks are trying to reposition in order to retain their dominant position in the financial sector. However, it seems that traditional banking is not well adapted to keeping up with the constantly changing technological landscape, according to SAP and IBM [1]. Banks are facing challenges in several areas, but there are four that stand out which affect banking information technology (IT). These are:

- Not making enough money. Despite all of the headlines about banking profitability, banks and financial institutions are still not making enough return on investment, or return on equity, that shareholders require.
- Consumer expectations. These days, it's all about the customer experience, and many banks are feeling pressure because they are not delivering the level of service that consumers are demanding, especially in regards to technology.
- Increasing competition from financial technology companies. Financial technology (FinTech) companies are usually start-up companies based on using software to provide financial services. The increasing popularity of FinTech companies is disrupting the way in which traditional banking

is being run. This creates a big challenge for traditional banks because they are not able to adjust quickly to the changes—not just in technology, but also in operations, culture, and other facets of the industry.

- Regulatory pressure. Regulatory and legal requirements continue to increase, and banks need to spend a large part of their discretionary budget on being compliant, and on building systems and processes, in order to keep up with the escalating requirements.

These challenges continue to grow, so traditional banks need to constantly evaluate and improve their operations and systems in order to keep up with the fast pace of change in the current banking and financial industry. Tackling these challenges requires new software developments, since much of the existing software dates from the beginning of the century, and is therefore not able to deal with present day issues and, of course, the future of the sector. That is why financial entities need to act in different critical aspects, and the companies that develop their software are possibly the main pillar of this action. The banking sector is one of the sectors requiring the most amount of software for its operation [2]. This is why the financial software industry needs to transform itself into an industrialised software manufacturer, able to provide software projects related to the efficiency, fast delivery, and quality that the financial markets expect today [3]. This industry not only needs to increase production capabilities, but also needs to produce more with the resources available for production, in order to increase productivity [4].

Our paper [5] published at the end of 2015 describes a case in which an FSF in Spain decided to review the concept of industrialisation of the software, to implement the principles and elements of the software factory approach [6], suggesting a strategic management approach using the BSC [7,8] that would increase the productivity of the different teams. This initial paper proposes a specific model for FSF as a way to improve sustainability and validates the model in a Spanish firm specialising in financial software. These FSF have special features that make them different from other software factories: they work almost exclusively for one financial group, which is both the owner and the principal customer, although revenue to a non-corporate group is increasingly important to financial groups; they have a greater demand for software development; and they have secured the payment of deliveries. These features make it necessary to include specific indicators to assess the financial perspective of the BSC, because the typical indicators for this perspective (Return on investment (ROI), Return on equity (ROE), or Economic value added (EVA)) are not suitable for these software companies in which shareholders and customers are both part of the same financial group. One problem with this initial proposal of a BSC framework is that it does not establish the importance of the perspectives and indicators in the BSC. The integration of BSC with multi-criteria decision-making techniques (MCDM), as AHP, has been adopted in this current paper as a useful method for calculating weights, and can help to establish an evaluation performance system [9]. In this study, AHP is proposed for determining the weights for the selected key performance indicators (KPIs) included in each of the four hierarchical perspectives of the BSC for an FSF, with the aim of ensuring business sustainability. This is related to achieving a viable business over time in terms of productivity and profitability, through appropriate decision-making. In addition, the results will be shown not only globally, but also by stakeholder roles, which represents a novel approach compared to other studies that apply a similar methodology to the one used in this paper.

The remainder of this paper is organised as follows. Section 2 reviews the literature and introduces the concepts of BSC, BSC for an FSF, and the AHP method as an integrated performance evaluation framework. Section 3 describes the research methodology. Section 4 shows the results of the study. Section 5 presents the analysis and discussion of the results and Section 6 presents the conclusions, implications, limitations, and future research directions related to this paper.

2. Performance Evaluation Framework for an FSF Based on BSC and AHP

In today's competitive world, only the companies that observe the needs of their customers and provide them with satisfaction can compete with others and gain benefits. Every organisation

needs a complete management system that includes all or nearly all of the elements or aspects of the company and permits an awareness of the productivity with which it is working, in order to protect its competitive advantages. However, the productivity measure in software development is more difficult than in other industries, due to the intangible nature of software and the difficulty in measuring the output [10]. Nevertheless, it is necessary for a management system to be able to monitor production. A framework that integrates BSC, a multiple perspective framework for performance assessment, and AHP, a decision-making tool used to prioritise multiple performance perspectives, can generate a metric [11] that helps achieve this objective.

2.1. The BSC Framework

In general, performance can be defined as the output or operating result at the end of a given period. This output is an indicator measuring the extent to which the companies reach their goals and, consequently, performance can be described as the general evaluation of all the efforts to accomplish their goals. Business performance is the degree of fulfilment of managerial goals in business practices and the realized outputs of these goals by the end of a certain period [12]. A performance measurement system can be defined as a system by which a company monitors its daily operations and evaluates whether the company is attaining its objectives [13]. To fully utilise the function of performance measurement, it is suggested that businesses set up a series of indexes, which properly reflect the performance of a company.

The BSC approach is probably the best-known management tool for a company. In 1992 and the years that followed, Kaplan and Norton, of Harvard University, presented The Balanced Scorecard [7] as a corporate performance tool that allows managers to look at the business from four important perspectives: financial, customer, internal business process, and learning and growth. In the following years, Kaplan and Norton presented new views and ways to improve the initial BSC approach, and linked it with measures, objectives, and business strategy [8,14]. The BSC is applied by many businesses to assess their performance in diverse aspects of their organisation, but the BSC is only a template and must be customised for the specific elements of an organisation. In addition, studies such as Bourguignon et al. [15] suggest that local ideology and culture should be taken into consideration, especially when the system has been born and developed in another culture. Since the BSC was introduced, many authors have proposed modifications for adapting the initial BSC to other scorecards that are specific to different areas or industrial environments. The studies about the IT BSC [16,17] in the information technologies sector, the Sustainability BSC (SBSC) [18,19] for a sustainable business and [20] for sustainable competitive strategies, those such as [21,22] that expose the benefits of using the BSC in the financial sector, and finally, the specific BSC for an FSF [5,23], are some previously published examples in relation to this study.

Figure 1 shows the BSC for an FSF [5] and includes the chosen KPIs with various fields assigned to each: Code, KPI Name, KPI Owner, Frequency Measurement, Value Measurement, Target Tendency, and the Upper and Lower Control Limits to manage the stability of processes. This BSC was established by the FSF as a control tool for the top management of the organization, according to the strategic objectives and the Mission and Vision of the FSF defined in its strategy map [5]. The indicators were derived from the strategic goals of the FSF through four different strategic lines:

1. Improve the performance and productivity of the FSF.
2. Delivery of software development must be of a good quality and the level of use of the delivered software by the customers should be increased.
3. Optimize and decrease the cost and expense of the software factory.
4. Sell the developments and services to companies outside of the owning financial group, to recover the development cost with external revenue.

The KPIs were defined during several work sessions with the participation of different roles of employees. Some of the KPIs were simple to create and easy to obtain, but others were difficult to

obtain because they were a compendium of different indicators and measures. The top management and consultants annually review the validity of the KPIs, and KPIs are modified or adjusted if necessary. Table 1 shows a short description and explanation of the KPIs included in the BSC for an FSF, which are extensively explained in our prior paper [5].

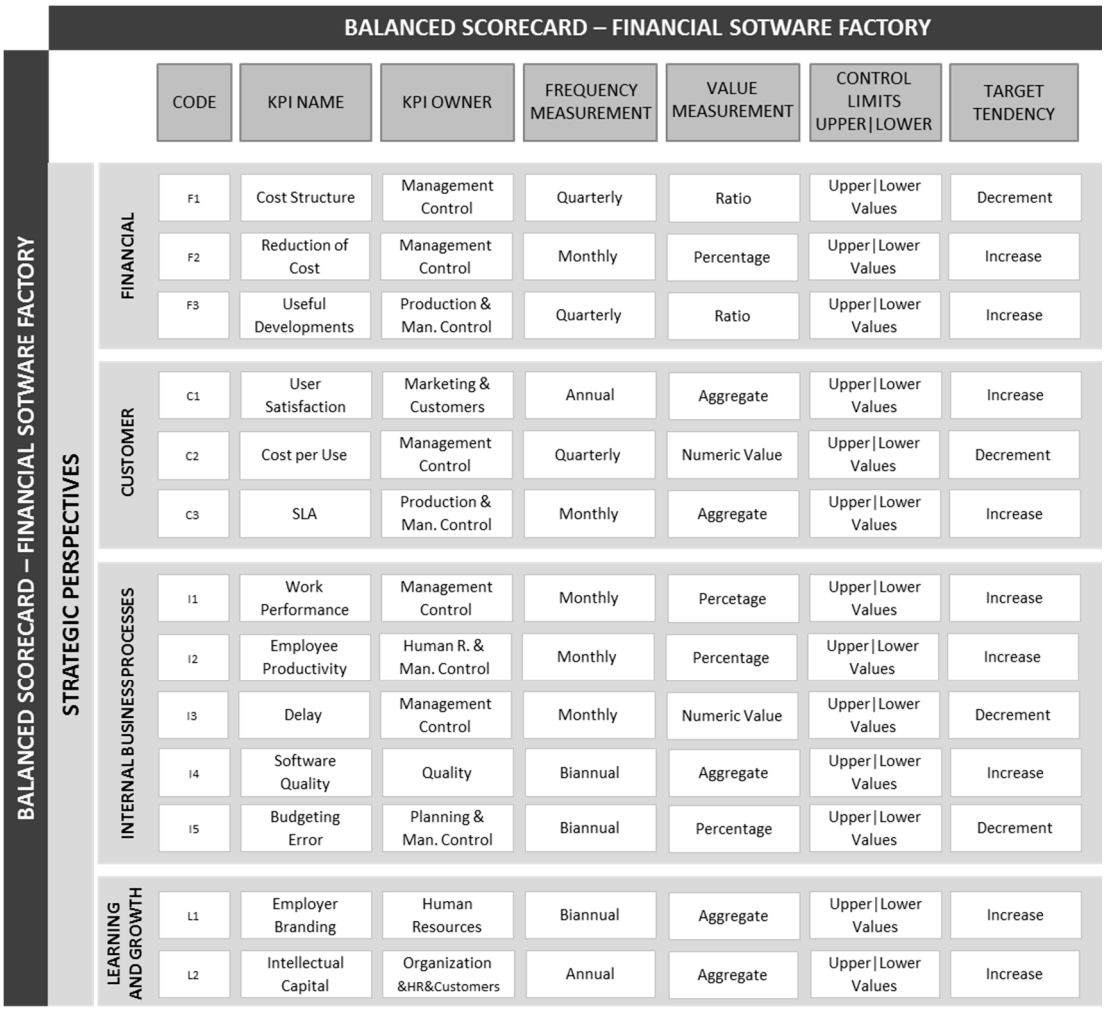

Figure 1. The BSC for an FSF. Adapted from [5].

Table 1. Descriptions and explanations of the selection of KPIs for FSF performance.

No.	KPIs	Description and Explanation
1	(F1) Cost Structure	Cost evolution according to financial entity size. The costs of the software factory and the size of the financial entity are compared in such way that when the size of the matrix financial group decreases, the costs of the software factory should also decrease in a similar proportion. This indicator is in connexion with the third strategic line (optimization of cost).
2	(F2) Reduction of Cost	The ratio of cost that is covered by sales to companies outside the group. The purpose of this indicator is to assess the percentage of the structural cost of the software factory that is covered by income over the last year, whose source is the sale of software developments and services to companies outside the corporate group. Because of the huge cost of software development, sales revenue outside the financial group owner is generally seen as a reduction of costs. The indicator is derived from the fourth strategic line (sell the developments and services to other companies different from the owning financial group).

Table 1. *Cont.*

No.	KPIs	Description and Explanation
3	(F3) Useful Developments	Degree of use of the delivered software by the customers. In this particular case, the degree of use of the developments is indicated by the number of software executions and the indicator is calculated as the cumulative number of these executions in relation to the size of the financial institution over the last year. In this framework is understood that the greater use of the developments, the higher income should be achieved. The indicator is derived from the second strategic line (the level of use of the delivered software by the customers should be increased).
4	(C1) User Satisfaction	Degree of customer satisfaction concerning software developments and services given by the software factory. Customers are the users of these software developments and services. The indicator is connected to the second strategic line.
5	(C2) Cost per Use	The proportion between the cost paid by the customer and the degree of use of the delivered software, measured by means of the cumulative number of executions as in (F3). The indicator is connected to the third strategic line.
6	(C3) SLA	Level of service expected from the software factory as a service provider. The proposed SLA indicator to use in the BSC is a multi-indicator that joins and unifies all the agreements reached with the financial group, and more specifically between the financial institution and the FSF. The indicator is connected to the first and second strategic lines.
7	(I1) Work Performance	Efficiency level in terms of improving rates of software built. The indicator is calculated as ratio between budgeted hours and the performed hours and it is derived from the strategic line of improve the performance and productivity of the FSF.
8	(I2) Employee Productivity	Amount of software that an employee produces for each hour on the job. The ratio is connected with the improvement of performance and productivity of the FSF.
9	(I3) Delay	Average waiting time for delivery of software. This indicator shows the delay in hours when the software factory is delivering software developments. The indicator is connected with the improvement of performance and productivity of the FSF.
10	(I4) Software Quality	Aggregated indicator that assess the software quality, in connection with the second strategic line (delivery of software development must be good quality).
11	(I5) Budgeting Error	Accuracy of the estimates linked to software development. The indicator shows how good the estimations are over the last year and it is related with the third strategic line.
12	(L1) Employer Branding	Reputation of the software factory as an employer. Employees, and especially high-quality employees as a very important part of intellectual capital, must be attracted and retained by firms, and employer branding can help them to address the different needs and expectations of potential and existing employees. This indicator contributes to support all the strategic lines.
13	(L2) Intellectual Capital	Aggregated indicator that assess the intellectual capital as a compendium of human, structural and relational capital. This indicator contributes to support all the strategic lines.

2.2. AHP

The AHP was initially developed by Saaty in the 1970's [24,25], to solve the allocation of scarce resources and the planning needs of the military. Since its introduction, the AHP has become one of the most widely used MCDM methods, and has been used to solve unstructured problems in different areas of human needs and interests, such as political, economic, social, and management sciences [26]. The AHP is a useful approach for solving complex problems. In this approach, selected stakeholders prioritise the relative importance of criteria by making pairwise comparisons of the factors using a nine-point scale.

The most creative part of decision-making is modelling the problem. The identification of the decision hierarchy is the key to success in using AHP. The process of building a hierarchy structure is to more accurately identify all of the elements of the decision and recognise the interrelationships

between them [27]. This hierarchical structure has at least three levels: the overall goal of the problem is located at the top, the multiple criteria that define the alternatives is found in the middle, and the competing alternatives (decision alternatives) are situated at the bottom [28]. In particular, AHP is useful for prioritising decision alternatives [29] and is effective in addressing many types of problems that involve multiple criteria [30], including the analysis of performance in business [31], which is the main objective of the present study.

Saaty [32] argues that five options (equal, weak, strong, very strong, and absolute) represent a manager's ability to make qualitative distinctions. The deployment of AHP in real-life decision-making involves successive comparisons between each alternative, criterion by criterion, according to the fundamental scale of Saaty [33], as presented in Table 2.

Table 2. Scale to use in making expert judgments [33].

Intensity of Importance on an Absolute Scale	Definition	Explanation
1	Equally important	Two activities contribute equally to the objective
3	Weakly important	Experience and judgment strongly favour one activity over another
5	Essentially important	Experience and judgment strongly favour one activity over another
7	Very strongly important	An activity is strongly favoured and its dominance demonstrated in practice
9	Absolutely important	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate value between two adjacent judgments	When compromise is needed
Reciprocals	If activity *i* has one of the above numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	

Different studies based on Saaty's AHP theory, such as [9,34], explain that, if an alternative A_i is preferable to an alternative A_j, then the value of the comparison scale $P_c(A_i, A_j) = a_{ij}$ indicates the intensity of relative importance of A_i over A_j, assigned by the decision maker. The scale allows, in a pairwise comparison, the investigator to establish which alternative is better. Higher values of a_{ij} indicate a stronger preference of alternative A_i over A_j. Finally, the matrix A is the result of all of the comparisons, and represents the relative importance a_{ij} of each element. Given that an element is as important as itself, and taking into account the theorem of reciprocity, then $a_{ij} = 1$ if $i = j$ and $a_{ij} = 1/a_{ji}$ if $i \neq j$. The calculation of weights relies on an iterative process in which matrix A is successively multiplied by itself, resulting in normalised weights, w_i, and these weights represent the importance of alternative A_i relative to all other alternatives. The judgment of decision makers in pairwise comparisons may present inconsistencies when all of the alternatives are taken into consideration simultaneously. The consistency index (CI) and the consistency ratio (CR) measure the degree to which judgments are not coherent [35]. If CR < 0.10, then the degree of consistency is satisfactory [36].

2.3. Integration of BSC Framework and AHP to Evaluate Performance

Several studies have proven that the BSC framework (see Section 2.1) is effective in helping organisations to evaluate performance [37]. However, the BSC, a tool which describes the perspectives of performance, does not determine perspective and indicator weights [38]. AHP is useful in a BSC analysis because it can explain several relevant dimensions of organisational performance [9] and their weight of importance in a comprehensive framework. In practice, however, perspectives and indicators

seldom have equal importance. As a valuable tool for prioritising and consolidating performance metrics based on multiple criteria, AHP is a promising mechanism to help overcome the limitations of BSC. It has been adopted in several cases as a method for calculating weights in an evaluation performance system [9,39].

Although there are many studies that use the BSC to improve and control organisation performance, there are far fewer cases in the software industry that have also chosen to study the relative weight of each indicator included in the BSC, with the intention to establish a metric to assess performance. In the IT sector, there are several studies [9,39] that propose these methods to create performance evaluations systems. In the financial sector, some studies [40,41] present different proposals using the BSC and AHP in order to evaluate performance for banking. Other studies combine BSC with AHP with the purpose of achieving the sustainability of companies [42,43]. Other variants of the AHP, such as the analytical network process (ANP), have also been used with the BSC for sustainable management [44]. This study proposes a combination between AHP and BSC for an FSF to evaluate performance in a factory that develops software for banking, with the aim of maintaining the sustainability of this business.

3. Methodology

This paper lies in the area of applied research because it focuses on a methodology used to solve a problem in the real-world and the results can be applied in real decision-making situations. In this research, the four perspectives of the BSC were taken as the framework for establishing the performance evaluation indexes. The analytical structure of this research is explained in Figure 2. We first used the BSC model for an FSF to study the different KPIs proposed. Next, we interviewed several managers in a Spanish financial software factory. We then ascertained the views of software factory experts and designed a pairwise comparisons questionnaire based on the hierarchical structure of the BSC. Finally, AHP was applied to obtain the weights of the KPIs included in the specific BSC for an FSF.

The steps taken to achieve this purpose are:

1. Analyse the BSC of the FSF (the studied organization).
2. Define the hierarchical framework related to this BSC.
3. Prepare a questionnaire in AHP format based on this hierarchy to obtain the opinion of experts regarding the indicators and perspectives of the BSC, with the aim of business sustainability.
4. Prepare the answers obtained from the experts and give them the necessary format for computer treatment with AHP software.
5. Calculate the weights of the global and different stakeholder roles of all the indicators and perspectives included in the BSC, according to the performance aim of the FSF.
6. Show the results and analyse them to discuss the result and obtain conclusions.

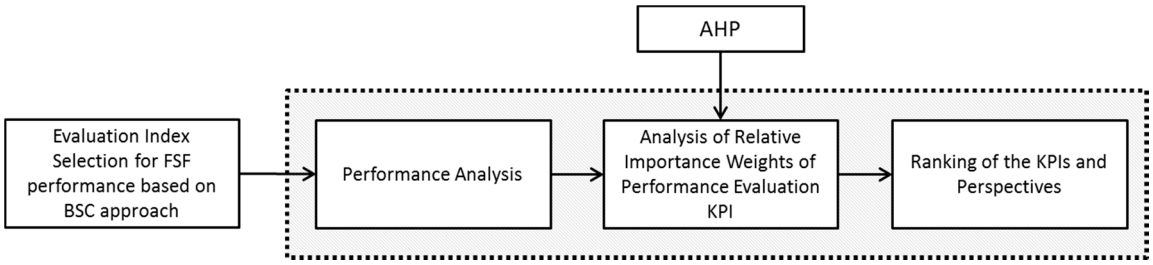

Figure 2. Performance evaluation framework of the research.

3.1. Hierarchical Framework of the BSC Performance Evaluation Criteria in an FSF

Based on the concept of the BSC for an FSF [5] and the literature review, this BSC is now adopted as a hierarchical research model of the BSC performance evaluation criteria (i.e., four perspectives and 13 KPIs) for this study, which is shown in Figure 3. To construct the hierarchy, we have used the four perspectives of the BSC for FSF and the KPIs included in each one of them. The 13 KPIs are grouped into the four BSC dimensions: "F: Financial (F1–F3)", "C: Customer (C1–C3)", "I: Internal Business Process (I1–I5)", and "L: Learning and Growth (L1–L2)". The four perspectives of the BSC provide a robust structure expressing the organisation's needs and its strategic objectives [45]. Each KPI and its value directly support the achievement of the mission and vision of the organisation [19].

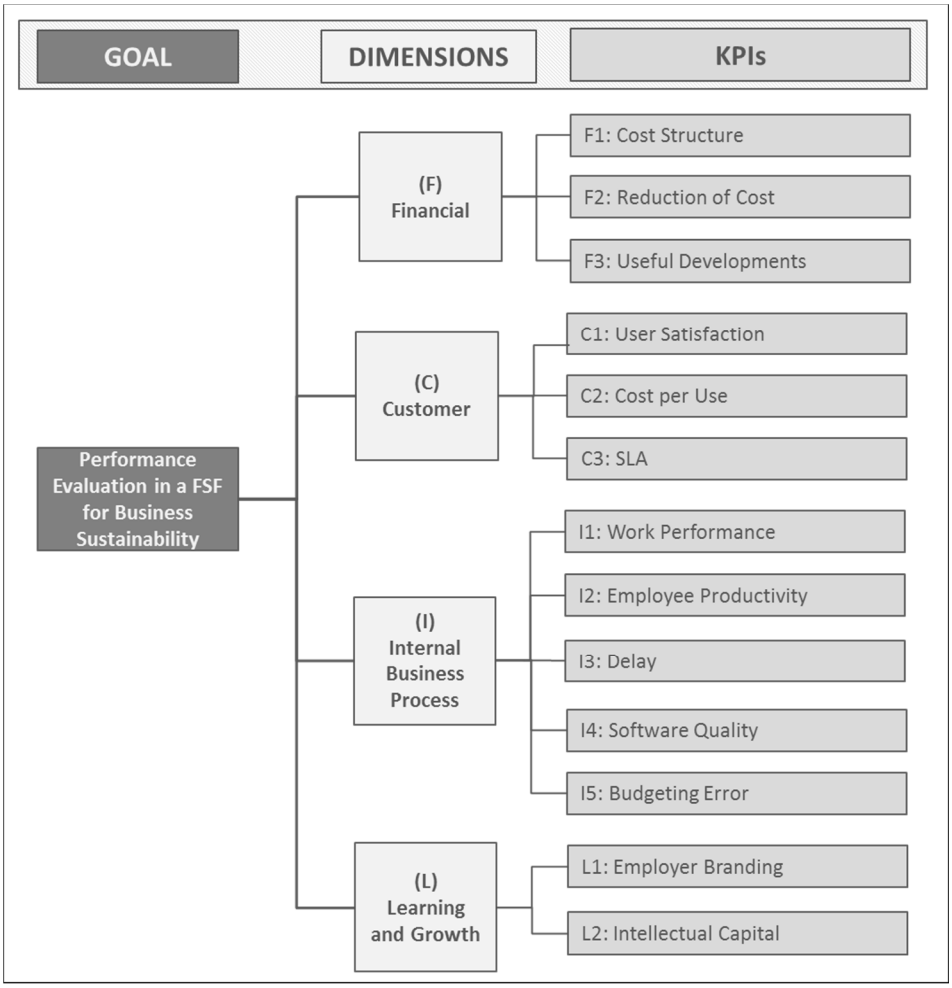

Figure 3. Hierarchical framework of BSC performance evaluation criteria for FSF.

3.2. Data Collection

Based on the BSC for an FSF hierarchy, a questionnaire was designed to ascertain the judgements of the participants with a conventional AHP questionnaire format, five-point scale, and pairwise comparison. The questionnaire included the definition and meaning of each criteria or sub-criteria included in every question. After the questionnaire was designed, it was given to experts, shareholders, and managers of an FSF, to test its reliability and validity. Their corrective views were taken into consideration in the final design and examples about the use of every KPI were included, to facilitate understanding and to avoid potential interpretation errors when the different stakeholders answered the questionnaire. An instruction sheet for completing the questionnaire was created to assist

respondents and an example of how the questionnaire is filled in was given to the respondents. A total of 83 questionnaires were distributed (by email and an online form) to different stakeholder roles related to FSF. These were grouped, according to the proposal of roles made by the top management of the FSF and with the purpose of considering different types of points of view, into shareholders, top management, middle managers, other employees, customers, and experts in the field of software factories. The latter were included to seek their professional opinions and the purpose of weighting criteria under the FSF sustainability aim. Table 3 shows the different stakeholder roles and their relation with an FSF.

Table 3. Different stakeholder roles and their relation with an FSF.

Stakeholder Roles	Relation with the FSF
Shareholders	The shareholders are the owners of the company. They are usually top management of the financial entities involved in the same financial group.
Top Management	Top management are the highest ranking executives responsible for the entire FSF. They translate policy into goals and strategies for the future. Top management make decisions affecting everyone in the software factory.
Middle Managers	The middle managers are the employees of the FSF who manage at least one subordinate level of managers, and report to the top management in the organisation to ensure smooth functioning of the software factory.
Other Employees	Other employees are the lowest level of managers and the rest of the employees of the software factory, including analysts and developers.
Customers	Customers are the financial entities for which the software factory develops software and offers services to them.
Experts in Software Factories	Experts are a group of managers of other software factories from different sectors, professors and researchers in relation to software factories.

Finally, 61 questionnaires were received (73.5% of questionnaires sent); three more were received late but were discarded for this reason (3.6% of questionnaires sent). Of the remaining 19 (22.9%) sent questionnaires for which we did not receive a response, the time required to answer the questionnaire (between 25 and 30 min), the deadline for filling in the questionnaire (one week), or the lack of interest in this study (as in the case of Other Employees role, only with 46.1% of received questionnaires), represent the three possible reasons why no response was received. The questionnaire responses were revised and adapted to the necessary format, in order to enter this information into the AHP system (the software used in this study was the FuzzyAHP package of R [46]), generating the pairwise comparison matrixes. The questionnaires that did not pass the consistency test (used to directly estimate the consistency of pairwise comparisons [47]), were revised and the values of the comparison matrix were considered and checked. In the cases in which the adjustments were minor or not significant, the procedure was repeated [48]. The definitive number of valid questionnaires was 44 (72.1% of questionnaires received and 53.0% of questionnaires sent). Table 4 shows the number and percentage of questionnaires sent, received, and validated, by stakeholder role. Finally, the AHP system calculated the comparison weights of KPIs and BSC perspectives, and generated the result with the weights of the perspectives and the KPIs.

Table 4. Number and percentage of sent, received, and valid questionnaires, by role.

Stakeholder Roles	Number of Sent Questionnaires	Number of Received Questionnaires		Number of Valid Received Questionnaires (Received/Sent)	
Shareholders	13	9	69.2%	6	66.7%/46.2%
Top Management	12	8	66.7%	6	75.0%/50.0%
Middle Managers	15	13	86.7%	8	61.5%/53.3%
Other Employees	13	6	46.1%	5	83.3%/38.5%
Customers	15	14	93.3%	10	71.4%/66.7%
Experts in Software Factories	15	11	73.3%	9	81.8%/60.0%
Total	**83**	**61**	73.5%	**44**	72.1%/53.0%

4. Results: A Case Study for FSF

The results of the four BSC dimensions for an FSF performance evaluation show that the Customer Perspective, with a priority weight of 0.4586, is the most important perspective. This is followed by the Finance Perspective, with a priority weight of 0.2035. The priority weight of the Internal Business Process Perspective is 0.1712, and the Learning and Growth Perspective has the lowest priority weight, of 0.1667.

The priority order of the 13 KPIs shows that User Satisfaction, with a priority weight of 0.2482, and SLA, with a value of 0.1319 (both included in the Customer Perspective), are the most important KPIs among all of those included in the BSC for an FSF. The third most important indicator is Intellectual Capital, with a weight of 0.1049 (included in the Learning and Growth Perspective), followed by Cost Structure, with a weight of 0.0841 (included in the Financial Perspective). The seventh indicator is Software Quality, with a weight of 0.0633 (included in the Internal Business Process Perspective). Finally, Figure 4 shows the initial hierarchy based on the BSC for an FSF (see Figure 3) and the global results ranked by weights.

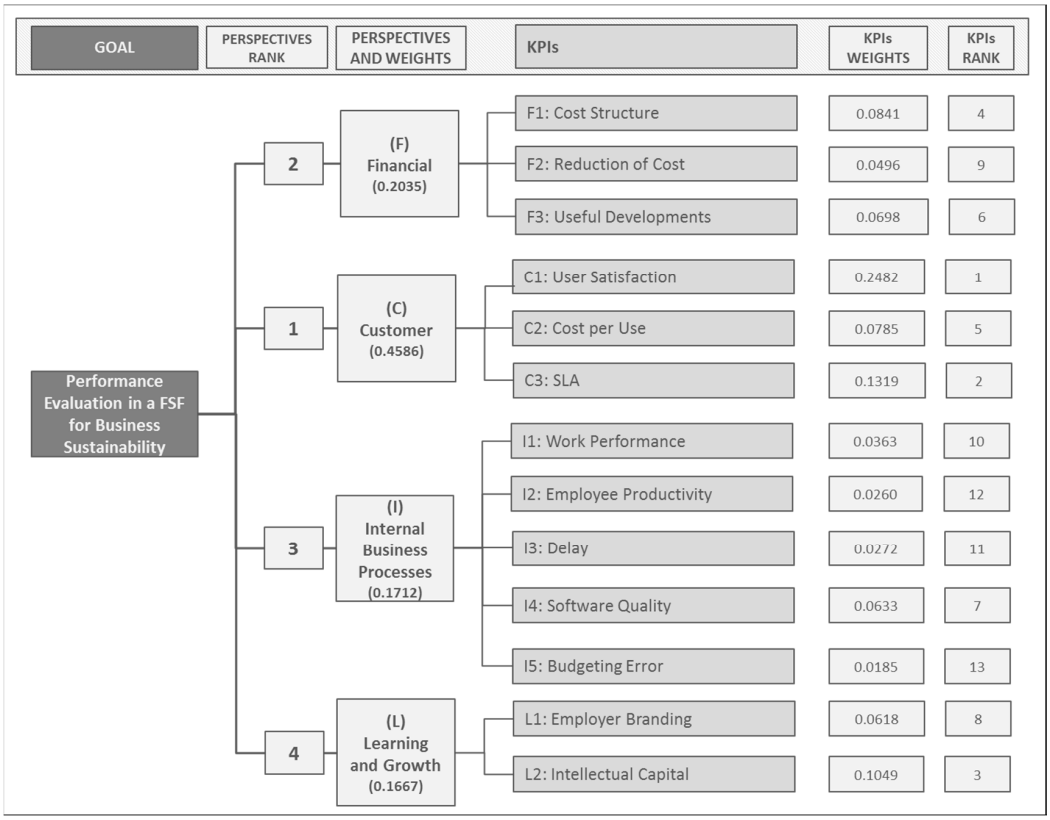

Figure 4. Weights and Ranking of the BSC for an FSF performance evaluation index by AHP.

5. Discussion

As shown in Table 5 and Figures 5 and 6, the results by role in the AHP analysis reveal that the Customer Perspective is the primary focus of the BSC, and that User Satisfaction is the most important evaluation KPI. The Customer Perspective is the most important by role (Other Employees being the only exception), but User Satisfaction is the best ranking KPI in all cases. The SLA indicator (also included in the Customer Perspective) is globally the second most important KPI, and is, in most cases, one of the four most important KPIs for the different roles (Other Employees is again the only exception). This means that the importance given to the Customer Perspective, which is twice as important as the Financial Perspective, which is the next important perspective, clearly demonstrates the relationship and mutual dependence between the FSF and its customers. All of this implies that the main objective of the FSF should be focused on the continuous improvement of the services offered to their customers, to cover their needs in the most efficient way.

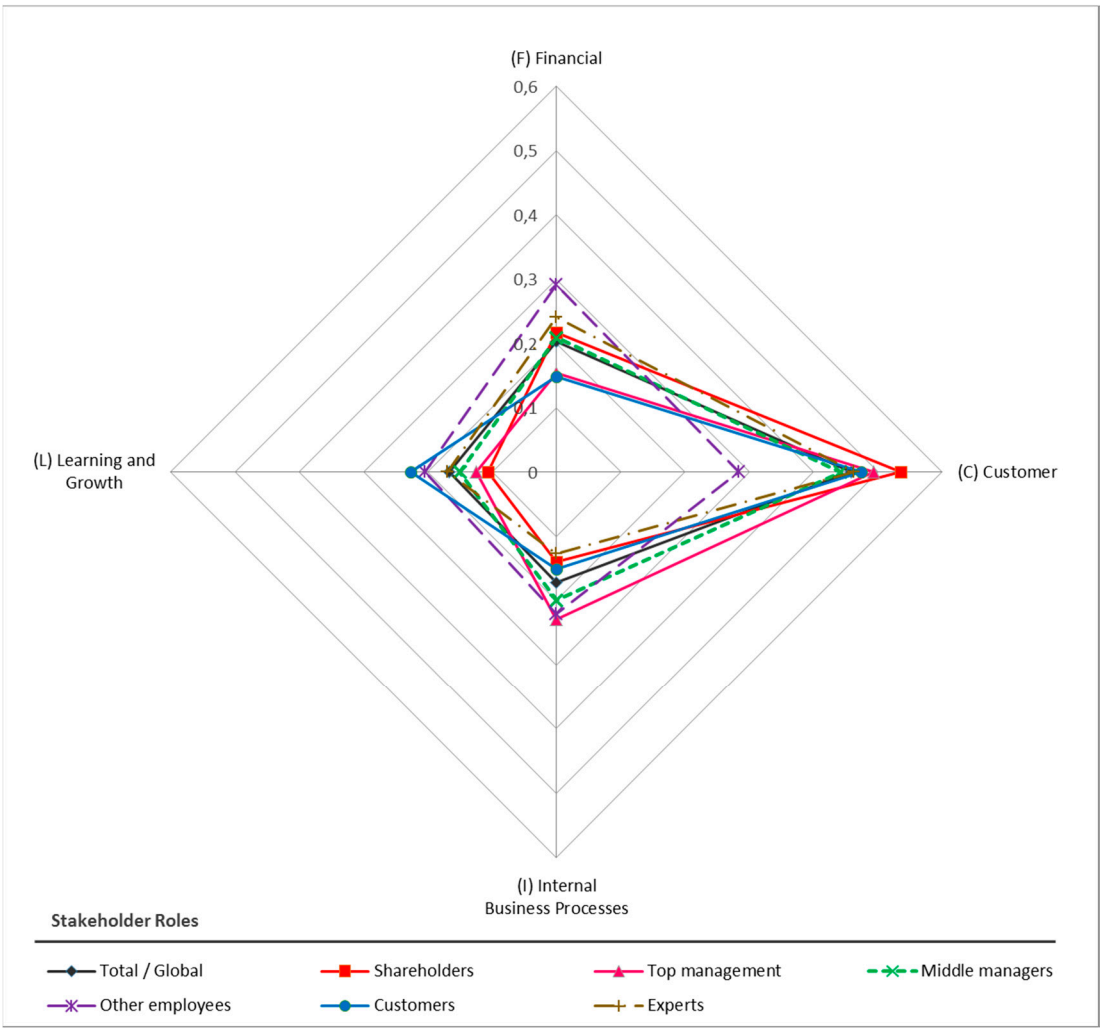

Figure 5. Criteria (Perspectives) weights radar graph for different stakeholder roles.

Table 5. Weights of perspectives and KPIs of BSC for an FSF performance evaluation index by AHP, according to the roles of different stakeholders of FSF.

Criteria and Sub-Criteria/Roles of Stakeholders	Total/Global	Share-Holders	Top Management	Middle Managers	Other Employees	Customers	Experts
(F) Finance	0.2035	0.2172	0.1536	0.2090	0.2914	0.1482	0.2407
(F1) Cost Structure	0.0841	0.1430	0.0446	0.0859	0.1051	0.0632	0.0825
(F2) Reduction of Cost	0.0496	0.0409	0.0430	0.0588	0.0522	0.0305	0.0684
(F3) Useful Developments	0.0698	0.0333	0.0659	0.0643	0.1340	0.0545	0.0898
(C) Customer	0.4586	0.5352	0.4933	0.4417	0.2829	0.4735	0.4628
(C1) User Satisfaction	0.2482	0.2263	0.2495	0.2284	0.1704	0.2508	0.2739
(C2) Cost per Use	0.0785	0.2041	0.0917	0.0446	0.0487	0.0646	0.0797
(C3) SLA	0.1319	0.1048	0.1522	0.1686	0.0638	0.1581	0.1093
(I) Internal Business Processes	0.1712	0.1403	0.2287	0.1992	0.2214	0.1510	0.1264
(I1) Work Performance	0.0363	0.0252	0.0381	0.0341	0.0508	0.0339	0.0320
(I2) Employee Productivity	0.0260	0.0178	0.0169	0.0219	0.0342	0.0364	0.0230
(I3) Delay	0.0272	0.0205	0.0455	0.0340	0.0348	0.0181	0.0198
(I4) Software Quality	0.0633	0.0580	0.0998	0.0906	0.0865	0.0527	0.0282
(I5) Budgeting Error	0.0185	0.0187	0.0285	0.0185	0.0151	0.0099	0.0234
(L) Learning and Growth	0.1667	0.1073	0.1244	0.1502	0.2043	0.2272	0.1700
(L1) Employer Branding	0.0618	0.0241	0.0459	0.0640	0.0473	0.1218	0.0591
(L2) Intellectual Capital	0.1049	0.0832	0.0785	0.0861	0.1570	0.1054	0.1110

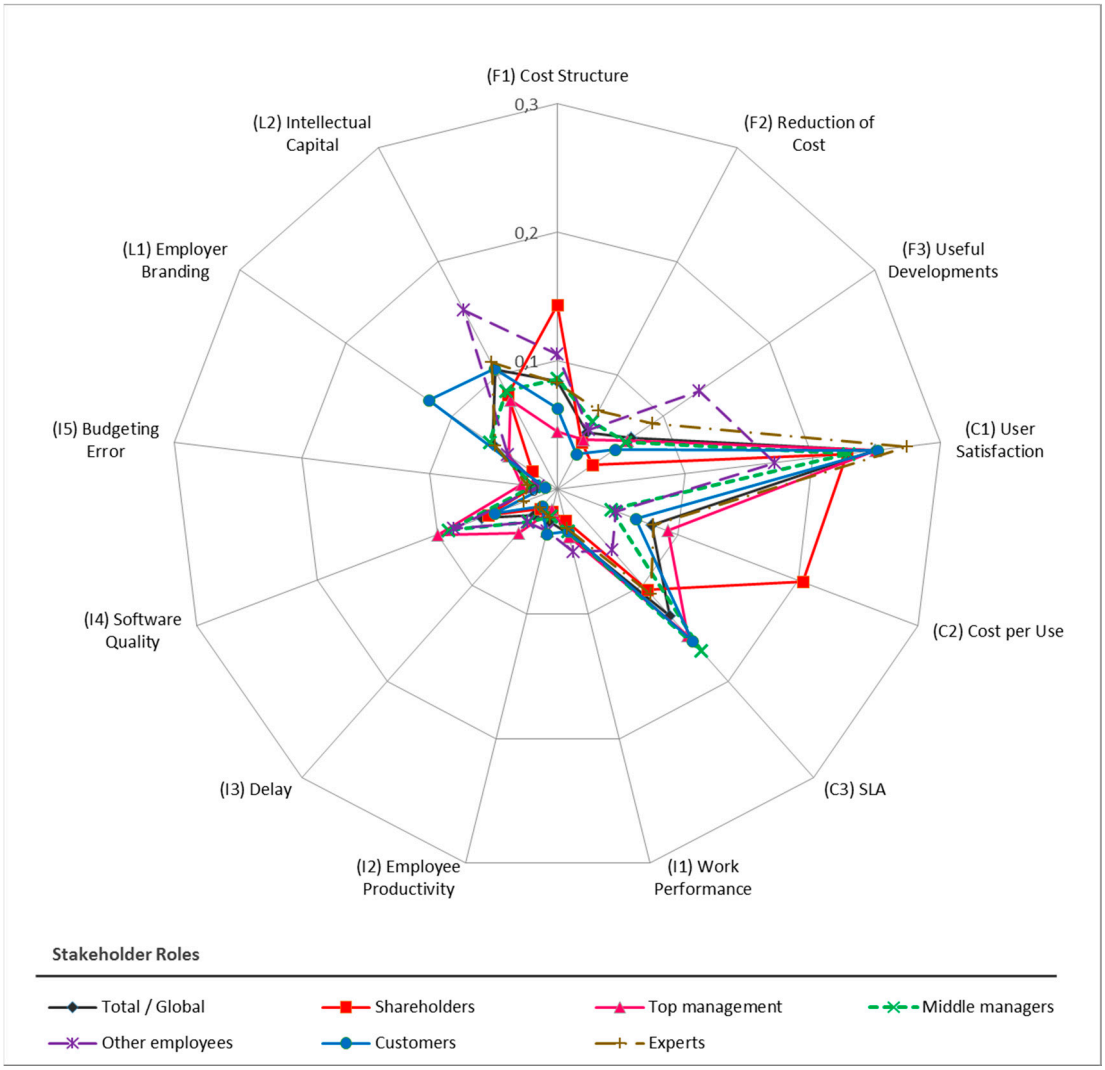

Figure 6. Sub-criteria (KPIs) weights radar graph for different stakeholder roles.

The third most important KPI is Intellectual Capital. Intellectual Capital is a compendium of human, structural, and relational capital indicators relating to the value of the organisation. The importance given to this indicator (included in the Learning and Growth Perspective) is that it provides evidence about the meaning of human factors in software development [49], where human capital plays a very important role [50]. The very nature of this kind of industry, when absolutely linked to the banking sector, means that one of the most important indicators for banks today is the Cost Structure (included in the Financial Perspective), which is the fourth most important KPI in this study. This indicator, like the Financial Perspective, holds a special meaning for shareholders and is the second most important indicator for them. The Software Quality KPI is the most important factor in the Internal Business Process Perspective. This indicator has a special relationship with the User Satisfaction KPI, because the degree to which customer needs are satisfied is part of Software Quality KPI, according to ISO/IEC 25010:2011 [51]. The relation between Software Quality with User Satisfaction, the most important KPI, is probably one of the causes that gives this indicator a much greater weight than the other indicators included in the Internal Business Processes Perspective.

On the other hand, and although it is not the main objective of this study, it can be concluded from the analysis of the results obtained for the different roles of participants, that each role places more importance to those indicators or perspectives that, in theory, have a greater relation to its own role. In this way, it can be observed that the shareholders give greater weight to the Financial Perspective. The employees (Top Management, Middle Managers and Other Employees) of the software factory place a greater value on the Internal Business Process Perspective. Customers are those that give less importance to the Financial Perspective, but instead, they attribute great importance to the assets and image of the company that offers them services. Although, to confirm this appreciation, User Satisfaction and SLA are the two main indicators for Customers. Furthermore, the role of Other Employees substantially differs from the rest of the employees, which could indicate the lack of organizational communication, related to the importance of customers for the FSF and satisfying their needs, from a higher level of employees to lower levels. The importance given to Intellectual Capital, an indicator that includes human capital value, by the Other Employees, is the highest of all the stakeholders.

6. Conclusions

The banking sector requires huge amounts of new software developments to satisfy its needs, which makes it necessary to increase both the production and the productivity of their developments. With the intention of achieving this aim, this study proposes a framework based on the BSC of an FSF and AHP incorporating the weights of each KPI, which allows a more efficient evaluation of the decisions that must be taken, depending on the different needs. To achieve this purpose, we have analysed the BSC of an FSF and then used its hierarchical structure to design the performance evaluation framework. According to this hierarchical structure of the BSC, we have designed a pairwise comparisons questionnaire in an AHP format to obtain the opinion of different stakeholder roles. Finally, we have treated their responses with AHP software to calculate the weights of all indicators and perspectives of the BSC of an FSF for business sustainability analysis of the results. In view of the results obtained, this study confirms that the combination of BSC with AHP provides a valid methodology for obtaining the necessary criteria and indicator weights to evaluate the performance of an FSF, in order to achieve a sustainable business. The results of this study are potentially useful to software factory managers. This is because, when viewed through the limits and characteristics of their own financial software factories, it can assist them in quantifying the magnitude of the changes required to increase the performance of the organisation. Knowing the ranking of importance of the perspectives and KPIs could be very useful for strategic plans and establishing priorities. This could be even more remarkable if the priorities of the different stakeholders are known. It could also be useful for reinforcing the organizational communication in order to avoid the gaps detected, for example, the different priorities identified for the employees. Although each organization will still have its own

idiosyncrasy, the results achieved here (for example the different view that employees have on some aspects) can be taken as illustrative of what can happen in many organizations.

The results presented in this paper clearly demonstrate the preponderant role of the Customer Perspective, and that satisfying customer needs should be the primary reference for decision-making in an FSF. User Satisfaction and SLA are the two most important indicators for an FSF, which is why the managers of the software factory must strive for continuous improvement in these indicators. Improving the Intellectual Capital (which is the main asset of a software development company), and achieving a viable cost structure for the organisation, are the two most important internal challenges facing the managers of an FSF. In practice, the results discussed here, and shown in Figure 4, will allow managers to justify their decisions and will allow an assessment of the impact of measures on FSF performance, focused on the organisation's sustainability.

It is also necessary to highlight the different behaviours observed according to the different stakeholder roles (see Table 5), which places a greater importance on those indicators or perspectives that have a closer relation to their role or function in the software factory. According to Figure 5, we can conclude that, regarding the perspectives, all of the different profiles are quite well aligned, except for the employees, and to a lesser extent, but as expected, the customers. Regarding the indicators, the differences are more remarkable. The profiles exhibiting the greatest differences are those of the employees and customers, but also the shareholders, who place more importance on the cost structure and cost per use. This fact implies that, in order to have a global vision that improves the performance and achieves the sustainability of this kind of organisation, it is necessary to take into account the perspectives of all the roles related to the FSF.

Future research will aim to improve the proposed framework in this study, integrating the strategy map and the BSC of an FSF with Fuzzy AHP. This integration will allow us to assess the impact that each indicator included in the BSC has on the different objectives defined in the strategy map of the organization. This knowledge should be the basis for making decisions based on the Mission and Vision of the organization. Furthermore, the use of methods such as fuzzy AHP, avoids the uncertainty and the ambiguity associated with human preferences. Fuzzy AHP, which could be incorporated with the pairwise comparison as an extension on AHP, allows for a more accurate description of the decision making process.

Acknowledgments: This work has been subsidized through the Plan of Science, Technology and Innovation of the Principality of Asturias (Ref: FC-15-GRUPIN14-132). The authors also thank anonymous referees who reviewed and gave important comments to this paper.

Author Contributions: Vicente Rodríguez Montequín and Francisco Ortega Fernández contributed in developing the conception of the research design; data interpretation; and writing. César Álvarez Pérez contributed in the development and execution of the research approach; literature review; data collection and integration; validation and writing. Joaquín Villanueva Balsera contributed in enhancing the research approach and data processing.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Schubert, J. Top Challenges Facing the Banking Industry Right Now. Available online: https://goo.gl/b5NMD0 (accessed on 27 November 2016).
2. De la Fuente Asprón, R. Medir la Productividad del Desarrollo de Software en Banca. Available online: http://www.financialtech-mag.com (accessed on 22 June 2013).
3. Emaldi Abasolo, M. The Software Factories. *Dyna Bilbao* **2007**, *82*, 330–333. (In Spanish).
4. Murphy, G.C. What is software development productivity, anyway? (Keynote). In Proceedings of the 2013 10th IEEE Working Conference on Mining Software Repositories (MSR), San Francisco, CA, USA, 18–26 May 2013.
5. Álvarez, C.; Rodríguez, V.; Ortega, F.; Villanueva, J. A Scorecard Framework Proposal for Improving Software Factories' Sustainability: A Case Study of a Spanish Firm in the Financial Sector. *Sustainability* **2015**, *7*, 15999–16021. [CrossRef]

6. Brown, A.; Lopez, A.; Reyes, L. Practical Experiences with Software Factory Approaches in Enterprise Software Delivery. In Proceedings of the 6th International Conference on Software Engineering Advances (ICSEA), Barcelona, Spain, 23–29 October 2011; IARIA: Barcelona, Spain, 2011; Volume 2011, pp. 465–470.
7. Kaplan, R.S.; Norton, D.P. The balanced scorecard—Measures that drive performance. *Harv. Bus. Rev.* **1992**, *70*, 71–79. [PubMed]
8. Kaplan, R.S.; Norton, D.P. *The Balanced Scorecard: Translating Strategy into Action*; Harvard Business Press: Boston, MA, USA, 1996.
9. Bentes, A.V.; Carneiro, J.; da Silva, J.F.; Kimura, H. Multidimensional assessment of organizational performance: Integrating BSC and AHP. *J. Bus. Res.* **2012**, *65*, 1790–1799. [CrossRef]
10. Netherlands Software Metrics Users Association Challenges in Productivity Measurement. Why Is It Hard to Measure Productivity in the Software Industry? Available online: https://goo.gl/GfkkAr (accessed on 4 February 2017).
11. De Felice, F.; Petrillo, A.; Autorino, C. Development of a framework for sustainable outsourcing: Analytic Balanced Scorecard Method (A-BSC). *Sustainability* **2015**, *7*, 8399–8419. [CrossRef]
12. Bulut, C.; Can, O. Business Performance. In *Encyclopedia of Corporate Social Responsibility*; Idowu, S.O., Capaldi, N., Zu, L., Gupta, A.D., Eds.; Springer: Berlin/Heidelberg, Germany, 2013; pp. 273–279.
13. Wu, H.-Y.; Tzeng, G.-H.; Chen, Y.-H. A fuzzy MCDM approach for evaluating banking performance based on Balanced Scorecard. *Expert Syst. Appl.* **2009**, *36*, 10135–10147. [CrossRef]
14. Kaplan, R.S.; Norton, D.P. Using the balanced scorecard as a strategic management system. *Harv. Bus. Rev.* **2007**, *85*, 150–161.
15. Bourguignon, A.; Malleret, V.; Nørreklit, H. *Balanced Scorecard versus French Tableau de Bord: Beyond Dispute, a Cultural and Ideological Perspective*; Groupe HEC: Cergy-Pontoise, France, 2001.
16. Van Grembergen, W. The Balanced Scorecard and IT Governance. *Inf. Syst. Control J.* **2000**, *2*, 40–43.
17. Keyes, J. *Implementing the IT Balanced Scorecard: Aligning IT with Corporate Strategy*; CRC Press: Boca Raton, FL, USA, 2016.
18. Figge, F.; Hahn, T.; Schaltegger, S.; Wagner, M. The Sustainability BSC—Theory and Applicantion of a Tool for Value-Based Sustainability Management. In *Corporate Social Responsability—Governance for Sustainability, Proceedings of the Greening of Industry Network Conference, Gothenburg, Sweden, June 23–26 2002*; Emerald Publishing Limited: Bingley, UK, 2002.
19. Rohm, H.; Montgomery, D. *Link Sustainability to Corporate Strategy Using the Balanced Scorecard*; The Balanced Scorecard Institute: Cary, NC, USA, 2011.
20. Lu, I.-Y.; Kuo, T.; Lin, T.-S.; Tzeng, G.-H.; Huang, S.-L. Multicriteria decision analysis to develop effective sustainable development strategies for enhancing competitive advantages: Case of the TFT-LCD industry in Taiwan. *Sustainability* **2016**, *8*, 646. [CrossRef]
21. Davis, S.; Albright, T. An investigation of the effect of balanced scorecard implementation on financial performance. *Manag. Account. Res.* **2004**, *15*, 135–153. [CrossRef]
22. Al-Najjar, S.M.; Kalaf, K.H. Designing a balanced scorecard to measure a bank's performance: A case study. *Int. J. Bus. Adm.* **2012**, *3*, 44. [CrossRef]
23. Montequín, V.R.; Fernández, F.O.; Pérez, C.Á.; Balsera, J.V. Scorecard and KPIs for monitoring software factories effectiveness in the financial sector. *Int. J. Inf. Syst. Proj. Manag.* **2013**, *1*, 29–43.
24. Saaty, T.L. A scaling method for priorities in hierarchical structures. *J. Math. Psychol.* **1977**, *15*, 234–281. [CrossRef]
25. Saaty, T.L. *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*; McGraw-Hill International Book Company: New York, NY, USA, 1980.
26. Wang, Y.; Xia, Q. A fuzzy AHP and BSC approach for evaluating performance of a software company based on knowledge management. In Proceedings of the IEEE 2009 First International Conference on Information Science and Engineering, Nanjing, China, 26–28 December 2009; pp. 2242–2245.
27. Dyer, J.S. Remarks on the analytic hierarchy process. *Manag. Sci.* **1990**, *36*, 249–258. [CrossRef]
28. Liu, D.; Bishu, R.R.; Najjar, L. Using the analytical hierarchy process as a tool for assessing service quality. *Ind. Eng. Manag. Syst.* **2005**, *4*, 129–135.
29. Hua Lu, M.; Madu, C.N.; Kuei, C.; Winokur, D. Integrating QFD, AHP and benchmarking in strategic marketing. *J. Bus. Ind. Mark.* **1994**, *9*, 41–50. [CrossRef]

30. Liberatore, M.J.; Monahan, T.F.; Stout, D.E. A framework for integrating capital budgeting analysis with strategy. *Eng. Econ.* **1992**, *38*, 31–43. [CrossRef]
31. Chan, Y.L.; Lynn, B.E. Performance evaluation and the analytic hierarchy process. *J. Manag. Account. Res.* **1991**, *3*, 57–87.
32. Thomas, S. *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*; Pittsburgh PA Univ.: Pittsburgh, PA, USA, 1980.
33. Saaty, T.L. How to make a decision: The analytic hierarchy process. *Eur. J. Oper. Res.* **1990**, *48*, 9–26. [CrossRef]
34. Voronin, A.N. A method of multicriteria evaluation and optimization of hierarchical systems. *Cybern. Syst. Anal.* **2007**, *43*, 384–390. [CrossRef]
35. Sharma, M.K.; Bhagwat, R. An integrated BSC-AHP approach for supply chain management evaluation. *Meas. Bus. Excell.* **2007**, *11*, 57–68. [CrossRef]
36. Saaty, T.L. An exposition of the AHP in reply to the paper "remarks on the analytic hierarchy process". *Manag. Sci.* **1990**, *36*, 259–268. [CrossRef]
37. Hosein, Z.Z.; Yousefie, A.; Mehrizi, S.M.T. Evaluating and Ranking Performance by Combination Model of Balanced Scorecard and Ariadne Uncertain Estimate. *Asian Soc. Sci.* **2014**, *10*, 70.
38. Noori, B. Prioritizing strategic business units in the face of innovation performance: Combining fuzzy AHP and BSC. *Int. J. Bus. Manag.* **2015**, *3*, 36–56. [CrossRef]
39. Yaghoobi, T.; Haddadi, F. Organizational performance measurement by a framework integrating BSC and AHP. *Int. J. Product. Perform. Manag.* **2016**, *65*, 959–976. [CrossRef]
40. Castrogiovanni, G.; Ribeiro-Soriano, D.; Mas-Tur, A.; Roig-Tierno, N. Where to acquire knowledge: Adapting knowledge management to financial institutions. *J. Bus. Res.* **2016**, *69*, 1812–1816. [CrossRef]
41. Chang, S.-C.; Tsai, P.-H. A hybrid financial performance evaluation model for wealth management banks following the global financial crisis. *Technol. Econ. Dev. Econ.* **2016**, *22*, 21–46. [CrossRef]
42. Rabbani, A.; Zamani, M.; Yazdani-Chamzini, A.; Zavadskas, E.K. Proposing a new integrated model based on sustainability balanced scorecard (SBSC) and MCDM approaches by using linguistic variables for the performance evaluation of oil producing companies. *Expert Syst. Appl.* **2014**, *41*, 7316–7327. [CrossRef]
43. Sundharam, V.N.; Sharma, V.; Stephan Thangaiah, I.S. An integration of BSC and AHP for sustainable growth of manufacturing industries. *Int. J. Bus. Excell.* **2013**, *6*, 77–92. [CrossRef]
44. Chung, C.-C.; Chao, L.-C.; Chen, C.-H.; Lou, S.-J. A Balanced Scorecard of Sustainable Management in the Taiwanese Bicycle Industry: Development of Performance Indicators and Importance Analysis. *Sustainability* **2016**, *8*, 518. [CrossRef]
45. Kaplan, R.S. Conceptual foundations of the balanced scorecard. *Handb. Manag. Account. Res.* **2008**, *3*, 1253–1269.
46. Caha, J.; Drážná, A. Information about Fuzzy AHP Package for R (Version 0.8.0). Available online: https://goo.gl/DXlLm8 (accessed on 20 March 2017).
47. Saaty, R.W. The analytic hierarchy process—What it is and how it is used. *Math. Model.* **1987**, *9*, 161–176. [CrossRef]
48. Malczewski, J. *GIS and Multicriteria Decision Analysis*; John Wiley & Sons: New York, NY, USA, 1999.
49. Amrit, C.; Daneva, M.; Damian, D. Human factors in software development: On its underlying theories and the value of learning from related disciplines. A guest editorial introduction to the special issue. *Spec. Issue Hum. Factors Softw. Dev.* **2014**, *56*, 1537–1542. [CrossRef]
50. Curtis, B.; Krasner, H.; Iscoe, N. A field study of the software design process for large systems. *Commun. ACM* **1988**, *31*, 1268–1287. [CrossRef]
51. Joint Technical Committee ISO/IEC JTC 1/SC7 ISO/IEC 25010:2011 Systems and Software Engineering—Systems and software Quality Requirements and Evaluation (SQuaRE)—System and Software Quality Models. Available online: https://www.iso.org/standard/35733.html (accessed on 20 March 2017).

4.2.3. PUBLICACIÓN – ARTÍCULO 3

Pérez, C.Á.; Montequín, V.R.; Fernández, F.O.; Balsera, J.V. Integration of Balanced Scorecard (BSC), Strategy Map, and Fuzzy Analytic Hierarchy Process (FAHP) for a Sustainability Business Framework: A Case Study of a Spanish Software Factory in the Financial Sector. Sustainability 2017, 9, 527. doi:10.3390/su9040527

sustainability

MDPI

Article

Integration of Balanced Scorecard (BSC), Strategy Map, and Fuzzy Analytic Hierarchy Process (FAHP) for a Sustainability Business Framework: A Case Study of a Spanish Software Factory in the Financial Sector

César Álvarez Pérez, Vicente Rodríguez Montequín *, Francisco Ortega Fernández and Joaquín Villanueva Balsera

Department of Project Engineering, University of Oviedo, C/Independencia 3, 33004 Oviedo, Spain; cesaralvarezcom@gmail.com (C.Á.P.); fran@api.uniovi.es (F.O.F.); balsera@api.uniovi.es (J.V.B.)
* Correspondence: montequi@api.uniovi.es; Tel.: +34-985-104-272

Academic Editor: Yongrok Choi
Received: 2 February 2017; Accepted: 28 March 2017; Published: 30 March 2017

Abstract: This paper presents a case study of how a Spanish financial software factory (FSF) has determined the weights of the indicators and objectives included in their strategy map with the aim of ensuring its business sustainability. A strategy map is a graphical representation of the cause-effect relationships between strategic objectives and indicators of a balanced scorecard (BSC). The detailed description of the strategy map development and deployment is not part of the aim of this work as it was described in a former paper. In this study, FAHP, a multicriteria decision-making (MCDM) method using the concepts of fuzzy set theory and hierarchical structure analysis, was used to calculate the weights. The analysis was carried out considering the points of view of different groups of stakeholders (shareholders, top management, middle managers, other employees, customers and some experts in the field of software factories) and the results are presented grouped by role to get a better understanding of the preferences of each kind of stakeholder. The conclusions of this study give a better insight of the corporative sustainability strategies of this kind of firms as well as the different vision of each stakeholder, what could be very valuable to the software factory managers for the decision-making and the strategic management of their organizations.

Keywords: balanced scorecard; strategy map; fuzzy analytic hierarchy process; software factory; software development

1. Introduction

The banking sector is one of the sectors that requires the most amount of software and the development of its business applications represents over 50% of the managed information technology (IT) budget [1], but banks usually pay for the time it takes to produce the software and not the amount produced, a model that in most cases increases the cost of the projects. Financial entities need software development firms to measure the "software production" they are delivering to them. With this information, they can create strategies to transform these software firms into industrialized software manufacturers able to provide software projects related to the efficiency, fast delivery and quality that the financial markets expect today [2]. In addition, since the advent of the Internet and especially since the emergence of smartphones, around the year 2007, banks have tried to relocate in order not to lose their dominant position in the financial sector, although, according to SAP and IBM [3], the traditional banking industry does not keep up very well with today's constantly changing technology landscape.

To solve these challenges, banking requires changes in the software factories that develop its software and systems to increase productivity and reduce costs to be able to face the new challenges in the sector.

Our paper [4] published at the end of 2015 describes the case in which a financial software factory FSF in Spain decided to review the concept of industrialization of software development to implement the principles and elements of the software factory approach [5]. This initial paper suggests a strategic management framework based on the balanced scorecard BSC [6,7] and the strategy map [8,9] to guarantee the business sustainability of FSF. One problem with this initial proposal of BSC framework is that it does not establish the importance weights of the indicators, perspectives and objectives defined in the strategy map of FSF. To know these weights, we have opted for the integration of BSC and strategy map with fuzzy analytic hierarchy process FAHP, a multicriteria decision-making useful method of calculating weights into an evaluation performance system [10] to ensure its sustainability.

The literature does not offer a general conceptual definition of sustainable business models in the context of technological, organizational and social innovation [11], but changes to business models are recognised as a fundamental approach to realise innovations for sustainability [12]. Wirtz's book [13] makes a systematic overview of business model management, and identifies three perspectives related to this model focused on: technology, organizational (deals with the business model as a strategic management tool to improve a company's value chain) and strategy-oriented (adds the element of market competition to the efficiency). The notion of sustainable business models builds on the business model concept and combines it with the important concepts of stakeholder management [14], sustainable value creation [15], and a long-term perspective. Sustainable business model is an emerging topic, but only few tools are currently available to assist companies in sustainable business modelling [16]. The sustainable business model outlined in this paper encourages the operational efficiency, long-term relationship with customers and a focus on their needs, expanding the customer portfolio and employee engagement.

This paper shows a case study in which a Spanish FSF opted to change its management system and establish a new framework based on a weighted strategy map with the aim of ensuring its business sustainability, which is related to achieving a viable sustainable business model over time in terms of productivity and profitability, through appropriate decision-making. In addition, the results will be analysed not only globally, but also by stakeholder roles grouped, which represents a fact to highlight compared to other studies that apply a similar methodology as this study.

The remainder of this paper is organized as follows. Section 2 reviews the literature related to the BSC, the strategy map, FAHP theory and their integration as an evaluation framework. Section 3 describes the research methodology. Section 4 shows the results of the study. Section 5 presents the analysis and discussion of the results. Finally, Section 6 exposes the conclusions, implications, limitations and future research directions related to this paper.

2. Sustainable Evaluation Framework for a FSF Based con BSC, Strategy Map and FAHP

This section includes a review of the literature on the BSC and the strategy map, paying particular attention to their application in a FSF. We then introduce the fuzzy set theory and the FAHP. Finally, and integration of the BSC and the strategy map with FAHP is presented to establish the importance weights for links among indicators and goals included in the strategy map for a sustainable evaluation framework.

2.1. The BSC for a FSF

In today's competitive world, every organization needs a management system that permits an awareness of the performance and productivity with which it is working in order to protect its competitive advantages. The productivity measure in software development is more difficult as is in other industries, due to the intangible nature of software and the difficult to measure output [17]. Nevertheless, it is a necessary management system that can monitor production. The BSC developed by Kaplan and Norton is probably the best–known management tool for companies. In 1992 and the

years that followed, Kaplan and Norton, of Harvard University, presented the BSC [6,7] as a corporate performance tool that allows managers to look at the business from four important perspectives: financial, customer, internal business processes and learning and growth. In the following years, Kaplan and Norton presented new views and ways to improve the initial BSC approach and linked it with measures, objectives and business strategy [18–20]. The BSC is applied by many businesses to assess their performance in diverse aspects of their organization, but it is only a template and must be customized for the specific elements of an organization. Since the BSC was introduced, many authors have proposed some modifications to adapt the initial BSC to other scorecards that were specific for different areas or industrial environments. Studies about the IT BSC [21,22] in the IT sector, the Sustainability BSC (SBSC) [23,24] for sustainable businesses, other studies such as [25,26] that expose the benefits of using the BSC in the financial sector, and finally the specific BSC for a FSF [4,27] are some examples in relation to this study.

Figure 1 shows the BSC for a FSF and includes the chosen key performance indicators (KPIs) with various fields assigned to each: Code, KPI Name, KPI Owner, Frequency Measurement, Value Measurement, Target Tendency and the Upper and Lower Control Limits to manage the stability of processes. This BSC was established by the FSF as a control tool for the top management of the organization according the strategic objectives and the mission and vision of the FSF defined in its strategy map. The KPIs were made in several work sessions with the participation of different roles of employees. Some of the KPIs were simple to create and easy to obtain, but others are difficult to obtain because they are a compendium of different indicators and measures. The top management and consultants review the validity of the KPIs annually, and KPIs are modified or adjusted if it is necessary. The description of the KPIs included in the BSC for a FSF are extensively explained in our prior paper [4].

BALANCED SCORECARD – FINANCIAL SOTWARE FACTORY

BALANCED SCORECARD – FINANCIAL SOTWARE FACTORY	STRATEGIC PERSPECTIVES	CODE	KPI NAME	KPI OWNER	FREQUENCY MEASUREMENT	VALUE MEASUREMENT	CONTROL LIMITS UPPER|LOWER	TARGET TENDENCY
	FINANCIAL	F1	Cost Structure	Management Control	Quarterly	Ratio	Upper|Lower Values	Decrement
		F2	Reduction of Cost	Management Control	Monthly	Percentage	Upper|Lower Values	Increase
		F3	Useful Developments	Production & Man. Control	Quarterly	Ratio	Upper|Lower Values	Increase
	CUSTOMER	C1	User Satisfaction	Marketing & Customers	Annual	Aggregate	Upper|Lower Values	Increase
		C2	Cost per Use	Management Control	Quarterly	Numeric Value	Upper|Lower Values	Decrement
		C3	SLA	Production & Man. Control	Monthly	Aggregate	Upper|Lower Values	Increase
	INTERNAL BUSINESS PROCESSES	I1	Work Performance	Management Control	Monthly	Percetage	Upper|Lower Values	Increase
		I2	Employee Productivity	Human R. & Man. Control	Monthly	Percentage	Upper|Lower Values	Increase
		I3	Delay	Management Control	Monthly	Numeric Value	Upper|Lower Values	Decrement
		I4	Software Quality	Quality	Biannual	Aggregate	Upper|Lower Values	Increase
		I5	Budgeting Error	Planning & Man. Control	Biannual	Percentage	Upper|Lower Values	Decrement
	LEARNING AND GROWTH	L1	Employer Branding	Human Resources	Biannual	Aggregate	Upper|Lower Values	Increase
		L2	Intellectual Capital	Organization &HR&Customers	Annual	Aggregate	Upper|Lower Values	Increase

Figure 1. The balanced scorecard (BSC) for a financial software factory (FSF). Adapted from [4].

2.2. The Strategy Map for a FSF

The main contribution of the BSC framework is that it includes performance measurements and strategic objectives. Kaplan and Norton introduced three principles that link the BSC of an organization to its own strategy: (1) cause–effect relationships; (2) performance drivers; and (3) linkage to financial goals [28]. Strategy maps are built according to the four perspectives of the BSC and they interface between the business strategy and the BSC. Strategy maps provide a visual framework that has been developed by companies in virtually all areas. In relation to this article, it is necessary to highlight the following proposals about the application of the BSC and the strategy maps in the financial sector [28,29], in the software development sector [30,31], in IT departments or companies [22,32,33] and other proposals related to business and corporate sustainability [24,34]. These studies are some examples about the application of strategy maps for linking measurements with business aims.

In software-intensive organizations, such as a software factory, it is necessary to link software measurement goals to higher-level goals. This linkage is important, as it helps to justify software measurement efforts and allows measurement data to contribute to higher-level decisions [30]. Furthermore, linking software activities to an organization's higher-level business goals can improve its performance [35]. Our prior paper [4] implements the business strategy in a FSF by applying the BSC framework, linking the measurement to higher-level goals for the FSF through its strategy map. Figure 2 shows the strategy map for a FSF. At the top of the strategy map are the strategic goals: the mission and vision, the two high-level goals and the six business goals. Under each business goal, a subset of KPIs is situated. This subset includes the KPIs that are directly linked and have an influence on each specific business goal. Every business goal has its own subset of KPIs, and every KPI can influence more than one business goal. This proposal shows the relationships among indicators, perspectives and objectives included in the strategy map, but it does not include weights for each of them.

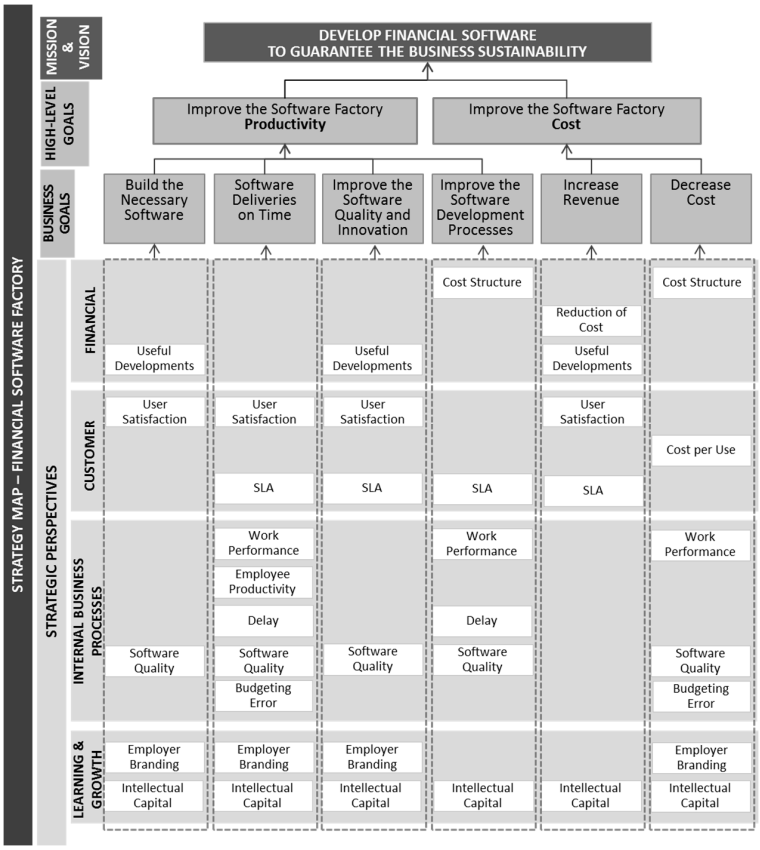

Figure 2. The strategy map for FSF. Adapted from [4].

2.3. Fuzzy Theory and FAHP

In this section, we review some relevant concepts as fuzzy numbers theory and its incorporation into the AHP, calling the resulting theory FAHP, used to determine criteria weights.

2.3.1. Fuzzy Numbers and Linguistic Variables

Evaluating different alternatives is a MCDM problem in the presence of many quantitative and qualitative attributes. The AHP is a method that has been widely used for selecting the best alternative among others [36,37], but fuzzy sets could be incorporated with the AHP, an approach that allows a more accurate description of the decision-making process [38]. Expressions such as "not very clear", "probably so", and "very likely" are used often in daily life and more or less represent some degree of uncertainty of human thought. The fuzzy set theory proposed by Zadeh in 1965 [39], an important concept applied in the scientific environment, has been available to other fields as well. Consequently, fuzzy theory has become a useful tool for automating human activities with uncertainty-based information [38]. Therefore, this research incorporates fuzzy theory into the performance measurement by objectifying the evaluators' subjective judgements. Below, some basic definitions of fuzzy sets, fuzzy numbers, and linguistic variables, mainly from Buckley, Zadeh, and others [40–44], are reviewed, similarly to those presented in other studies [38,45] that combine the FAHP and the BSC framework.

In classical set theory, the truth value of a statement can be given by the membership function as $\mu_A(x)$:

$$\mu_A(x) = \begin{cases} 1 \text{ if } x \in A \\ 0 \text{ if } x \notin A \end{cases} \tag{1}$$

Central to fuzzy set theory is the notion of the fuzzy number. Fuzzy numbers are a fuzzy subset of real numbers and they represent the expansion of the idea of a confidence interval. According to the definition by Dubois and Prade [46], the fuzzy number $\widetilde{A}$ is a fuzzy set and its membership function is $\mu_{\widetilde{A}}(x) : R \to [0,1] \left(0 \leqq \mu_{\widetilde{A}}(\chi) \leqq 1, x \in X\right)$, where x represents the criterion and is described by the following characteristics: (1) $\mu_{\widetilde{A}}(x)$ is a continuous mapping from R (real line) to the closed interval [0, 1]; (2) $\mu_{\widetilde{A}}(x)$ is a convex fuzzy subset; and (3) $\mu_{\widetilde{A}}(x)$ is the normalization of a fuzzy subset, which means that there exists a number x_0 such that $\mu_{\widetilde{A}}(x_0) = 1$.

In applications, it is often convenient to work with triangular fuzzy numbers (TFNs) because of their computational simplicity [47–49], and they are useful in promoting representation and information processing in a fuzzy environment [50]. For instance, the TFN $\widetilde{A} = (l, m, u)$ can be defined as Equation (2) and the TFN membership function is shown in Figure 3:

$$\mu_{\widetilde{A}}(x) = \begin{cases} (x-l)/(m-l) \text{ if } l \leq x \leq m \\ (u-x)/(u-m) \text{ if } m \leq x \leq u \\ 0 \text{ otherwise.} \end{cases} \tag{2}$$

Based on the characteristics of TFNs and the extension definitions proposed by Zadeh [41], given any two positive TFNs $\widetilde{A}_1 = (l_1, m_1, u_1)$ and $\widetilde{A}_2 = (l_2, m_2, u_2)$ and a positive real number r, some algebraic operations of the TFNs $\widetilde{A}_1$ and $\widetilde{A}_2$ can be expressed as follows:

$$\text{Addition of two TFNs } \oplus: \quad \widetilde{A}_1 \oplus \widetilde{A}_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2) \tag{3}$$

$$\text{Multiplication of two TFNs } \otimes: \quad \widetilde{A}_1 \otimes \widetilde{A}_2 = (l_1\, l_2, m_1\, m_2, u_1\, u_2) \tag{4}$$

$$\text{Multiplication of any real number } r \text{ and a TFN } \otimes: \quad r \otimes \widetilde{A}_1 = (rl_1, rm_1, ru_1) \text{ for } r > 0 \text{ and } l_i > 0,\ m_i > 0,\ u_i > 0 \tag{5}$$

$$\text{Subtraction of two TFNs } \ominus: \quad \widetilde{A}_1 \ominus \widetilde{A}_2 = (l_1 - u_2, m_1 - m_2, u_1 - l_2) \text{ for } l_i > 0,\ m_i > 0,\ u_i > 0 \tag{6}$$

$$\text{Division of two TFNs } \oslash: \quad \widetilde{A}_1 \oslash \widetilde{A}_2 = (l_1/u_2, m_1/m_2, u_1/l_2) \tag{7}$$

$$\text{Reciprocal of a TFN:} \quad \widetilde{A}_1^{-1} = (1/u_1, 1/m_1, 1/l_1) \text{ for } l_i > 0,\ m_i > 0,\ u_i > 0 \tag{8}$$

According to [41], a conventional quantification of reasonable expression in situations that are complex or hard to define is very difficult. In these cases, the notion of a linguistic variable is vital. Linguistic variables are variables whose values are words or sentences in a natural or artificial language. In other words, they are variables with lingual expression as their values [41,51].

This paper uses five basic linguistics terms for comparing the best plan evaluation criteria: "equally important", "weakly important", "essentially important", "very strongly important", and "absolutely important", according to the fundamental scale of Saaty [52]. The membership function of a linguistic term is defined by Mon et al. [53] and displayed in Table 1.

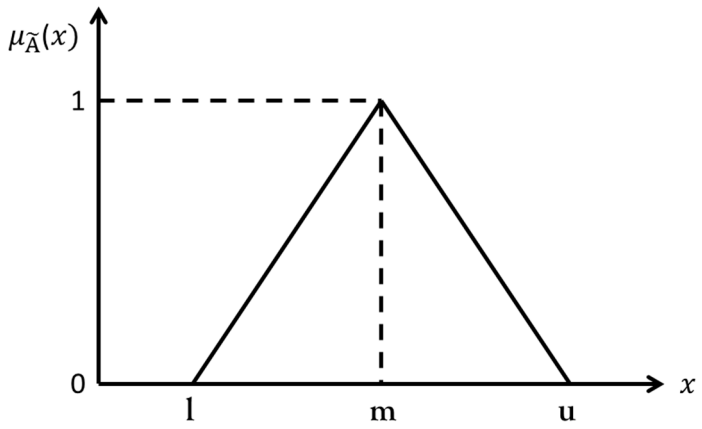

Figure 3. Membership function of the triangular fuzzy number (TFN).

Table 1. Membership function of the linguistic scale.

Fuzzy Number	Linguistic Scale	TFN ($\tilde{a}_{ij}$)	Reciprocal of a TFN ($\tilde{a}_{ij}$)
$\widetilde{1}$	Equally important	(1, 1, 3)	(1/3, 1, 1)
$\widetilde{3}$	Weakly important	(1, 3, 5)	(1/5, 1/3, 1)
$\widetilde{5}$	Essentially important	(3, 5, 7)	(1/7, 1/5, 1/3)
$\widetilde{7}$	Very strongly important	(5, 7, 9)	(1/9, 1/7, 1/5)
$\widetilde{9}$	Absolutely important	(7, 9, 9)	(1/9, 1/9, 1/7)
$\widetilde{2}, \widetilde{4}, \widetilde{6}, \widetilde{8}$	Intermediate value between two adjacent judgements		

The evaluators are asked to conduct their judgements, and each linguistic variable can be indicated by a TFN. An example of membership functions of five levels of linguistic variables is shown in Figure 4.

The use of linguistic variables is applied widely. In this paper, linguistic variables expressed by TFNs are adopted to represent evaluators' subjective measures to determine the degrees of importance among evaluation criteria and also to assess the performance value of alternatives.

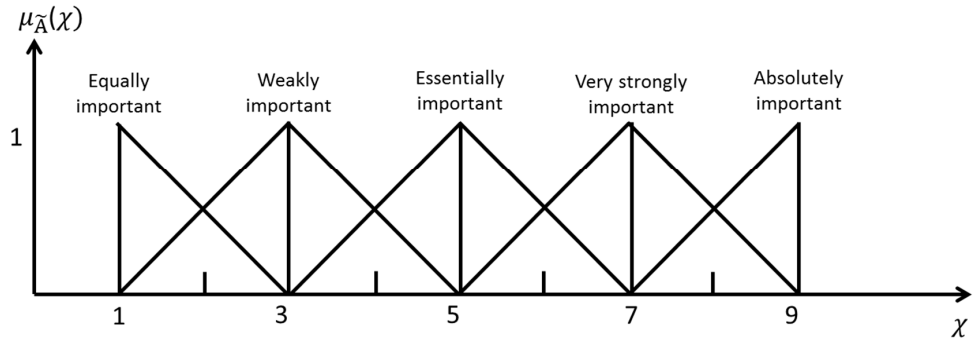

Figure 4. Membership functions of the linguistic variables for criteria comparisons.

2.3.2. FAHP

AHP was developed by Saaty in the 1970s [54–58], initially to solve the scarce resources allocation and planning needs of the military. Since its introduction, the AHP has become one of the most widely used MCDM methods and has been used to solve unstructured problems in different areas of human needs and interests [59]. Finally, the AHP became a useful approach to solve complex decision problems that prioritizes the relative importance of a list of criteria (critical factors and sub-factors) through pairwise comparisons amongst the factors by relevant experts using a nine-point scale. However, due to the vagueness and uncertainty of judgements of the decision-makers, the fuzzy number logic was introduced in the pairwise comparison of the AHP to make up for this deficiency in the conventional AHP [60]. Buckley [40] incorporated fuzzy theory into the AHP, calling the resulting theory FAHP. In 1996, Chang introduced a new approach for handling FAHP with the use of TFNs [61] for pairwise comparisons. FAHP generalizes the calculation of the consistent ratio into a fuzzy matrix.

The procedure of the FAHP for determining the evaluation weights is explained as follows:

- *Step 1: Construct fuzzy pairwise comparison matrices*. Through expert questionnaires, each expert is asked to assign linguistic terms by TFNs (as shown in Table 2 and Figure 4) to the pairwise comparisons among all criteria in the dimensions of a hierarchy system. The result of the comparisons is constructed as fuzzy pairwise comparison matrices ($\widetilde{A}$) as shown in Equation (9).
- *Step 2: Examine the consistency of the fuzzy pairwise comparison matrices*. According to this research [40], it proves that if $A = [a_{ij}]$ is a positive reciprocal matrix then $\widetilde{A} = [\widetilde{a}_{ij}]$ is a fuzzy positive reciprocal matrix. That is, if the result of the comparisons of $A = [a_{ij}]$ is consistent, it implies that the result of the comparisons of $\widetilde{A} = [\widetilde{a}_{ij}]$ is also consistent. Therefore, this research employs this method to validate the questionnaire:

$$\widetilde{A} = \begin{bmatrix} 1 & \widetilde{a}_{12} & \cdots & \widetilde{a}_{1n} \\ \widetilde{a}_{21} & 1 & \cdots & \widetilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{a}_{n1} & \widetilde{a}_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \widetilde{a}_{12} & \cdots & \widetilde{a}_{1n} \\ 1/\widetilde{a}_{12} & 1 & \cdots & \widetilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\widetilde{a}_{1n} & 1/\widetilde{a}_{2n} & \cdots & 1 \end{bmatrix} \quad (9)$$

- *Step 3: Compute the fuzzy geometric mean for each criterion.* The geometric technique is used to calculate the geometric mean ($\widetilde{r}_i$) of the fuzzy comparison values of criterion i to each criterion, as shown in Equation (10), where $\widetilde{a}_{in}$ is a fuzzy value of the pairwise comparison of criterion i to criterion n [40].

$$\widetilde{r}_i = [\widetilde{a}_{i1} \otimes \cdots \otimes \widetilde{a}_{in}]^{1/n} \quad (10)$$

- *Step 4: Compute the fuzzy weights by normalization.* The fuzzy weight of the ith criterion ($\widetilde{w}_i$) can be derived as Equation (11), where $\widetilde{w}_i$ is denoted as $\widetilde{w}_i = (L_{wi}, M_{wi}, U_{wi})$ by a TFN and L_{wi}, M_{wi}, and U_{wi} represent the lower, middle, and upper values of the fuzzy weight of the ith criterion.

$$\widetilde{w}_i = \widetilde{r}_i \otimes (\widetilde{r}_1 \oplus \widetilde{r}_2 \oplus \cdots \oplus \widetilde{r}_n)^{-1} \tag{11}$$

2.3.3. The Synthetic Value of Fuzzy Judgement

Since Bellman and Zadeh [62] proposed the decision-making methods in fuzzy environments in 1970, an increasing number of related models have been applied in various fields, including control engineering, expert systems, artificial intelligence, management science, operations research, and MCDM. The main application to decision-making problems is focused on criteria evaluation or project selection and can assist in selecting the best alternative or ranking the order of projects or alternatives.

Due to the differences in the subjective judgements among the experts about each evaluation criterion, the overall valuation of the fuzzy judgement is employed to synthesize the various experts' opinions in order to achieve a reasonable and objective evaluation. The calculation steps to obtain the synthetic value are as follows:

- *Step 1: Performance evaluation of the alternatives.* Against the evaluation criteria, each linguistic variable can be represented by a TFN. Assume that $\widetilde{E}_{ij}^k$ denotes the fuzzy valuation of performance given by the evaluator k towards alternative i under criterion j, as Equation (12) shows, then:

$$\widetilde{E}_{ij}^k = \left(LE_{ij}^k, ME_{ij}^k, UE_{ij}^k\right) \tag{12}$$

In this research, $\widetilde{E}_{ij}^k$ represents the average fuzzy judgement values integrated by m evaluators as

$$\widetilde{E}_{ij} = (1/m) \otimes \left(\widetilde{E}_{ij}^1 \oplus \widetilde{E}_{ij}^2 \oplus \cdots \oplus \widetilde{E}_{ij}^m\right) \tag{13}$$

According to Buckley [40], the three end points of $\widetilde{E}_{ij}$ can be computed as

$$LE_{ij} = \left(\sum_{k=1}^{m} LE_{ij}^k\right)/m,\ ME_{ij} = \left(\sum_{k=1}^{m} ME_{ij}^k\right)/m,\ UE_{ij} = \left(\sum_{k=1}^{m} UK_{ij}^k\right)/m \tag{14}$$

- *Step 2: Fuzzy synthetic judgement.* According to the fuzzy weight, $\widetilde{w}_j$, of each criterion calculated by FAHP, the criteria vector ($\widetilde{w}$) is derived as Equation (15). The fuzzy performance matrix ($\widetilde{E}$), as presented in Equation (16), of all the alternatives can be acquired from the fuzzy performance value of each alternative under n criteria.

$$\widetilde{w} = \left(\widetilde{w}_1, \cdots, \widetilde{w}_j, \cdots \widetilde{w}_n\right)^t, \tag{15}$$

$$\widetilde{E} = \left[\widetilde{e}_{ij}\right] \tag{16}$$

Then, the final fuzzy synthetic decision can be deduced from the criteria weight vector ($\widetilde{w}$) and the fuzzy performance matrix ($\widetilde{E}$), and then the derived result, the final fuzzy synthetic decision matrix ($\widetilde{R}$), is calculated by $\widetilde{R} = \widetilde{E} \leftrightarrow \widetilde{w}$, where the sign $\leftrightarrow$ indicates the computation of the fuzzy number, consisting of both fuzzy addition and fuzzy multiplication. Considering that the computation of fuzzy multiplication is rather complicated, the approximate result of the fuzzy multiplication is used here. For instance, the approximate fuzzy number ($\widetilde{R}_i$) of the fuzzy synthetic decision of the alternative i is denoted as Equation (17), where LR_i, MR_i, and UR_i are the lower, middle, and upper synthetic performance values of alternative i, respectively, and the calculations of each are illustrated as Equation (18).

$$\widetilde{R}_i = (LR_i, MR_i, UR_i) \tag{17}$$

where

$$LR_i = \sum_{j=1}^{n} Lw_j \times LE_{ij},\ MR_i = \sum_{j=1}^{n} Mw_j \times ME_{ij},\ UR_i = \sum_{j=1}^{n} Uw_j \times UE_{ij}. \quad (18)$$

Next, the procedure of defuzzification [51,63] locates the best nonfuzzy performance (BNP) value. There are different methods that can be used in such defuzzified fuzzy ranking, but in this study we used the Center of Area method to find out the BNP because it is simple and practical without the need to bring in the preferences of any evaluators. The BNP value of the fuzzy number $\widetilde{R}_i$ can be found by

$$BNP_i = \frac{[(UR_i - LR_i) + (MR_i - LR_i)]}{3} + LR_i \forall i \quad (19)$$

According to the value of the derived BNP for each alternative, the weight of each of the alternatives and criteria can then proceed.

2.4. Integration of BSC and Strategy Map Framework with FAHP

Although the integration of BSC with MCDM techniques such as AHP or FAHP has usually been adopted as a useful method of calculating weights and can help establish an evaluation performance system, the integration of strategy maps with AHP or FAHP to establish the importance or weights for business strategic objectives has only been used in a few studies. In most cases, it has been used to define the strategy map of a company, but this study integrates the BSC and the strategy map of a FSF with FAHP to assess the impact of each indicators measure changes in the affected business strategies, facilitating to the FSF managers the decision-making based on the improvement of the desired strategy. Wu [28] presents a structural evaluation methodology to link KPIs into a strategy map of the BSC for banking institutions, using MCDM analytical techniques to construct the strategy map for banks. For information services firms, Chen and Wang [64] propose a fuzzy–delphi AHP combined with performance indexes to help firms adjust their business strategies and make better business decisions. Ren et al. [65] present a comprehensive methodology with AHP to translate strategic objectives into performance metrics in supply-chain decision-making, linking the strategy map to low-level metrics with weights. Taticchi et al. [66] present a framework based on business performance measurements and AHP for providing direction and guidance to an organization. It identifies cause–effect relationships in business processes and measures performance and business strategic objectives in a hierarchical strategy branch. Quezada et al. [67] present an application of AHP to support the creation of a strategy map and propose the relationships that are important (with weights for each of them) within the strategy map. With a similar aim, another paper of Quezada and López-Ospina [68] presents a method of designing a strategy map using AHP and linear programming. Lu et al. [69] propose a multicriteria decision analysis to develop effective sustainable development strategies for enhancing competitive advantages. Finally, in the auto industry and dairy companies, respectively, Abdolshah et al. [70] and Sorayaei et al. [71] propose an integrated approach to analyse the strategy map using the BSC and the FAHP, and they determine weights for each strategy and each aspect.

The study presented here proposes an integration of BSC and strategy map with FAHP to determine the relative weights for the KPIs and objectives included in the strategy map to assess the impact of changes in the mission and vision of the organization.

3. Methodology

This section presents the research methods used to conduct the study. We explain the methodology steps and how the necessary data and information to address the research objectives were collected, presented and analysed.

3.1. Methodology Steps

In this research, the BSC and the strategy map for a FSF were taken as the framework for establishing weights for KPIs, perspectives, business goals, and high-level goals. The analytical structure of this research is explained in Figure 5. We first used the BSC and the strategy map for a FSF to study the different KPIs and strategic objectives and then we interviewed several managers in a Spanish FSF. We then got the views of software factory experts and we designed a pairwise comparison questionnaire based on the hierarchical structure of the BSC and the strategy map. Finally, FAHP was applied to obtain the weights of KPIs and objectives included in the strategy map. Afterwards, these weights were treated with the purpose of determining the influence that KPI measures exert on the mission and vision of the organization, depending on the business strategy to be valued.

The steps taken to achieve this purpose are as follows:

1. Analyse the BSC and the strategy map of the FSF.
2. Define the hierarchical framework related to the BSC and strategy map of FSF.
3. Prepare a questionnaire in AHP format to obtain the opinions of experts regarding KPIs, perspectives and goals, under the premise of achieving the mission and vision defined in the strategy map of the organization.
4. Prepare the answers obtained from the experts and give these answers the necessary format for their computer treatment with FAHP software.
5. Calculate the local and overall weights of all the KPIs and perspectives included in the BSC.
6. Calculate the local and global weights of all the objectives included in the strategy map.
7. Based on the relationships between KPIs and goals defined in the strategy map, calculate the relative weight of each indicator according to the business goal that it affects directly. The total weight of the indicators is distributed in proportion to the weight of the affected business goals.
8. Incorporate the calculated weights in the strategy map, which allows the impact of each KPI on the mission and vision of the organization to be known.

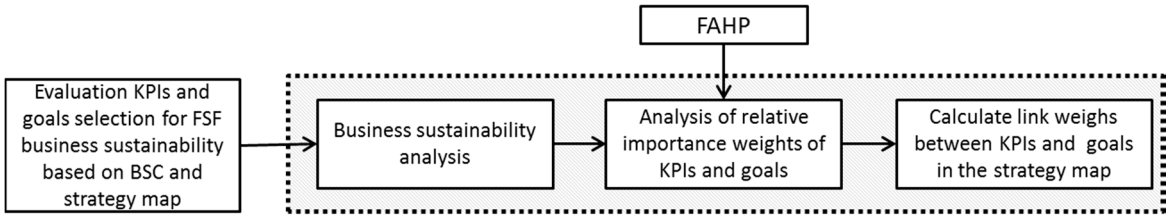

Figure 5. Performance evaluation framework of the research.

3.2. Hierarchical Framework of the BSC and the Strategy Map for Evaluation Criteria in a FSF

The BSC and the strategy map for a FSF have been adopted as hierarchical models in this study. The hierarchical framework of the BSC performance evaluation criteria and sub-criteria (i.e., four perspectives and thirteen KPIs) for a FSF is shown in Figure 6 and uses the four perspectives of the BSC for FSF and the indicators included in each one of them to create the hierarchy. The thirteen KPIs are grouped into the four BSC perspectives: "F: Financial (F1–F3)", "C: Customer (C1–C3)", "I: Internal Business Process (I1–I5)", and "L: Learning and Growth (L1–L2)". On the other hand, the hierarchical framework of the strategy map evaluation criteria and sub-criteria (i.e., six business goals and two high-level goals) for a FSF is shown in Figure 7 and uses the existing relationships between the strategic objectives defined in the strategy map to create the hierarchy. The six business goals are grouped into the two high-level goals: "HLG1: Improve Productivity (BG1–BG4)" and "HLG2: Improve Cost (BG5–BG6)". These hierarchies provide a structure to express the organization's needs [72] and directly support achievement of the mission and vision of the company [24].

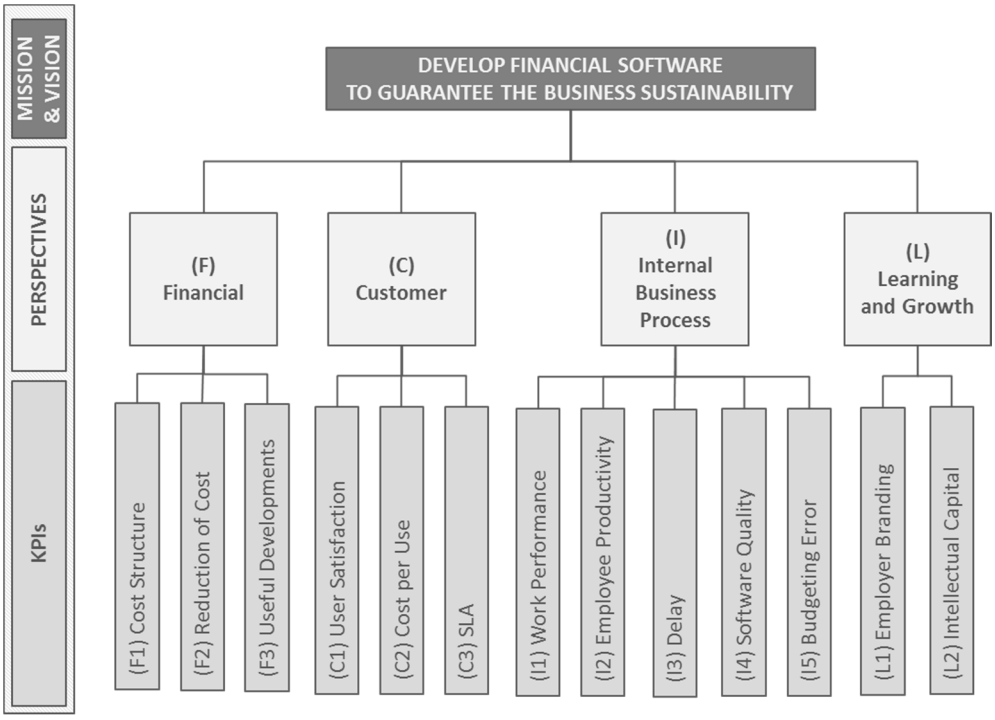

Figure 6. Hierarchical framework of BSC for FSF.

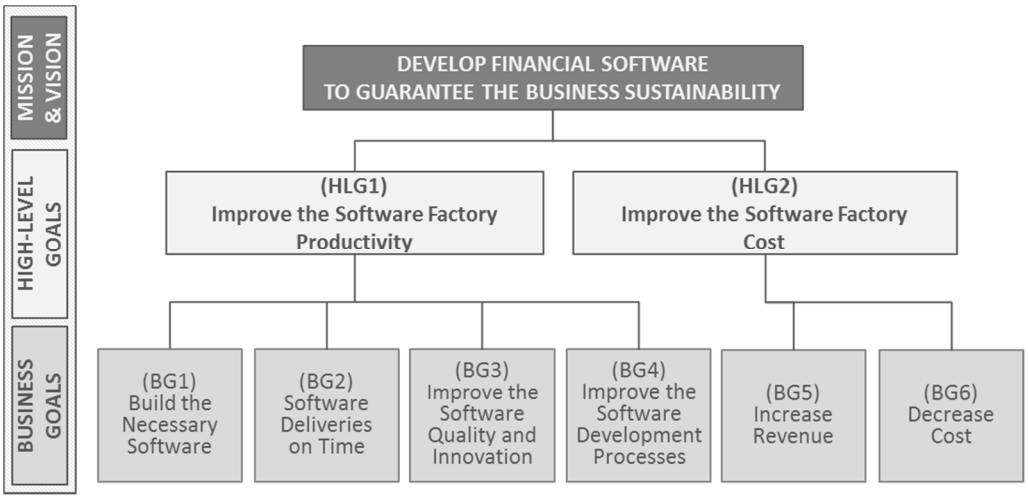

Figure 7. Hierarchical framework of strategy map for FSF.

3.3. Data Collection

Based on the hierarchies shown in Figures 6 and 7, a questionnaire to find out the participants' judgements was designed with a conventional AHP questionnaire format, the five-point linguistic scale shown in Table 1, and pairwise comparison. The questionnaire included the definition and meaning of each criterion or sub-criterion included in every question. After the questionnaire was designed, it was given to some experts, shareholders, and managers of a FSF to test its reliability and validity. Their corrective views were taken into consideration in the final design to avoid potential interpretation errors when the different stakeholders answered the questionnaire. An instruction sheet for completing the questionnaire was created to assist respondents and an example of how the questionnaire should be filled in was given to them. A total of 83 questionnaires were distributed (by email and online form) to stakeholders with different roles related with the FSF. These were grouped, according to the proposal

of roles made by the top management of the FSF and the purpose of consider different types of points of view, into Shareholders, Top management, Middle managers, Other employees, Customers and Experts in the field of software factories. The latter were included to seek their professional opinions and the purpose of weighting criteria under the FSF business sustainability aim. Table 2 shows the different stakeholder roles and their relation with a FSF.

Table 2. Different stakeholder roles and their relation with a FSF.

Stakeholder Roles	Relation with the FSF
Shareholders	The shareholders are the owners of the company. They are usually top management of the financial entities involved in the same financial group.
Top management	Top management are the highest ranking executives responsible for the entire FSF. They translate policy into goals and strategies for the future. Top management make decisions affecting everyone in the software factory.
Middle managers	The middle managers are the employees of the FSF who manage at least one subordinate level of managers, and report to the top management in the organisation to ensure smooth functioning of the software factory.
Other employees	Other employees are the lowest level of managers and the rest of the employees of the software factory, including analysts and developers.
Customers	Customers are the financial entities for which the software factory develops software and offers services to them.
Experts	Experts are a group of managers of other software factories from different sectors, professors and researchers in relation to software factories.

Finally, 61 questionnaires were received (73.5% of questionnaires sent). The questionnaire responses were revised and adapted to the necessary format in order to put this information into the FAHP system (the software used in this study was the FuzzyAHP package of R [73]) generating the pairwise comparison matrixes. The questionnaires that did not pass the consistency test (used to directly estimate the consistency of pairwise comparisons [56]) were revised and the values of the comparison matrix were considered and checked. In those cases in which the adjustments were minor or not significant, the procedure was repeated [74]. The definitive number of valid questionnaires was 44 (72.1% of questionnaires received). Table 3 shows the number and percentage of questionnaires sent, received and validated by stakeholder role. Finally, the FAHP system calculated the comparison weights and generates as output of the FAHP process the result with the weights of the KPIs, perspectives and strategic objectives.

Table 3. Number and percentage of sent, received and valid questionnaires by role.

Stakeholder Roles	Number of Sent Questionnaires	Number of Received Questionnaires		Number of Valid Received Questionnaires	
Shareholders	13	9	69.2%	6	66.7%
Top Management	12	8	66.7%	6	75.0%
Middle Managers	15	13	86.7%	8	61.5%
Other Employees	13	6	46.1%	5	83.3%
Customers	15	14	93.3%	10	71.4%
Experts in Software Factories	15	11	73.3%	9	81.8%
Total	**83**	**61**	73.5%	**44**	72.1%

4. Results: A Case Study for a Spanish FSF

The results of this study are shown in two different ways: first they are shown globally as a main result of this research. Then, the results are shown grouped by stakeholder roles, which allow assessing the different points of view according to the relationship of each role with the software factory.

4.1. Global Results

The intermediate global results of the study are shown in Tables 4 and 5. Table 4 shows the results for the weights of KPIs and perspectives in the BSC ranked by weights. The Customer Perspective, with a priority weight of 0.4254, is the most important perspective. This is followed by the Financial Perspective, with a priority weight of 0.2134. The priority weight of the Learning and Growth Perspective is 0.1808, and the Internal Business Processes Perspective has the lowest priority weight of 0.1804. The priority order of the thirteen KPIs shows that User Satisfaction, with a priority weight of 0.2109, and SLA with 0.1268 (both included in the Customer Perspective), are the most important KPIs among all of those included in the BSC for a FSF. The third most important KPI is Intellectual Capital, with a weight of 0.1053 (included in the Learning and Growth Perspective), followed by Cost Structure, with a weight of 0.0877 (included in the Financial Perspective). The eighth KPI is Software Quality, with a weight of 0.0633 (included in the Internal Business Processes Perspective). Table 5 shows the results for the weights of objectives in the strategy map ranked by weights. The Improve Productivity high-level goal (HLG) is the most important of the two, with a priority weight of 0.7083, and the other HLG, Improve Costs, has a priority weight of 0.2917. The priority order of the six business goals shows that Building the Necessary Software and Software Deliveries on Time are the most important strategies among the business goals.

Table 4. Fuzzy weights of BSC for a FSF sustainable business index by FAHP.

Criteria and Sub-Criteria (Perspectives and KPIs)	Local Weights TFN (*L*, *M*, *U*)	Overall Weights TFN (*L*, *M*, *U*)	BNP [1]	STD BNP [2]	Rank of Weights
(F) Financial	**(0.1148; 0.2035; 0.3518)**		**0.2234**	**0.2134**	**2**
(F1) Cost Structure	(0.2870; 0.4134; 0.5503)	(0.0329; 0.0841; 0.1936)	0.1036	0.0877	4
(F2) Reduction of Cost	(0.1568; 0.2438; 0.3741)	(0.0180; 0.0496; 0.1316)	0.0664	0.0562	9
(F3) Useful Developments	(0.2255; 0.3429; 0.4844)	(0.0259; 0.0698; 0.1704)	0.0887	0.0751	6
(C) Customer	**(0.2957; 0.4586; 0.5817)**		**0.4454**	**0.4254**	**1**
(C1) User Satisfaction	(0.3781; 0.5411; 0.6655)	(0.1118; 0.2481; 0.3871)	0.2490	0.2109	1
(C2) Cost per Use	(0.1090; 0.1712; 0.2881)	(0.0322; 0.0785; 0.1676)	0.0928	0.0786	5
(C3) SLA	(0.1745; 0.2876; 0.4568)	(0.0516; 0.1319; 0.2657)	0.1497	0.1268	2
(I) Internal Business Processes	**(0.1057; 0.1712; 0.2897)**		**0.1889**	**0.1804**	**4**
(I1) Work Performance	(0.1376; 0.2118; 0.3225)	(0.0145; 0.0363; 0.0934)	0.0481	0.0407	10
(I2) Employee Productivity	(0.0955; 0.1516; 0.2431)	(0.0101; 0.0260; 0.0704)	0.0355	0.0301	12
(I3) Delay	(0.0979; 0.1587; 0.2558)	(0.0103; 0.0272; 0.0741)	0.0372	0.0315	11
(I4) Software Quality	(0.2361; 0.3698; 0.5018)	(0.0250; 0.0633; 0.1454)	0.0779	0.0659	8
(I5) Budgeting Error	(0.0675; 0.1082; 0.1944)	(0.0071; 0.0185; 0.0563)	0.0273	0.0231	13
(L) Learning and Growth	**(0.1078; 0.1667; 0.2934)**		**0.1893**	**0.1808**	**3**
(L1) Employer Branding	(0.2644; 0.3708; 0.5154)	(0.0285; 0.0618; 0.1512)	0.0805	0.0682	7
(L2) Intellectual Capital	(0.4846; 0.6292; 0.7356)	(0.0522; 0.1049; 0.2158)	0.1243	0.1053	3

[1] BNP (Best non-fuzzy performance) = $[(U - L) + (M - L)]/3 + L$. [2] STD_BNP: standardised BNP.

Table 5. Fuzzy weights of goals of strategy map for a FSF sustainable business index by FAHP.

Criteria and Sub-Criteria (HLG and Business Goals)	Local Weights TFN (*L*, *M*, *U*)	Overall Weights TFN (*L*, *M*, *U*)	BNP [1]	STD BNP [2]	Rank of Weights
(HLG1) Improve Productivity	**(0.6243; 0.7156; 0.8180)**		**0.7193**	**0.7083**	**1**
(BG1) Build the Necessary SW	(0.1959; 0.2971; 0.4056)	(0.1223; 0.2126; 0.3318)	0.2222	0.2043	1
(BG2) SW Deliveries on Time	(0.1730; 0.2679; 0.3850)	(0.1080; 0.1917; 0.3149)	0.2049	0.1883	2
(BG3) Improve the SW Quality and Innovation	(0.1642; 0.2541; 0.3740)	(0.1025; 0.1818; 0.3059)	0.1967	0.1808	3
(BG4) Improve the SW Development Processes	(0.1197; 0.1810; 0.2881)	(0.0747; 0.1295; 0.2357)	0.1466	0.1348	5
(HLG2) Improve Cost	**(0.2099; 0.2845; 0.3946)**		**0.2963**	**0.2917**	**2**
(BG5) Increase Revenue	(0.4340; 0.5550; 0.6875)	(0.0911; 0.1579; 0.2713)	0.1734	0.1594	4
(BG6) Decrease Cost	(0.3602; 0.4450; 0.5821)	(0.0756; 0.1266; 0.2297)	0.1440	0.1323	6

[1] BNP (Best non-fuzzy performance) = $[(U - L) + (M - L)]/3 + L$. [2] STD_BNP: standardised BNP.

The result of the study is shown in Table 6. This table shows the link weights between KPIs and business goals in the strategy map. The overall weight of each KPI has been distributed in proportion to the weight of the business goals affected by this indicator, thus obtaining both the overall impact on the organization's mission and the particular impact of each KPI according to the different strategies defined by the business goals. Finally, Figure 8 shows the strategy map of a FSF and the calculated link weights between KPIs and strategic goals.

Table 6. Fuzzy weights of links between KPIs and business goals in the strategy map for a FSF.

KPIs and Business Goals	KPI and Business Goal Overall Weights	Link Weights between KPIs and Business Goals
(F1) Cost Structure	**0.0877**	
(BG4) Improve the Software Development Processes	0.1348	0.0443
(BG6) Decrease Cost	0.1323	0.0434
(F2) Reduction of Cost	**0.0562**	
(BG5) Increase Revenue	0.1595	0.0562
(F3) Useful Developments	**0.0751**	
(BG1) Build the Necessary Software	0.2043	0.0282
(BG3) Improve the Software Quality and Innovation	0.1808	0.0249
(BG5) Increase Revenue	0.1595	0.0220
(C1) User Satisfaction	**0.2109**	
(BG1) Build the Necessary Software	0.2043	0.0588
(BG2) Software Deliveries on Time	0.1883	0.0542
(BG3) Improve the Software Quality and Innovation	0.1808	0.0520
(BG5) Increase Revenue	0.1595	0.0459
(C2) Cost per Use	**0.0786**	
(BG6) Decrease Cost	0.1323	0.0786
(C3) Service Level Agreements (SLA)	**0.1268**	
(BG2) Software Deliveries on Time	0.1883	0.0360
(BG3) Improve the Software Quality and Innovation	0.1808	0.0346
(BG4) Improve the Software Development Processes	0.1348	0.0258
(BG5) Increase Revenue	0.1595	0.0305
(I1) Work Performance	**0.0407**	
(BG2) Software Deliveries on Time	0.1883	0.0168
(BG4) Improve the Software Development Processes	0.1348	0.0120
(BG6) Decrease Cost	0.1323	0.0118
(I2) Employee Productivity	**0.0301**	
(BG2) Software Deliveries on Time	0.1883	0.0301
(I3) Delay	**0.0315**	
(BG2) Software Deliveries on Time	0.1883	0.0184
(BG4) Improve the Software Development Processes	0.1348	0.0131
(I4) Software Quality	**0.0659**	
(BG1) Build the Necessary Software	0.2043	0.0160
(BG2) Software Deliveries on Time	0.1883	0.0148
(BG3) Improve the Software Quality and Innovation	0.1808	0.0142
(BG4) Improve the Software Development Processes	0.1348	0.0106
(BG6) Decrease Cost	0.1323	0.0104
(I5) Budgeting Error	**0.0231**	
(BG2) Software Deliveries on Time	0.1883	0.0136
(BG6) Decrease Cost	0.1323	0.0095
(L1) Employer Branding	**0.0682**	
(BG1) Build the Necessary SW	0.2043	0.0197
(BG2) Software Deliveries on Time	0.1883	0.0182
(BG3) Improve the Software Quality and Innovation	0.1808	0.0175
(BG6) Decrease Cost	0.1323	0.0128
(L2) Intellectual Capital	**0.1053**	
(BG1) Build the Necessary Software	0.2042	0.0215
(BG2) Software Deliveries on Time	0.1883	0.0198
(BG3) Improve the Software Quality and Innovation	0.1808	0.0190
(BG4) Improve the Software Development Processes	0.1348	0.0142
(BG5) Increase Revenue	0.1595	0.0168
(BG6) Decrease Cost	0.1323	0.0139

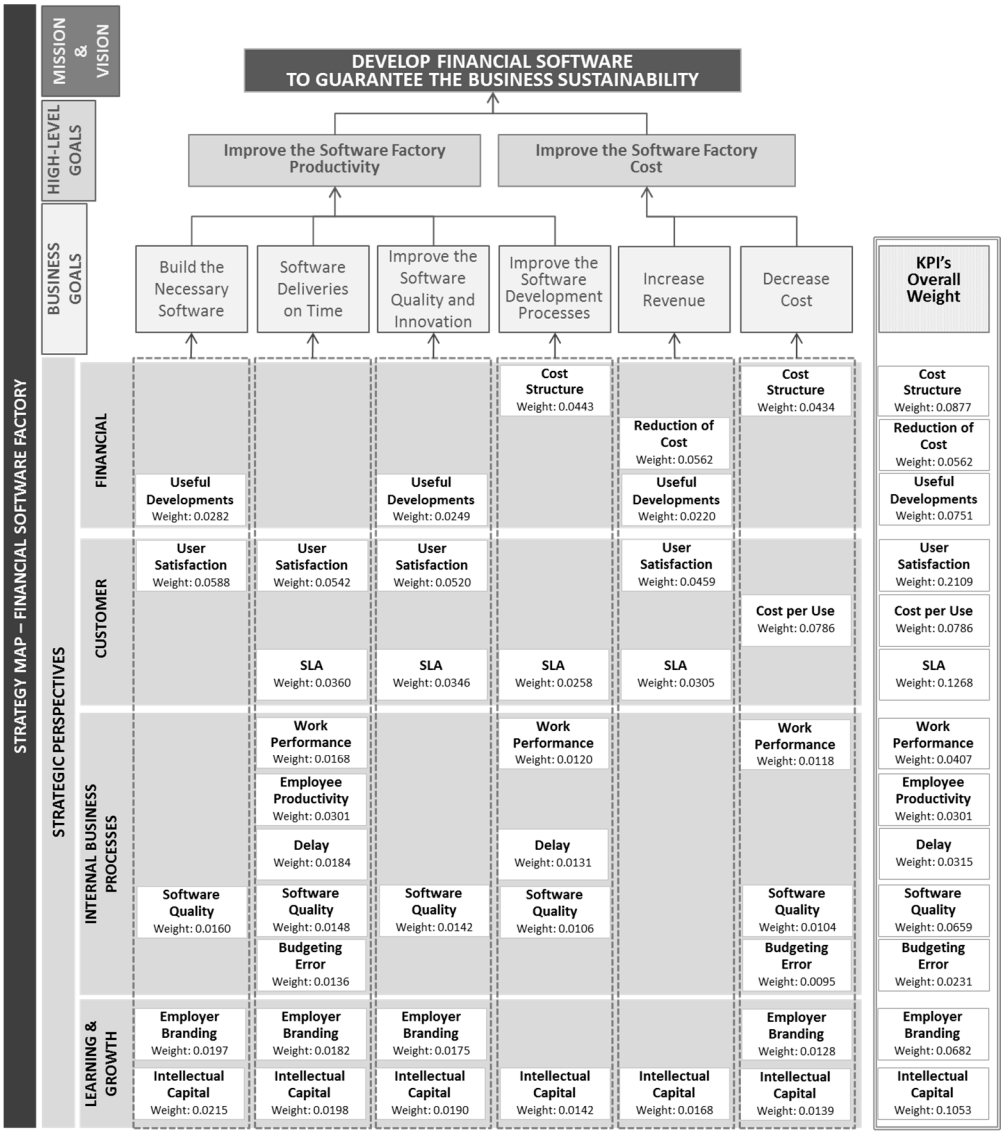

Figure 8. The strategy map of a FSF with weights for links between KPIs and business goals.

4.2. Results Grouped by Stakeholder Roles

Table 7 shows the results about KPIs and perspectives of BSC by stakeholder role. As is shown, the results by role in the FAHP analysis reveal that the Customer Perspective is the primary focus of the BSC, and User Satisfaction is the most important evaluation KPI. The Customer Perspective is the most important by role (Other Employees being the only exception), but User Satisfaction is the best ranking KPI in all cases. The SLA indicator is globally the second most important KPI, and is mostly one of the four most important KPIs for the different roles (Other Employees is again the only exception). The third most important KPI is Intellectual Capital, which is always one of the five most important KPIs for the different roles.

Table 8 shows the results about strategic goals of the strategy map by role. These results grouped by role show that Improve Productivity is the main HLG for all roles, with a weight always higher than 0.6384. Results by role for business goals show that none of them is determinant for all roles.

Table 7. Weights of KPIs and perspectives of BSC for a FSF sustainable business, index by FAHP according to the different stakeholder roles.

Criteria and Sub-Criteria/ Stakeholder Roles	Total/ Global	Share-Holders	Top Management	Middle Managers	Other Employees	Customers	Experts
(F) Financial	**0.2134**	**0.2315**	**0.1733**	**0.2210**	**0.2809**	**0.1597**	**0.2471**
(F1) Cost Structure	0.0877	0.1386	0.0538	0.0916	0.1029	0.0686	0.0858
(F2) Reduction of Cost	0.0562	0.0487	0.0559	0.0655	0.0567	0.0363	0.0759
(F3) Useful Developments	0.0751	0.0414	0.0700	0.0725	0.1202	0.0615	0.0936
(C) Customer	**0.4254**	**0.4810**	**0.4415**	**0.4144**	**0.2780**	**0.4391**	**0.4254**
(C1) User Satisfaction	0.2109	0.1947	0.2009	0.2004	0.1437	0.2155	0.2223
(C2) Cost per Use	0.0786	0.1762	0.0914	0.0455	0.0570	0.0676	0.0801
(C3) SLA	0.1268	0.1037	0.1357	0.1552	0.0726	0.1494	0.1095
(I) Internal Business Processes	**0.1804**	**0.1620**	**0.2398**	**0.2000**	**0.2296**	**0.1635**	**0.1379**
(I1) Work Performance	0.0407	0.0333	0.0447	0.0388	0.0587	0.0392	0.0379
(I2) Employee Productivity	0.0301	0.0252	0.0214	0.0251	0.0416	0.0423	0.0278
(I3) Delay	0.0315	0.0276	0.0541	0.0376	0.0427	0.0230	0.0242
(I4) Software Quality	0.0659	0.0658	0.0977	0.0869	0.0883	0.0580	0.0346
(I5) Budgeting Error	0.0231	0.0273	0.0373	0.0241	0.0210	0.0134	0.0287
(L) Learning and Growth	**0.1808**	**0.1255**	**0.1455**	**0.1647**	**0.2115**	**0.2377**	**0.1896**
(L1) Employer Branding	0.0682	0.0304	0.0543	0.0697	0.0604	0.1200	0.0665
(L2) Intellectual Capital	0.1053	0.0872	0.0829	0.0872	0.1345	0.1053	0.1132

Table 8. Weights of business goals and high-level goals of strategy map for a FSF sustainable business, index by FAHP according to the different stakeholder roles.

Criteria and Sub-Criteria/ Stakeholder Roles	Total/ Global	Share-Holders	Top Management	Middle Managers	Other Employees	Customers	Experts
(HLG1) Improve Productivity	**0.7083**	**0.6384**	**0.7209**	**0.6933**	**0.7906**	**0.7584**	**0.6590**
(BG1) Build the Necessary SW.	0.2043	0.1714	0.1722	0.1494	0.2732	0.2641	0.1886
(BG2) SW Deliveries on Time	0.1883	0.1670	0.2760	0.2295	0.1004	0.1515	0.2079
(BG3) Improve the SW. Q.&I.	0.1808	0.1973	0.1498	0.1706	0.1929	0.2244	0.1355
(BG4) Improve SW. Dev. Proc.	**0.1348**	**0.1027**	**0.1229**	**0.1438**	**0.2241**	**0.1185**	**0.1270**
(HLG2) Improve Cost	0.2917	0.3616	0.2791	0.3067	0.2094	0.2416	0.3410
(BG5) Increase Revenue	0.1594	0.1753	0.1473	0.1872	0.1266	0.1107	0.2052
(BG6) Decrease Cost	0.1323	0.1862	0.1318	0.1194	0.0828	0.1309	0.1358

5. Discussion

As shown in Table 4 and focusing on the BSC, the result of the FAHP analysis reveals that the Customer Perspective is the primary focus of the BSC and User Satisfaction is the most important evaluation KPI. The SLA KPI, also included in the Customer Perspective, is the second most important KPI. This means that the importance given to the Customer Perspective, which is twice as high as that of the next most important perspective, the Financial Perspective, makes clear the relationship and mutual dependence between the FSF and its customers. All of this implies that the main objective of the FSF should be focusing on the continuous improvement of the services offered to its customers to meet the customers' needs in the most efficient way. The third most important KPI is Intellectual Capital, a compendium of human, structural, and relational capital indicators concerning the value of the organization. The importance given to this indicator, included in the Learning and Growth Perspective, is that it provides evidence about the meaning of human factors in software development [75], where human capital plays a very important role [76]. The very nature of this kind of industry, which is absolutely linked to the banking sector, makes Cost Structure, a very important indicator for banks and included in the Financial Perspective of the BSC for an FSF, appear as the fourth most important KPI in this study. The Software Quality KPI is the most important in the Internal Business Processes Perspective. The importance that the software quality has on the user satisfaction [77], the most important KPI, is probably one of the factors that give Software Quality KPI a much greater weight than the other indicators included in the Internal Business Processes Perspective. Furthermore, it is necessary to emphasize the great difference in valuation between the indicators that have the highest weights and those that have the lowest; this difference in valuation reaches a factor of nine in

the most extreme cases, ranging from a weight of 0.2109 for the User Satisfaction KPI to a weight of 0.0231 for the Budgeting Error, which is the KPI with the lowest weight.

As shown in Table 5 and focusing on the strategic goals included in the strategy map, the result of the FAHP analysis reveals that the Improve Productivity HLG is the primary focus of the strategy map and Build the Necessary Software is the most important evaluation business goal. Contrary to what happens with the KPI weights, in the case of the business goals, the difference in weights among them is much less significant, ranging from a weight of 0.2043 for Build the Necessary Software to a weight of 0.1323 for Decrease Cost, which is the business goal with the least weight. The priority order of the six business goals shows that building the necessary software on time and with the expected quality and innovation is directly linked to User Satisfaction (the most important KPI) and these are the most important strategies included in the strategy map of the FSF. Finally, Table 6 shows the link weights assigned to each indicator according to the affected business strategy. These link weights are included in the new proposal of strategy map of a FSF (see Figure 8), which provides a powerful and graphical tool for controlling the company's framework and must allow the correct decision-making in the software development processes in a FSF.

In relation to the result by stakeholder roles, Figures 9 and 10 reveal that the Customer Perspective is the most important by role (Other employees being the only exception), but User Satisfaction is the best ranking KPI in all cases. The SLA indicator (also included in the Customer Perspective) is globally the second most important KPI, and is mostly one of the four most important KPIs for the different roles (Other employees is again the only exception). Intellectual Capital, the third most important KPI, is mostly one of the five most important KPI for the different role. On the other hand, as shown in Figure 11 in relation to the business strategies, there are no significant differences among the results for the different strategies by role, although the Other Employees role assign greater importance to the Improve Productivity HLG than the rest of roles, as also happens with the shareholders with the Improve Cost HLG.

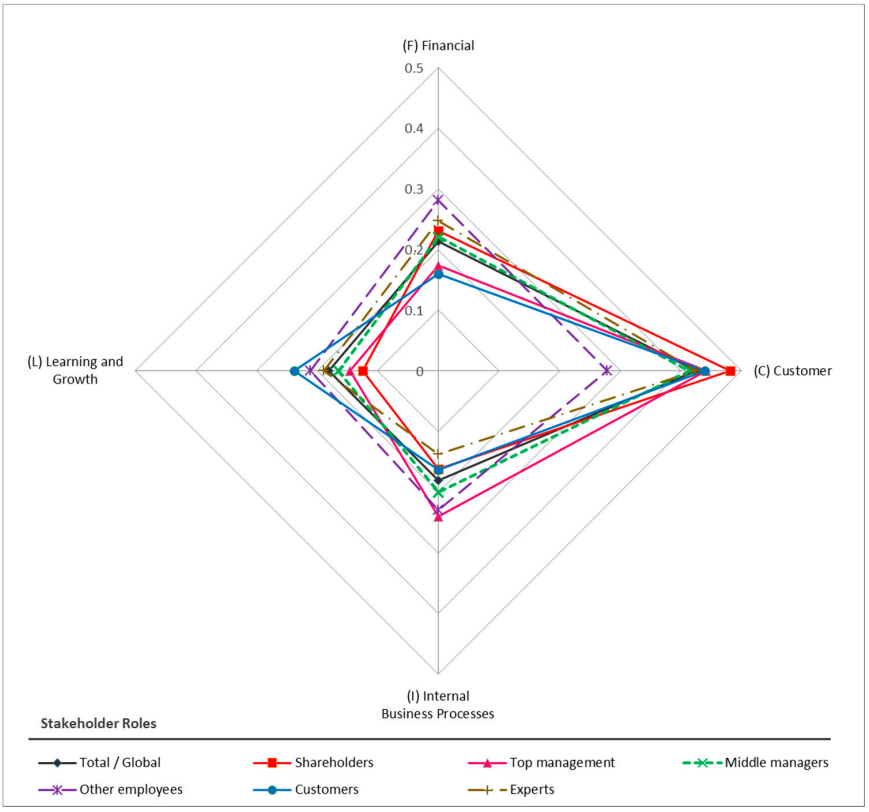

Figure 9. Perspectives weights radar graph for different stakeholder roles.

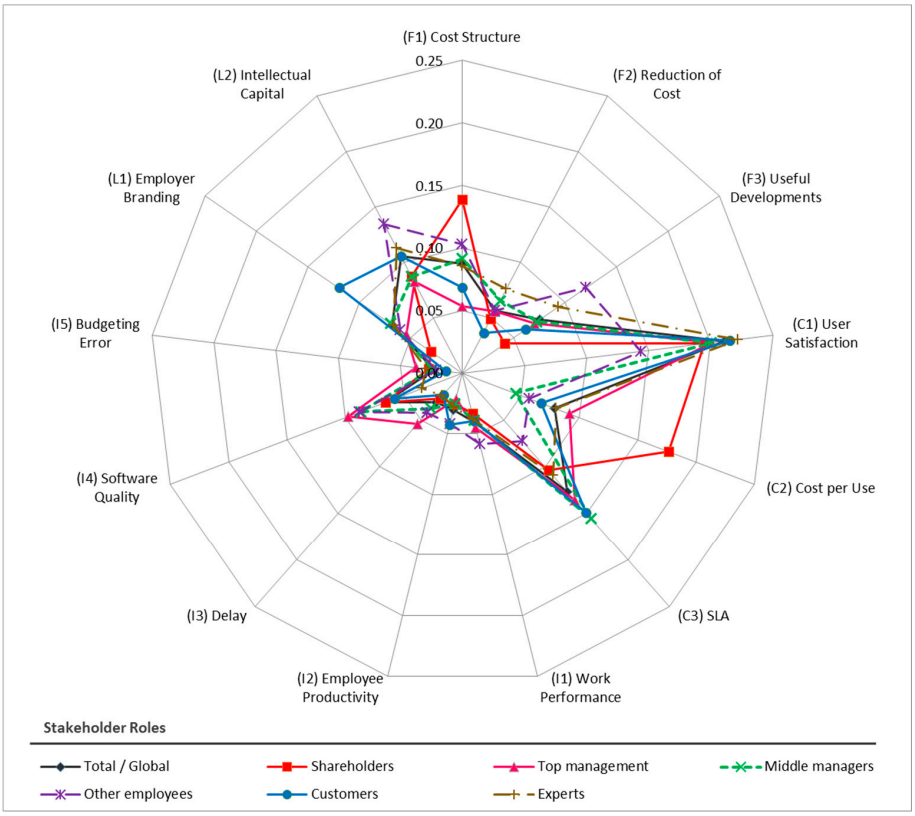

Figure 10. KPIs weights radar graph for different stakeholder roles.

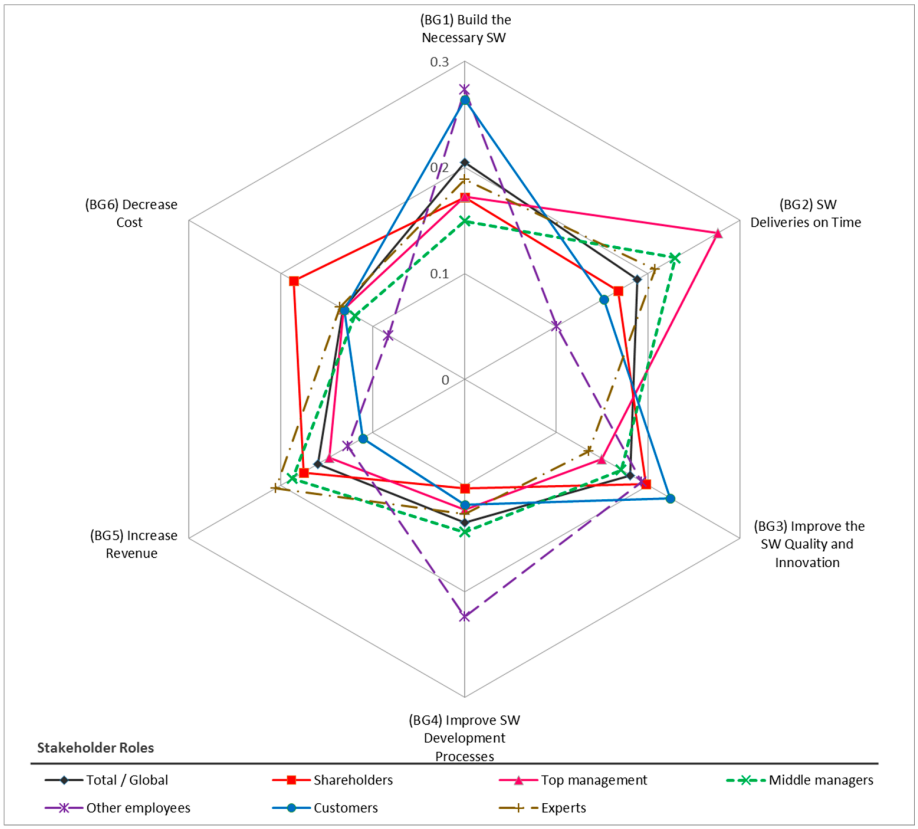

Figure 11. Business goals weights radar graph for different stakeholder roles.

6. Conclusions

The case of how a Spanish FSF involved in a corporate transformation towards sustainability has determined the weights of the KPIs and goals included in their strategy map presented here. The results enable assessing the impact that each KPI included in the BSC has on the different strategic goals defined in the strategy map of the FSF. This knowledge could be the basis for making decisions based on strategic business goals of the organization. The strategy map defines the relationships between indicators and strategic goals to achieve the mission and vision of the organization. Knowing the overall weight that each indicator and goal has in the strategy map and the links between them, it is possible to know the specific effect of each indicator according to each strategic goal. This in turn makes it possible to know the importance of each indicator in the organization's strategy map according to the perspective of the BSC in which it is included and under the influence of each different business strategy defined by the business and high-level goals.

This article shows the case study of a FSF in Spain which refocuses its business model on one based on a new strategy map to achieve the sustainability of its business. In order to know the impact of the decisions in the business sustainability, it was decided to integrate the BSC and the strategy map with FAHP to determine the value that each indicator and objective had in the FSF, according to the opinions of stakeholders and experts of software factories under the premise of achieving the mission of the organization. With the information provided by this new proposal of weighted strategy map, the FSF management can make the most appropriate strategic decisions according to the desired business goal, knowing in advance the relative impact of changes in KPI's measures for the sustainability of the FSF. Banking software faces a constantly changing landscape, so it is necessary that the FSF that develops this software can know in advance the impact of decision-making in order to take the most appropriate decision at any time according to the mission and vision of the company.

The analysis of the results obtained for each kind of stakeholder shows that each stakeholder gives more importance to those indicators or perspectives that, in theory, have a greater relation to its own role. In this sense, as presented in Table 7 and Figures 9 and 10, the shareholders give greater weight to the Financial Perspective. The employees (Top management, Middle managers and Other employees) of the software factory place greater value on the Internal Business Process Perspective. Customers are those that give less importance to the Financial Perspective, but instead they attribute great importance to the assets and image of the company that offers them services. In addition, to confirm this appreciation, User Satisfaction and SLA are the two main indicators for Customers. Furthermore, the role of Other employees differs substantially from the rest of employees, which could indicate the lack of organizational communication, related to the importance of customers for the FSF and satisfying their needs, from higher level of employees to lower levels. The importance given to Intellectual Capital, an indicator that includes human capital value, by the Other employees is the highest of all the stakeholders.

According to the analysis of the results of strategic goals, the different points of view of each kind of stakeholder were presented in Table 8 and Figure 11. The most important differences of points of view are shown for the roles of Shareholders and Other employees. Similar to what happens with the valuation of KPIs and perspectives, the Shareholders is the role who gives the highest value to the business strategies based on improving costs, and Other employees role gives the highest weight to the business strategies related to the improvement of productivity, especially with the improvement of software development processes.

This proposal was applied to the specific case of an FSF, but the methodology proposed in this paper can be applied in other types of organizations that present a framework similar to the one exposed in this paper.

Future research will aim to study the differences in criteria that can represent the different stakeholder roles when they evaluate the strategy map of a FSF, as well as the repercussions of these differences in software development performance.

Acknowledgments: This work has been subsidized through the Plan of Science, Technology and Innovation of the Principality of Asturias (Ref: FC-15-GRUPIN14-132). The authors also thank anonymous referees who reviewed and gave important comments to this paper.

Author Contributions: Vicente Rodríguez Montequín and Francisco Ortega Fernández contributed in developing the conception of the research design, data interpretation, and writing. César Álvarez Pérez contributed in the development and execution of the research approach, literature review, data collection and integration, and validation and writing. Joaquín Villanueva Balsera contributed in enhancing the research approach and data processing.

Conflicts of Interest: The authors declare no conflict of interest.

Glossary

Abbreviations	Full Forms	Meaning
BSC	Balanced scorecard	The BSC is a performance metric used in strategic planning and management system.
AHP	Analytic hierarchy process	Method used to select the best alternative among others and prioritize their relative importance.
FAHP	Fuzzy analytic hierarchy process	Method that incorporates the fuzzy theory into the AHP.
MCDM	Multicriteria decision-making	MCDM is a subdiscipline of operations research that explicitly evaluates multiple conflicting criteria in decision-making
FSF	Financial software factory	Software factory specializes in software development for the financial sector
KPI	Key performance indicator	Performance measurable value that shows how effectively a company is achieving its business objectives.
TFN	Triangular fuzzy numbers	A type of fuzzy number (fuzzy subset of real numbers which represent the expansion of the idea of a confidence interval) easy to use for its computational simplicity.
BNP	Best nonfuzzy performance	BNP is a real number obtained from the defuzzification of a fuzzy number
HLG	High-level goal	A HLG is a set of business goals that directly supports achievement of the mission and vision of the organization

References

1. De la Fuente Asprón, R. Medir la Productividad del Desarrollo de Software en Banca. Available online: http://www.financialtech-mag.com (accessed on 22 June 2013).
2. Emaldi Abasolo, M. The Software Factories. *Dyna Bilbao* **2007**, *82*, 330–333. (In Spanish).
3. Schubert, J. 4 Top Challenges Facing The Banking Industry Right Now. Available online: https://goo.gl/b5NMD0 (accessed on 27 November 2016).
4. Álvarez, C.; Rodríguez, V.; Ortega, F.; Villanueva, J. A Scorecard Framework Proposal for Improving Software Factories' Sustainability: A Case Study of a Spanish Firm in the Financial Sector. *Sustainability* **2015**, *7*, 15999–16021. [CrossRef]
5. Brown, A.W.; Lopez Mancisidor, A.; Reyes Oliva, L. Practical Experiences with Software Factory Approaches in Enterprise Software Delivery. In Proceedings of the Sixth International Conference on Software Engineering Advances, ICSEA, Barcelona, Spain, 23–29 October 2011; pp. 465–470.
6. Kaplan, R.S.; Norton, D.P. The balanced scorecard—Measures that drive performance. *Harv. Bus. Rev.* **1992**, *70*, 71–79. [PubMed]
7. Kaplan, R.S.; Norton, D.P. Putting the balanced scorecard to work. *Harv. Bus. Rev.* **1993**, *71*, 134–140.
8. Kaplan, R.S.; Norton, D.P. *Strategy maps: Converting Intangible Assets into Tangible Outcomes*; Harvard Business Press: Boston, MA, USA, 2004.
9. Kaplan, R.S.; Norton, D.P. The strategy map: Guide to aligning intangible assets. *Strategy Leadersh.* **2004**, *32*, 10–17. [CrossRef]
10. Bentes, A.V.; Carneiro, J.; da Silva, J.F.; Kimura, H. Multidimensional assessment of organizational performance: Integrating BSC and AHP. *J. Bus. Res.* **2012**, *65*, 1790–1799. [CrossRef]

11. Boons, F.; Lüdeke-Freund, F. Business models for sustainable innovation: State-of-the-art and steps towards a research agenda. *J. Clean. Prod.* **2013**, *45*, 9–19. [CrossRef]
12. Evans, S.; Vladimirova, D.; Holgado, M.; Van Fossen, K.; Yang, M.; Silva, E.A.; Barlow, C.Y. *Business Model Innovation for Sustainability: Towards a Unified Perspective for Creation of Sustainable Business Models*; Business Strategy and the Environment: Sydney, Australia, 2017.
13. Wirtz, B.W. *Business Model Management. Design–Instruments–Success Factors*; Gabler Verlag: Wiesbaden, Germany, 2011.
14. Donaldson, T.; Preston, L.E. The stakeholder theory of the corporation: Concepts, evidence, and implications. *Acad. Manag. Rev.* **1995**, *20*, 65–91.
15. Evans, S.; Rana, P.; Short, S.W. *Deliverable 2.6. Final Set of Tools & Methods that Enable Analysis of Future Oriented, Novel, Sustainable, Value Adding Business-Models and Value-Networks*; University Cambridge: Cambridge, UK, 2014.
16. Geissdoerfer, M.; Bocken, N.M.P.; Hultink, E.J. Design thinking to enhance the sustainable business modelling process—A workshop based on a value mapping process. *J. Clean. Prod.* **2016**, *135*, 1218–1232. [CrossRef]
17. Netherlands Software Metrics Users Association Challenges in Productivity Measurement. Why Is It Hard to Measure Productivity in the Software Industry? Available online: https://goo.gl/GfkkAr (accessed on 4 February 2017).
18. Kaplan, R.S.; Norton, D.P. *The Balanced Scorecard: Translating Strategy into Action*; Harvard Business Press: Boston, MA, USA, 1996.
19. Kaplan, R.S.; Norton, D.P. Linking the balanced scorecard to strategy. *Calif. Manag. Rev.* **1996**, *39*, 53–79. [CrossRef]
20. Kaplan, R.S.; Norton, D.P. Using the balanced scorecard as a strategic management system. *Harv. Bus. Rev.* **1996**, *74*, 75–85.
21. Van Grembergen, W. The balanced scorecard and IT governance. *Inf. Syst. Control J.* **2000**, *2*, 40–43.
22. Keyes, J. *Implementing the IT Balanced Scorecard: Aligning IT with Corporate Strategy*; CRC Press: Boca Raton, FL, USA, 2016.
23. Figge, F.; Hahn, T.; Schaltegger, S.; Wagner, M. The Sustainability BSC—Theory and Applicantion of a Tool for Value-Based Sustainability Management. In *Corporate Social Responsability—Governance for Sustainability, Proceedings of the Greening of Industry Network Conference, Gothenburg, Sweden, 23–26 June 2002*; Emerald Publishing Limited: Bingley, UK, 2002.
24. Rohm, H.; Montgomery, D. *Link Sustainability to Corporate Strategy Using the Balanced Scorecard*; Balanced Scorecard Institute: Cary, NC, USA, 2011.
25. Davis, S.; Albright, T. An investigation of the effect of balanced scorecard implementation on financial performance. *Manag. Account. Res.* **2004**, *15*, 135–153. [CrossRef]
26. Al-Najjar, S.M.; Kalaf, K.H. Designing a balanced scorecard to measure a bank's performance: A case study. *Int. J. Bus. Adm.* **2012**, *3*, 44. [CrossRef]
27. Rodríguez Montequín, V.; Álvarez Pérez, C.; Ortega Fernández, F.; Villanueva Balsera, J. Scorecard and KPIs for monitoring software factories effectiveness in the financial sector. *Int. J. Inf. Syst. Proj. Manag.* **2013**, *1*, 29–43.
28. Wu, H.-Y. Constructing a strategy map for banking institutions with key performance indicators of the balanced scorecard. *Eval. Prog. Plan.* **2012**, *35*, 303–320. [CrossRef] [PubMed]
29. Glykas, M. Fuzzy cognitive strategic maps in business process performance measurement. *Expert Syst. Appl.* **2013**, *40*, 1–14. [CrossRef]
30. Basili, V.; Heidrich, J.; Lindvall, M.; Münch, J.; Regardie, M.; Rombach, D.; Seaman, C.; Trendowicz, A. Bridging the Gap between Business Strategy and Software Development. Available online: aisel.aisnet.org/icis2007/25/ (accessed on 20 March 2017).
31. Basili, V.; Heidrich, J.; Lindvall, M.; Münch, J.; Regardie, M.; Rombach, D.; Seaman, C.; Trendowicz, A. Linking Software Development and Business Strategy through Measurement. *IEEE Comput.* **2010**, *43*, 57–65. [CrossRef]
32. Basili, V.; Lampasona, C.; Ramírez, A.E.O. Aligning Corporate and IT Goals and Strategies in the Oil and Gas Industry. Available online: http://link.springer.com/chapter/10.1007/978-3-642-39259-7_16 (accessed on 23 March 2017).

33. Van Grembergen, W.; Saull, R.; De Haes, S. Linking the IT balanced scorecard to the business objectives at a major Canadian financial group. *J. Inf. Technol. Case Appl. Res.* **2003**, *5*, 23–50. [CrossRef]
34. Figge, F.; Hahn, T.; Schaltegger, S.; Wagner, M. The sustainability balanced scorecard—Linking sustainability management to business strategy. *Bus. Strategy Environ.* **2002**, *11*, 269–284. [CrossRef]
35. Kathuria, R.; Joshi, M.P.; Porth, S.J. Organizational alignment and performance: Past, present and future. *Manag. Decis.* **2007**, *45*, 503–517. [CrossRef]
36. Ayag, Z. An analytic-hierarchy-process based simulation model for implementation and analysis of computer-aided systems. *Int. J. Prod. Res.* **2002**, *40*, 3053–3073. [CrossRef]
37. Palma-Mendoza, J.A. Analytical hierarchy process and SCOR model to support supply chain re-design. *Int. J. Inf. Manag.* **2014**, *34*, 634–638. [CrossRef]
38. Wu, H.-Y.; Tzeng, G.-H.; Chen, Y.-H. A fuzzy MCDM approach for evaluating banking performance based on Balanced Scorecard. *Expert Syst. Appl.* **2009**, *36*, 10135–10147. [CrossRef]
39. Zadeh, L.A. Fuzzy sets. *Inf. Control* **1965**, *8*, 338–353. [CrossRef]
40. Buckley, J.J. Fuzzy hierarchical analysis. *Fuzzy Sets Syst.* **1985**, *17*, 233–247. [CrossRef]
41. Zadeh, L.A. The concept of a linguistic variable and its application to approximate reasoning—II. *Inf. Sci.* **1975**, *8*, 301–357. [CrossRef]
42. Kaufman, A.; Gupta, M.M. *Introduction to Fuzzy Arithmetic*; Van Nostrand Reinhold Company: New York, NY, USA, 1991.
43. Negi, D.S. Fuzzy Analysis and Optimization. Ph.D. Thesis, Kansas State University, Kansas, KS, USA, 1989.
44. Zimmermann, H.-J. Fuzzy Control. In *Fuzzy Set Theory—and Its Applications*; Springer: New York, NY, USA, 2001.
45. Shaverdi, M.; Akbari, M.; Tafti, S.F. Combining fuzzy MCDM with BSC approach in performance evaluation of Iranian private banking sector. *Adv. Fuzzy Syst.* **2011**, *2011*, 148712. [CrossRef]
46. Dubois, D.; Prade, H. Operations on fuzzy numbers. *Int. J. Syst. Sci.* **1978**, *9*, 613–626. [CrossRef]
47. Giachetti, R.E.; Young, R.E. A parametric representation of fuzzy numbers and their arithmetic operators. *Fuzzy Sets Syst.* **1997**, *91*, 185–202. [CrossRef]
48. Moon, J.H.; Kang, C.S. Application of fuzzy decision making method to the evaluation of spent fuel storage options. *Prog. Nucl. Energy* **2001**, *39*, 345–351. [CrossRef]
49. Tang, Y.-C. An approach to budget allocation for an aerospace company—Fuzzy analytic hierarchy process and artificial neural network. *Neurocomputing* **2009**, *72*, 3477–3489. [CrossRef]
50. Liang, G.-S.; Wang, M.-J.J. A fuzzy multi-criteria decision-making approach for robot selection. *Robot. Comput. Integr. Manuf.* **1993**, *10*, 267–274. [CrossRef]
51. Hsieh, T.-Y.; Lu, S.-T.; Tzeng, G.-H. Fuzzy MCDM approach for planning and design tenders selection in public office buildings. *Int. J. Proj. Manag.* **2004**, *22*, 573–584. [CrossRef]
52. Saaty, T.L. How to make a decision: The analytic hierarchy process. *Eur. J. Oper. Res.* **1990**, *48*, 9–26. [CrossRef]
53. Mon, D.-L.; Cheng, C.-H.; Lin, J.-C. Evaluating weapon system using fuzzy analytic hierarchy process based on entropy weight. *Fuzzy Sets Syst.* **1994**, *62*, 127–134. [CrossRef]
54. Saaty, T.L. A scaling method for priorities in hierarchical structures. *J. Math. Psychol.* **1977**, *15*, 234–281. [CrossRef]
55. Thomas, S. *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*; McGraw-Hill International Book Company: New York, NY, USA, 1980.
56. Saaty, R.W. The analytic hierarchy process—What it is and how it is used. *Math. Model.* **1987**, *9*, 161–176. [CrossRef]
57. Saaty, T.L. What Is the Analytic Hierarchy Process? *Mathematical Models for Decision Support*. Available online: https://link.springer.com/chapter/10.1007/978-3-642-83555-1_5 (accessed on 23 March 2017).
58. Saaty, T.L. *Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process*; RWS Publications: Pittsburgh, PA, USA, 1994; Volume 6.
59. Wang, Y.; Xia, Q. A Fuzzy AHP and BSC Approach for Evaluating Performance of a Software Company Based on Knowledge Management. Available online: http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=5454173#TitleHist (23 March 2017).
60. Ayağ, Z.; Özdemir, R.G. A fuzzy AHP approach to evaluating machine tool alternatives. *J. Intell. Manuf.* **2006**, *17*, 179–190. [CrossRef]

61. Chang, D.-Y. Applications of the extent analysis method on fuzzy AHP. *Eur. J. Oper. Res.* **1996**, *95*, 649–655. [CrossRef]
62. Bellman, R.E.; Zadeh, L.A. Decision-making in a fuzzy environment. *Manag. Sci.* **1970**, *17*, B-141–B-164. [CrossRef]
63. Opricovic, S.; Tzeng, G.-H. Defuzzification within a multicriteria decision model. *Int. J. Uncertain. Fuzziness Knowl. Based Syst.* **2003**, *11*, 635–652. [CrossRef]
64. Chen, M.-K.; Wang, S.-C. The use of a hybrid fuzzy-Delphi-AHP approach to develop global business intelligence for information service firms. *Expert Syst. Appl.* **2010**, *37*, 7394–7407. [CrossRef]
65. Ren, C.; Dong, J.; Ding, H.; Wang, W. Linking Strategic Objectives to Operations: Towards a More Effective Supply Chain Decision Making. Available online: http://ieeexplore.ieee.org/document/4117767/ (accessed on 23 March 2017).
66. Taticchi, P.; Tonelli, F.; Cagnazzo, L. A decomposition and hierarchical approach for business performance measurement and management. *Meas. Bus. Excell.* **2009**, *13*, 47–57. [CrossRef]
67. Quezada, L.E.; Palominos, P.I.; Gonzalez, M.A. Application of AHP in the Design of a Strategy Map. *iBusiness* **2013**, *5*, 133. [CrossRef]
68. Quezada, L.E.; López-Ospina, H.A. A method for designing a strategy map using AHP and linear programming. *Int. J. Prod. Econ.* **2014**, *158*, 244–255. [CrossRef]
69. Lu, I.-Y.; Kuo, T.; Lin, T.-S.; Tzeng, G.-H.; Huang, S.-L. Multicriteria decision analysis to develop effective sustainable development strategies for enhancing competitive advantages: Case of the TFT-LCD industry in Taiwan. *Sustainability* **2016**, *8*, 646. [CrossRef]
70. Abdolshah, M.; Javadinia, M.; Astanbous, M.; Eslami, M. An integrated approach to analyze strategy map using BSC–FUZZY AHP: A case study of auto industry. *Manag. Sci. Lett.* **2002**, *2*, 705–712. [CrossRef]
71. Sorayaei, A.; Abedi, A.; Khazaei, R.; Hossien Zadeh, M.; Agha Maleki, S.M.S.A. An integrated approach to analyze strategy map using BSC–FUZZY AHP: A case study of Dairy companies. *Eur. Online J. Nat. Soc. Sci.* **2014**, *2*, 1315–1322.
72. Kaplan, R.S. Conceptual foundations of the balanced scorecard. *Handb. Manag. Account. Res.* **2008**, *3*, 1253–1269.
73. Caha, J.; Drážná, A. Information about FuzzyAHP Package for R (ver.0.8.0). Available online: https://goo.gl/DXlLm8 (accessed on 20 March 2017).
74. Malczewski, J. *GIS and Multicriteria Decision Analysis*; John Wiley & Sons: New York, NY, USA, 1999.
75. Amrit, C.; Daneva, M.; Damian, D. Human factors in software development: On its underlying theories and the value of learning from related disciplines. A guest editorial introduction to the special issue. *Spec. Issue Hum. Factors Softw. Dev.* **2014**, *56*, 1537–1542. [CrossRef]
76. Curtis, B.; Krasner, H.; Iscoe, N. A field study of the software design process for large systems. *Commun. ACM* **1988**, *31*, 1268–1287. [CrossRef]
77. Joint Technical Committee. ISO/IEC JTC 1/SC7 ISO/IEC 25010:2011 Systems and Software Engineering—Systems and Software Quality Requirements and Evaluation (SQuaRE)—System and Software Quality Models. Available online: https://www.iso.org/standard/35733.html (accessed on 20 March 2017).

5

DISCUSIÓN DE LOS RESULTADOS

5. Discusión de los Resultados

Durante los últimos 25 años han sido escritos muchos artículos que proponen el BSC *framework* como herramienta de gestión para la mejora del negocio. Valorar el rendimiento y la eficiencia con la que una compañía gestiona su proceso productivo no es una tarea sencilla. Y aún es más complicada si esa compañía se dedica al desarrollo de software, debido a su naturaleza intangible y a la dificultad de medir del resultado final [22]. Pero esto no significa que los gestores de las factorías software no necesiten de medios que les permitan controlar la producción y el conocimiento necesario para establecer políticas y estrategias con las que alcanzar las metas fijadas.

Esta tesis propone un modelo de negocio sostenible para las FSF, basado en el BSC *framework*, que debe satisfacer y dar respuesta a las necesidades de sus gestores. Para este propósito y bajo un entorno de producción industrializado basado en el *software factory approach*, se determinaron los indicadores, objetivos y relaciones entre ellos que permitiesen valorar aquellos aspectos de interés para los distintos *stakeholders* de una FSF.

Los indicadores incluidos en *Internal Business Processes Perspective* del BSC aportan el conocimiento necesario para realizar las correcciones e iniciativas de mejora en los procesos productivos que permitan alcanzar el rendimiento deseado. La relación entre la cantidad de software producido y tiempo necesario para su producción permite valorar la evolución y desviaciones de los proyectos, teniendo en cuenta las horas planificadas, las realizadas y las variaciones de coste frente a las estimaciones. Los indicadores incluidos en *Financial Perspective*, algunos de ellos específicos para su utilización en este tipo de FSF, permiten valorar esta perspectiva teniendo en cuenta la casuística del grupo financiero, que es al mismo tiempo propietario y principal cliente. Aportan también información acerca de la viabilidad económica de la FSF, que puede ser comparada con otras factorías software del sector. Los indicadores incluidos en *Learning and Growth Perspective* y en *Customer Perspective* proporcionan información sobre las relaciones entre la organización y sus empleados y clientes. La información mostrada en estas dos perspectivas valora la satisfacción y continuidad de los clientes y comprueba si la planificación del capital intelectual y reputacional de la compañía promueve la continuidad y crecimiento del negocio.

Las relaciones entre indicadores y *strategic goals* definidas en el *strategy map* permiten determinar el tipo de iniciativas que favorecen la consecución de unos u otros objetivos. La propuesta final de *strategy map* ponderado permite valorar el impacto que esas iniciativas tienen sobre los *strategic goals*, optimizando así la toma de decisiones por parte de los gestores de la FSF.

El estudio por roles de *stakeholder* de la FSF, expuesto en esta tesis, pone de manifiesto las diferencias existentes entre unos y otros roles en la valoración e importancia que otorgan para las mismas alternativas bajo el mismo objetivo global de sostenibilidad del negocio, lo que es un hecho importante de cara a la sostenibilidad del negocio.

Como se muestra en la Tabla 10, en referencia a la valoración global del BSC, los resultados del análisis con FAHP publicados en el Artículo 3 de esta tesis y mostrados en el Apartado 3.3.7 *Resultados por roles de Stakeholder*, revelan que *Customer Perspective* es el principal foco de atención del BSC, y *User Satisfaction*, incluido en esa perspectiva, es el indicador más importante y con mayor influencia en la consecución de los distintos objetivos de la FSF. El indicador de SLA, también incluido en *Customer Perspective*, es el segundo indicador en importancia. Este hecho da muestra de la importancia otorgada a la satisfacción del cliente, a la necesidad de hacer frente a sus peticiones y cumplir los compromisos contraídos con ellos. El peso de *Customer Perspective* es el doble que el de la segunda perspectiva en importancia, *Financial Perspective*, lo que deja claro la relación de mutua dependencia entre la FSF y sus clientes. Estos hechos expuestos infieren que el principal objetivo de la FSF debe estar centrado en el cliente y en mejorar continuamente los servicios que demande para satisfacer sus necesidades de la manera más eficiente. El tercer indicador en importancia es *Intellectual Capital*, un compendio de otros indicadores que valoran el capital humano, estructural y relacional de la organización. La importancia dada a este indicador, incluido en *Learning and Growth Perspective*, da evidencia del significado que el componente humano tiene en el desarrollo del

software [101], donde el capital intelectual juega un papel muy importante [102]. La propia naturaleza de las FSF, absolutamente ligadas al sector financiero, hace que *Cost Structure*, uno de los indicadores más importantes para la banca y que está incluido en *Financial Perspective*, sea el cuarto indicador más importante en este estudio. El indicador *Software Quality* es el más importante de los incluidos en *Internal Business Processes Perspective*. La importancia que este indicador tiene sobre la satisfacción del usuario [103], que a la postre es el aspecto mejor valorado del BSC, es probablemente uno de los factores que otorguen a este indicador mucha más importancia que la otorgada al resto de indicadores incluidos en la misma perspectiva. Finalmente, es necesario resaltar la gran diferencia existente entre los indicadores más valorados y los menos valorados; en el caso más extremo la importancia dada al *User Satisfaction* es casi diez veces mayor que la dada al indicador *Budgeting Error* (error de presupuestación), que es el que ha recibido menor valoración de entre todos los indicadores.

La valoración global de los *business goals* y de los *high-level goals*, presentada en la Tabla 11, revela que *Improve Productivity high-level goal* es el principal foco de atención del *strategy map*, y *Build the Necessary Software* es el *business goal* más importante. Al contrario de lo que sucede con las valoraciones de los indicadores, en el caso de los *business goals*, las diferencias de valoración entre ellos son mucho menos significativas, y van desde un 0.2043 para *Build the Necessary Software,* hasta un 0.1323 asignado a *Decrease Cost* (Decrementar los Costes), que es el *business goal* de menor importancia. El orden de prioridad de los seis *business goals* muestra que desarrollar el software necesario, para el momento necesario y con la calidad e innovación esperada, todo ello relacionado con la satisfacción del usuario, representan las estrategias de negocio mejor valoradas de las incluidas en el *strategy map*.

La importancia de las relaciones causa-efecto entre indicadores y *business goals* mostrados en la Tabla 9, aparecen incluidos en la propuesta final de *strategy map* ponderado para una FSF presentada en la Figura 11. Este *strategy map* ponderado se confirma como una potente herramienta gráfica para controlar el modelo de negocio de las FSF, que guía a los gestores de la organización en la toma de decisiones para decantarse por aquellas más adecuadas que aseguren la sostenibilidad de su modelo de gestión del negocio.

En relación a los resultados obtenidos por roles de *stakeholder* para el análisis del BSC, presentados en la Tabla 10 y gráficamente en la Figura 12 y la Figura 13, se puede confirmar la existencia de dependencia entre las valoraciones dadas por cada rol y su tipo de relación con la FSF, en el sentido de que cada rol de stakeholder da mayor importancia a aquellos indicadores, perspectivas y objetivos que guardan mayor relación con su propio rol dentro de la organización. En este sentido, los *Shareholders* dan mayor importancia a *Financial Perspective*; los empleados (*Top Management*, *Middle Managers* y *Other Employees*) dan mayor importancia a *Internal Business Processes Perspective* que el resto de roles; los clientes son los que menos importancia dan a *Financial Perspective*, pero sin embargo le atribuyen gran importancia a la valoración de la imagen de la compañía que le proporciona sus servicios. Además, y para confirmar esta apreciación, los indicadores *User Satisfaction* y SLA son los dos más importantes para los clientes. Las valoraciones realizadas por *Other employees* difieren sustancialmente de la del resto de empleados, lo que podría indicar la falta de comunicación institucional (en relación con la importancia que los clientes tienen para la FSF y la necesidad de satisfacer sus necesidades) desde los puestos de alto nivel hacia los niveles más bajos. La importancia que *Other Employees* al indicador de *Intellectual Capital*, un indicador que incluye la valoración del capital humano, es la más alta dada de entre todos los roles. Este comportamiento también se aprecia en las valoraciones por roles realizadas para los *strategic goals*, presentadas en la Tabla 11 y en la Figura 14, especialmente en el caso de los *Shareholders* y los *Other Employees*. Al igual que sucede en la valoración de indicadores y perspectivas, los *Shareholders* son el rol que da mayor importancia a las estrategias de negocio relacionadas con la mejora de la estructura de costes de la FSF, y los *Other employees* son los que dan más importancia a las estrategias relacionadas con la mejora de la productividad, especialmente las ligadas a las mejoras en los procesos de desarrollo de software.

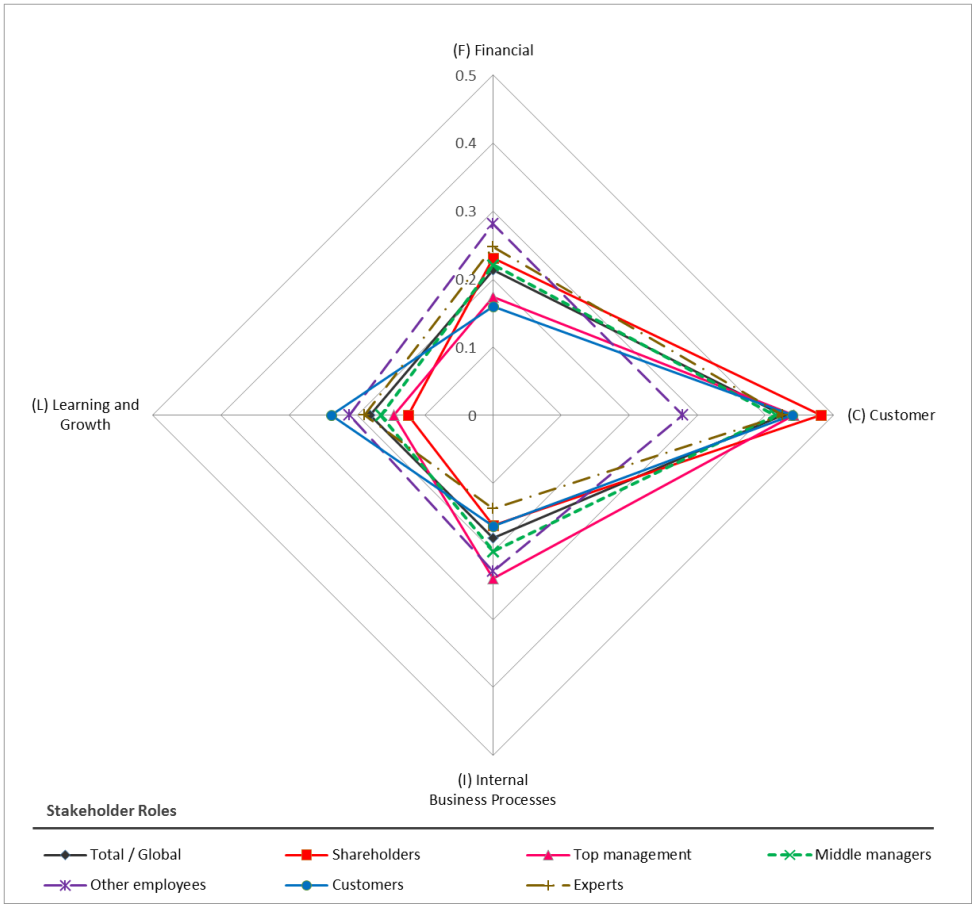

Figura 12. Gráfico de radar con las valoraciones de las perspectivas por roles de *stakeholder* [4].

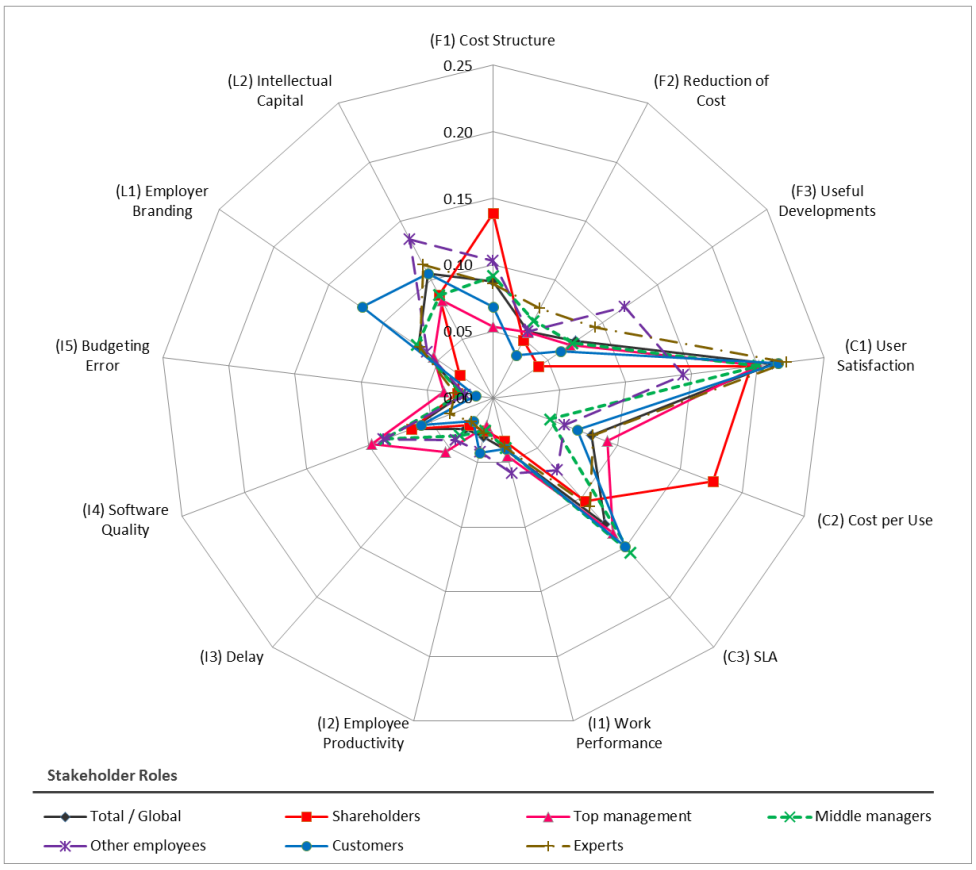

Figura 13. Gráfico de radar con las valoraciones de los indicadores por roles de *stakeholder* [4].

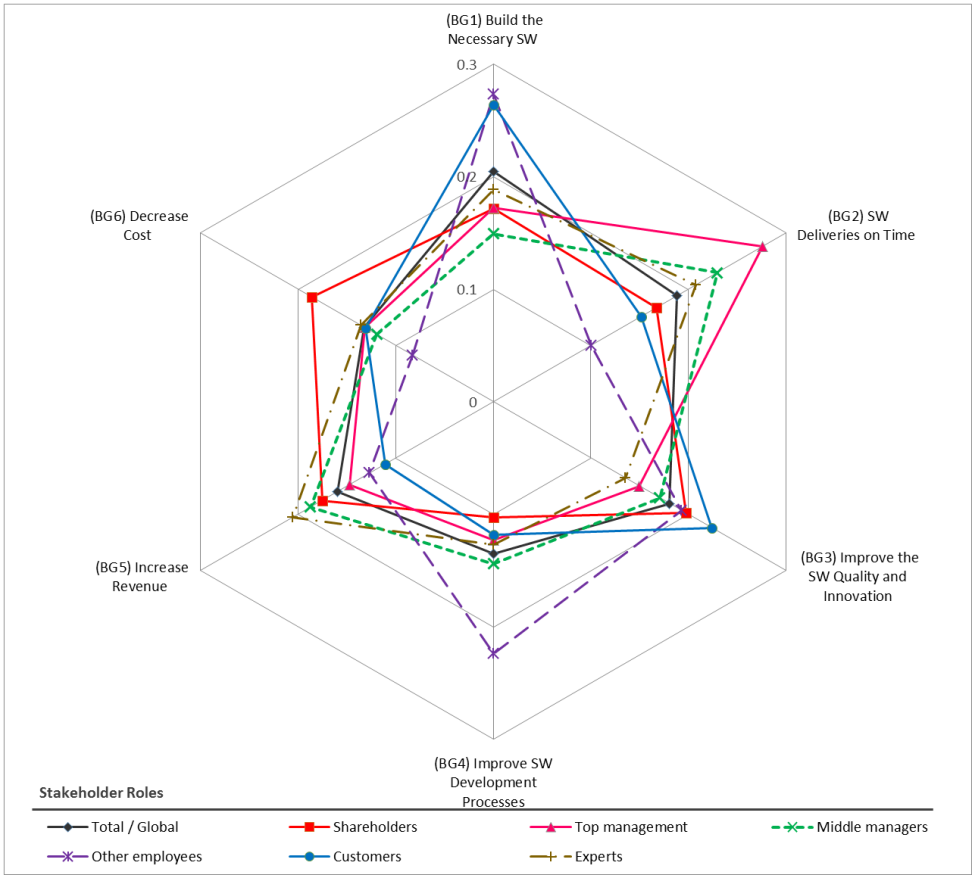

Figura 14. Gráfico de radar con las valoraciones de los *business goals* por roles de stakeholder [4].

6

PLAN DE VALIDACIÓN PRELIMINAR

6. Plan de Validación Preliminar

Un plan de validación proporciona una oportunidad para desarrollar y mejorar la confianza en un nuevo modelo de negocio. En este caso, la dirección de la FSF necesitará utilizar el nuevo modelo propuesto de una forma efectiva en la toma de decisiones que permita mejorar los procesos ligados al desarrollo de software. Un plan de validación eficaz requiere de un enfoque coherente a través de todas las características de validación que permite el modelo de gestión basado en el marco de trabajo del BSC. Para conseguirlo, la dirección de la FSF debe considerar todos los procesos ligados al desarrollo de software. Un plan de validación, para ser efectivo, requiere tiempo y esfuerzo para probar y validar las siguientes fases del plan de validación: planificación, ejecución, revisión y valoración, y como último paso, la realización de un análisis de situación y elaboración de informes de gestión [104]. Además es necesaria una herramienta que apoye y de soporte a la realización de estos pasos. El plan de validación tiene un papel importante para la mejora del nuevo modelo, ya que ayudará a comprender e identificar sus debilidades, fortalezas y limitaciones. El plan de validación será un punto clave para la aprobación definitiva del modelo de negocio sostenible propuesto para las FSF, que culminará con un informe de validación que plasmará el alcance de la propia validación.

La factoría software estudiada en este trabajo ya ha proporcionado algunos de los primeros datos del seguimiento y control de gestión necesarios para la validación del modelo. Hasta ahora únicamente se dispone de datos validados y con la temporalidad suficiente para algunos de los indicadores, especialmente los que hacen referencia a rendimiento y costes. Estos datos ya permiten realizar un análisis preliminar del plan de validación y obtener las primeras conclusiones, que deben ser respaldadas con los datos que se obtengan durante los siguientes años, además de la valoración que se debe hacer del resto de indicadores.

La Tabla 12 muestra los valores y ratios de algunos de los indicadores propuestos en el modelo de los últimos años. Los indicadores presentados muestran valores esperanzadores, que evidencian una mejora de la eficiencia en el desarrollo de software, incrementando el rendimiento global de la factoría un 4.45% y de la productividad de los empleados un 29.90%, debido en buena medida al *outsourcing* de los desarrollos. Al mismo tiempo, el coste por uso de los desarrollos se ha reducido para las entidades del grupo financiero un 33.02% en cuatro años. El coste total de los servicios y desarrollos para las entidades del grupo se ha reducido en los últimos cuatro años un 20.57%, y los ingresos ajenos al grupo han crecido en este mismo periodo un 11.31%, pasando de representar el 32.24% de los ingresos totales en 2012 hasta llegar a representar un 45.18% en 2016, con un incremento porcentual del 40.14%. Por el contrario, el indicador de *Budgeting Error*, que refleja las desviaciones presupuestadas, necesita de acciones correctivas que lo lleven a una situación más precisa, ya que las desviaciones siguen siendo superiores al 25%.

Tabla 12. Datos y valores de los KPIs obtenidos durante 2012, 2014 y 2016.

Data/Year	2012	2014	2016	Var.% 2012-2014	Var.% 2012-2016
No. Finished Software Request	338	424	554	25.44%	63.91%
Budgeted Hours	251,019	257,951	377,762	2.76%	50.49%
Performed Hours	354,722	339,847	511,101	−4.19%	44.08%
Group Revenues	60,418,000 €	54,681,000 €	47,989,690 €	−9.50%	-20.57%
External Revenues	19,478,840 €	19,068,180 €	21,682,690 €	-2.11%	11.31%
Total Revenues	79,896,840 €	73,749,180 €	69,672,380 €	-7.69%	-12.80%
Total Employees Cost	25,040,940 €	23,993,410 €	29,696,260 €	-4.18%	18.59%
Core Transactions	1,296,439,281	1,276,054,739	1,537,419,979	−1.57%	18.59%

KPIs/Year	2012	2014	2016	Var.%	Var.%
Cost per Use	0.0466	0.0429	0.0312	−8.05%	-33.02%
Work Performance	70.77	75.90	73.91	7.26%	4.45%
Employee Productivity	0.84	0.90	1.06	7.25%	29.90%
Budgeting Error	29.23	24.10	26.09	−17.57%	-10.76%
Reduction of Cost	32.24	34.87	45.18	8.16%	40.14%

Durante los próximos años se recopilarán, revisarán y evaluarán nuevos datos que sirvan para finalizar el plan de validación y poder confirmar las mejoras detectadas hasta ahora.

7

CONCLUSIONES

7. Conclusiones y Líneas de Investigación Futuras

Esta tesis propone un modelo de gestión sostenible para una factoría software que se ha validado en una compañía española especializada en el desarrollo de software financiero. El caso de estudio muestra como esta compañía decidió realizar una transformación de su modelo de gestión hacia un nuevo modelo de gestión sostenible, centrado en la mejora de la eficiencia de su cartera de proyectos software. Estas mejoras se desarrollan optimizando la productividad y costes de todos los procesos ligados al desarrollo de software y de gestión de la organización.

El modelo de gestión sostenible del negocio se basa en el denominado BSC *framework*, que establece las relaciones causa-efecto entre los indicadores de la gestión, que deben guiar la toma de decisiones, y las diferentes estrategias de negocio, que necesitan ser optimizadas. Este enfoque ha sido finalmente plasmado en un *strategy map* ponderado específicamente diseñado para este tipo de factorías software especializadas en desarrollo se software bancario. El *strategy map* es una potente herramienta que, de manera gráfica, muestra las interconexiones entre los indicadores y perspectivas del BSC con los objetivos estratégicos de una compañía, para facilitar la consecución de sus metas. El *strategy map*, al igual que sucede con el BSC, muestra las relaciones entre los diferentes elementos que lo componen, pero no determina el grado de influencia que cada elemento ejerce sobre aquellos otros a los que afecta. Como resultado final del trabajo de investigación desarrollado en esta tesis, publicado en el Artículo 3, se ha optado por valorar la importancia de las relaciones causa-efecto existentes en el *strategy map* de una FSF, proporcionando un *strategy map* ponderado que permite evaluar el impacto entre los indicadores y los objetivos estratégicos de la compañia. De esta forma se hace posible una optimización de la toma de decisiones por parte de los gestores de la FSF, al poder cuantificar cuánto afectará a cada uno de los objetivos estratégicos las decisiones tomadas, que tendrán su reflejo en las mediciones de los distintos indicadores. Este efecto podrá ser considerado tanto de manera individual, por cada estrategia de negocio, como a nivel global, valorando conjuntamente todas las estrategias para alcanzar la misión y visión de la organización.

El conocimiento que emana de este *strategy map* ponderado debe ser la base para la toma de decisiones en el modelo propuesto. Para determinar los pesos utilizados en la ponderación del *strategy map*, se optó por integrar el BSC y el *strategy map* con FAHP, acorde a las opiniones de *stakeholders* y expertos en factorías software bajo la premisa de la sostenibilidad del negocio. Tras una revisión exhaustiva del estado del arte, no se ha encontrado ningún ejemplo que integre estas tres herramientas tal como se ha realizado en esta tesis para hacer una valoración global del rendimiento y sostenibilidad del negocio mediante la ponderación de las relaciones definidas en el *strategy map* de la organización.

El sector bancario tiene que hacer frente a un entorno en constante cambio, especialmente en lo que a tecnología se refiere, por lo que es necesario que las empresas que desarrollan su software tengan herramientas como la presentada en esta tesis que les permita valorar de antemano el efecto que la toma de decisiones tiene en la eficiencia ligada a la gestión de su cartera de proyectos. Así se puede tomar en cada momento la decisión más apropiada para la finalidad deseada.

Por otro lado, del análisis de los resultados obtenidos por roles de *stakeholder*, se concluye que cada uno de ellos da más importancia a aquellos indicadores o perspectivas que, en teoría, tienen mayor relación con su propio papel o relación con la factoría software. La existencia de importantes diferencias en la valoración de las distintas alternativas según el rol desempeñado, hace que sea necesario incluir todas ellas dentro de un modelo de gestión que fomenta su propia sostenibilidad. Decisiones basadas exclusivamente en un tipo de rol determinado podría dar lugar a desequilibrios o desatención de ciertas necesidades, que siendo importantes para el resto de roles, no lo sean para quien finalmente toma las decisiones en estas factorías software. La gran importancia que todos los roles asignan en la valoración de las perspectivas e indicadores a todo aquello que guarda relación directa con los clientes, hace que la toma de decisiones deba tener como principal motivación la satisfacción de las necesidades del cliente.

La propuesta realizada en esta tesis ha sido aplicada en una factoría software del sector financiero, pero la metodología aquí propuesta podría ser de aplicación en otros tipos de organizaciones que presentan un entorno de trabajo similar al aquí expuesto.

Del contenido y ámbito de esta tesis se pueden proponer varias líneas de investigación futuras, que apliquen la metodología propuesta o bien hagan nuevas propuestas para seguir mejorando la eficiencia en la gestión de este tipo de factorías software. Estas son algunas de las propuestas:

- Como se puede ver en el *Plan de Validación Preliminar*, el indicador *Budgeting Error* presenta un error en la planificación superior al 25%. Si bien su error se ha reducido en los últimos cuatro años, cabe esperar una revisión de la metodología utilizada, valorando también si se trata de algo puntual de esta FSF o si está extendido al resto de este tipo de factorías. Existe literatura que identifica el "optimismo en la planificación" como el error más común en el desarrollo de software, presente en casi el 70% de los proyectos [105]. Una posible línea de trabajo estaría encaminada a la mejora de las herramientas de presupuestación en este tipo de FSF.
- Otra línea de investigación podría mejorar y establecer métricas ligadas a indicadores que permitan valorar el capital intelectual en el desarrollo de software. Existe en general abundante literatura en relación a cómo medir el capital intelectual [106–108], pero no lo es tan amplia en relación al desarrollo de software, industria con alto componente de capital humano como parte del capital intelectual.
- Partiendo del estudio por roles presentado en esta tesis, una futura línea de investigación podría valorar las diferencias en la sostenibilidad del negocio según el rol o conjunto de roles que tomen las decisiones.
- Esta tesis afronta la mejora de la eficiencia en la gestión de la cartera de proyectos, pero un tema de gran importancia en este tipo de FSF, es la elección de los proyectos a desarrollar, conocido como "gestión de la demanda". En este tipo de empresas existen muchas variables que afectan a la elección de los proyectos: normativa legal, fechas de entrega obligatoria, la duración, el coste, la prioridad que tenga el proyecto para el cliente, la disponibilidad de los equipos y la especialización de los equipos en determinado tipo de desarrollos, son algunas de ellas. Este podría ser un punto de partida para elaborar un sistema de gestión de la demanda, que en función de las diferentes variables, establezca el orden de asignación de proyectos para maximizar la eficiencia y fortalecer la sostenibilidad del negocio.

8

REFERENCIAS

8. Referencias

1. Garzás, J.; Piattini, M. *Factorías de Software: Experiencias, Tecnologías y Organización.*; Ra-ma, 2007.
2. Álvarez, C.; Rodríguez, V.; Ortega, F.; Villanueva, J. A Scorecard Framework Proposal for Improving Software Factories' Sustainability: A Case Study of a Spanish Firm in the Financial Sector. *Sustainability* **2015**, *7*, 15999–16021.
3. Álvarez Pérez, C.; Rodríguez Montequín, V.; Ortega Fernández, F.; Villanueva Balsera, J. Integrating Analytic Hierarchy Process (AHP) and Balanced Scorecard (BSC) Framework for Sustainable Business in a Software Factory in the Financial Sector. *Sustainability* **2017**, *9*, 486.
4. Pérez, C. Á.; Montequín, V. R.; Fernández, F. O.; Balsera, J. V. Integration of Balanced Scorecard (BSC), Strategy Map, and Fuzzy Analytic Hierarchy Process (FAHP) for a Sustainability Business Framework: A Case Study of a Spanish Software Factory in the Financial Sector. *Sustainability* **2017**, *9*, 527.
5. Álvarez, C.; R. Montequín, V.; Alba, C.; Fernández, L. Modelo de Cuadro de Mando para Factorías Software del Sector Financiero. In; Valencia, 2012; pp. 2313–2323.
6. Montequin, V. R.; Álvarez, C.; Ortega, F.; Villanueva, J. Scorecard for Improving Software Factories Effectiveness in the Financial Sector. In *CENTERIS 2013 - Conference on ENTERprise Information Systems / PRojMAN 2013 - International Conference on Project MANagement / HCIST 2013 - International Conference on Health and Social Care Information Systems and Technologies*; Procedia Technology: Lisbon, Portugal, 2013; Vol. 9, pp. 670–675.
7. Rodríguez Montequín, V.; Álvarez Pérez, C.; Ortega Fernández, F.; Villanueva Balsera, J. Scorecard and KPIs for monitoring software factories effectiveness in the financial sector. *International Journal of Information Systems and Project Management* **2013**, *1*, 29–43.
8. R. Montequín, V.; Álvarez Pérez, C.; Ortega Fernández, F.; Balsera, J. V. Cuadro de mando para la gobernanza de factorías software del sector financiero. In *Gobernanza empresarial de tecnologías de la información*; Ed. Universidad de Cantabria, 2015; Vol. 210, pp. 51–62.
9. Álvarez, C.; Rodríguez, V.; Ortega, F.; Villanueva, J. Integrating fuzzy analytic hierarchy process and balanced scorecard framework for evaluating performance in a software factory in the financial sector. *International Journal of Information Management (En revisión).*
10. de la Fuente Asprón, R. Medir la Productividad del Desarrollo de Software en Banca. *FinancialTech Magazine* **2010**, *217*.
11. Schubert, J. 4 Top Challenges Facing The Banking Industry Right Now https://goo.gl/b5NMD0 (accessed Nov 27, 2016).
12. Papalexandris, A.; Ioannou, G.; Prastacos, G. P. Implementing the Balanced Scorecard in Greece: a Software Firm's Experience. *Long Range Planning* **2004**, *37*, 351–366.
13. Murphy, G. C. What is software development productivity, anyway? (Keynote). In *Mining Software Repositories (MSR), 2013 10th IEEE Working Conference on*; 2013; pp. 1–1.
14. Emaldi Abasolo, M. The Software Factories. *Dyna (Bilbao)* **2007**, *82*, 330–333.

15. Fenton, N.; Bieman, J. *Software metrics: a rigorous and practical approach*; CRC Press, 2014.
16. Brown, A. W.; Lopez Mancisidor, A.; Reyes Oliva, L. Practical Experiences with Software Factory Approaches in Enterprise Software Delivery. In *Proceedings of the Sixth International Conference on Software Engineering Advances, ICSEA, Barcelona, Spain*; 2011; pp. 23–29.
17. de Vries, M. Measuring Success with Software Factories. *The Architecture Journal–Software Factories* **2006**, *9*.
18. Poppendieck, M.; Poppendieck, T. Lean software Development: An agile toolkit. *Addison Wesley* **2003**.
19. Hotle, M.; Landry, S. Application Delivery and Support Organizational Archetypes: the Software Factory. *Gartnet Research Report G00167531* **2009**.
20. Djotio Ndie, T.; Tangha, C.; Ekwoge Ekwoge, F. MDA (Model Driven Architecture) as a Software Factory Industrialization Pattern: An Approach for a Pragmatic Software Factories. *J. Software Engineering & Applications* **2010**, *3*, 561–571.
21. Peredo Valderrama, R.; Canales Cruz, A.; Peredo Valderrama, I. An Approach Toward a Software Factory for the Development of Educational Materials under the Paradigm of WBE. *Interdisciplinary Journal of E-Learning and Learning Objects* **2011**, *7*.
22. Netherlands Software Metrics Users Association Challenges in Productivity Measurement. Why is it hard to measure productivity in the software industry? https://goo.gl/GfkkAr (accessed Feb 4, 2017).
23. Kaplan, R. S.; Norton, D. P. The balanced scorecard - Measures that drive performance. *Harvard Business Review, Jan./Feb.* **1992**, *70*, 71–79.
24. Kaplan, R. S.; Norton, D. P. Putting the balanced scorecard to work. *Harvard Business Review* **1993**, *71*, 134–140.
25. Kaplan, R. S.; Norton, D. P. The balanced scorecard: measures that drive performance. *Harvard business review* **2005**, *83*, 172.
26. Bourguignon, A.; Malleret, V.; Nørreklit, H. *Balanced scorecard versus French tableau de bord: beyond dispute, a cultural and ideological perspective*; Groupe HEC, 2001.
27. Van Grembergen, W. The balanced scorecard and IT governance. In *IRMA Conference*; 2000; pp. 1123–1124.
28. Keyes, J. *Implementing the IT balanced scorecard: Aligning IT with corporate strategy*; CRC Press, 2016.
29. Figge, (Frank); Hahn, T.; Schaltegger, S.; Wagner, M. The Sustainability BSC - Theory and Applicantion of a Tool for Value-Based Sustainability Management. In *Corporate Social Responsability - Governance for Sustainability*; Gothenburg, 2002.
30. Rohm, H.; Montgomery, D. Link Sustainability to Corporate Strategy Using the Balanced Scorecard. *The Balanced Scorecard Institute* **2011**.
31. Lu, I.-Y.; Kuo, T.; Lin, T.-S.; Tzeng, G.-H.; Huang, S.-L. Multicriteria decision analysis to develop effective sustainable development strategies for enhancing competitive advantages: Case of the TFT-LCD industry in Taiwan. *Sustainability* **2016**, *8*, 646.
32. Davis, S.; Albright, T. An investigation of the effect of balanced scorecard implementation on financial performance. *Management accounting research* **2004**, *15*, 135–153.

33. Brewer, P. C.; Albright, T.; Davis, S. Security regional bank: implementing a Balanced Scorecard using the business modeling approach. *Journal of Corporate Accounting & Finance* **2004**, *15*, 73–83.
34. Al-Najjar, S. M.; Kalaf, K. H. Designing a balanced scorecard to measure a bank's performance: A case study. *International journal of business administration* **2012**, *3*, 44.
35. Kaplan, R. S.; Norton, D. P. *The balanced scorecard: Translating strategy into action*; Harvard Business Press, 1996.
36. Kaplan, R. S.; Norton, D. P. Linking the balanced scorecard to strategy. *California management review* **1996**, *39*, 53–79.
37. Kaplan, R. S.; Norton, D. P. *Using the balanced scorecard as a strategic management system*; Harvard business review, 1996.
38. Kaplan, R. S.; Norton, D. P. *Strategy maps: Converting intangible assets into tangible outcomes*; Harvard Business Press, 2004.
39. Kaplan, R. S. Conceptual foundations of the balanced scorecard. *Handbooks of management accounting research* **2008**, *3*, 1253–1269.
40. Wu, H.-Y. Constructing a strategy map for banking institutions with key performance indicators of the balanced scorecard. *Evaluation and Program Planning* **2012**, *35*, 303–320.
41. Glykas, M. Fuzzy cognitive strategic maps in business process performance measurement. *Expert Systems with Applications* **2013**, *40*, 1–14.
42. Basili, V. R. Matching software measurements to business goals. In *Keynote Address at the 2003 Software Management Conference, San Jose, California*; 2003.
43. Basili, V.; Heidrich, J.; Lindvall, M.; Münch, J.; Regardie, M.; Rombach, D.; Seaman, C.; Trendowicz, A. Bridging the gap between business strategy and software development. *ICIS 2007 Proceedings* **2007**, 25.
44. Basili, V.; Heidrich, J.; Lindvall, M.; Münch, J.; Regardie, M.; Rombach, D.; Seaman, C.; Trendowicz, A. Linking Software Development and Business Strategy Through Measurement. *IEEE Computer* **2010**, *43*, 57–65.
45. Van Grembergen, W.; Saull, R.; De Haes, S. Linking the IT balanced scorecard to the business objectives at a major Canadian financial group. *Journal of Information Technology Case and Application Research* **2003**, *5*, 23–50.
46. Basili, V.; Lampasona, C.; Ramírez, A. E. O. Aligning corporate and IT goals and strategies in the oil and gas industry. In *International Conference on Product Focused Software Process Improvement*; Springer, 2013; pp. 184–198.
47. Figge, F.; Hahn, T.; Schaltegger, S.; Wagner, M. The sustainability balanced scorecard – linking sustainability management to business strategy. *Business strategy and the Environment* **2002**, *11*, 269–284.
48. Kathuria, R.; Joshi, M. P.; Porth, S. J. Organizational alignment and performance: past, present and future. *Management Decision* **2007**, *45*, 503–517.
49. Chi, D.-J.; Hung, H.-F. Is the BSC really helpful for improving performance? Evidence from software companies in China and Taiwan. *African Journal of Business Management* **2011**, *5*, 224–239.
50. Mooraj, S.; Oyon, D.; Hostettler, D. The Balanced Scorecard: a Necessary Good or an Unnecessary Evil? *European Management Journal* **1999**, *17*, 481–491.

51. Marr, B. How To Design Key Performance Indicators, Management Case Study. *The Advanced Performance Institute* **2010**, *www.ap-institute.com*.
52. Bentes, A. V.; Carneiro, J.; da Silva, J. F.; Kimura, H. Multidimensional assessment of organizational performance: Integrating BSC and AHP. *Journal of business research* **2012**, *65*, 1790–1799.
53. De Felice, F.; Petrillo, A.; Autorino, C. Development of a framework for sustainable outsourcing: Analytic Balanced Scorecard Method (A-BSC). *Sustainability* **2015**, *7*, 8399–8419.
54. Saaty, T. L. A scaling method for priorities in hierarchical structures. *Journal of mathematical psychology* **1977**, *15*, 234–281.
55. Saaty, T. L. *The analytic hierarchy process: planning, priority setting, resource allocation*; McGraw-Hill International Book Company, 1980.
56. Wang, Y.; Xia, Q. A fuzzy AHP and BSC approach for evaluating performance of a software company based on knowledge management. In *2009 First International Conference on Information Science and Engineering*; IEEE, 2009; pp. 2242–2245.
57. Saaty, T. L. How to make a decision: the analytic hierarchy process. *European journal of operational research* **1990**, *48*, 9–26.
58. Dyer, J. S. Remarks on the analytic hierarchy process. *Management science* **1990**, *36*, 249–258.
59. Liu, D.; Bishu, R. R.; Najjar, L. Using the analytical hierarchy process as a tool for assessing service quality. *Industrial Engineering and Management Systems* **2005**, *4*, 129–135.
60. Hua Lu, M.; Madu, C. N.; Kuei, C.; Winokur, D. Integrating QFD, AHP and benchmarking in strategic marketing. *Journal of Business & Industrial Marketing* **1994**, *9*, 41–50.
61. Liberatore, M. J.; Monahan, T. F.; Stout, D. E. A framework for integrating capital budgeting analysis with strategy. *The Engineering Economist* **1992**, *38*, 31–43.
62. Chan, Y. L.; Lynn, B. E. Performance evaluation and the analytic hierarchy process. *Journal of Management Accounting Research* **1991**, *3*, 57–87.
63. Voronin, A. N. A method of multicriteria evaluation and optimization of hierarchical systems. *Cybernetics and Systems Analysis* **2007**, *43*, 384–390.
64. Sharma, M. K.; Bhagwat, R. An integrated BSC-AHP approach for supply chain management evaluation. *Measuring Business Excellence* **2007**, *11*, 57–68.
65. Saaty, T. L. An exposition of the AHP in reply to the paper "remarks on the analytic hierarchy process." *Management science* **1990**, *36*, 259–268.
66. Hosein, Z. Z.; Yousefie, A.; Mehrizi, S. M. T. Evaluating and Ranking Performance by Combination Model of Balanced Scorecard and Ariadne Uncertain Estimate. *Asian Social Science* **2014**, *10*, 70.
67. Noori, B. Prioritizing strategic business units in the face of innovation performance: Combining fuzzy AHP and BSC. *International Journal of Business and Management* **2015**, *3*, 36–56.
68. Yaghoobi, T.; Haddadi, F. Organizational performance measurement by a framework integrating BSC and AHP. *International Journal of Productivity and Performance Management* **2016**, *65*, 959–976.

69. Castrogiovanni, G.; Ribeiro-Soriano, D.; Mas-Tur, A.; Roig-Tierno, N. Where to acquire knowledge: Adapting knowledge management to financial institutions. *Journal of Business Research* **2016**, *69*, 1812–1816.
70. Chang, S.-C.; Tsai, P.-H. A hybrid financial performance evaluation model for wealth management banks following the global financial crisis. *Technological and Economic Development of Economy* **2016**, *22*, 21–46.
71. Rabbani, A.; Zamani, M.; Yazdani-Chamzini, A.; Zavadskas, E. K. Proposing a new integrated model based on sustainability balanced scorecard (SBSC) and MCDM approaches by using linguistic variables for the performance evaluation of oil producing companies. *Expert Systems with Applications* **2014**, *41*, 7316–7327.
72. Sundharam, V. N.; Sharma, V.; Stephan Thangaiah, I. S. An integration of BSC and AHP for sustainable growth of manufacturing industries. *International Journal of Business Excellence* **2013**, *6*, 77–92.
73. Chung, C.-C.; Chao, L.-C.; Chen, C.-H.; Lou, S.-J. A Balanced Scorecard of Sustainable Management in the Taiwanese Bicycle Industry: Development of Performance Indicators and Importance Analysis. *Sustainability* **2016**, *8*, 518.
74. Caha, J.; Drážná, A. *Information about FuzzyAHP package for R (ver.0.8.0)*; 2016.
75. Saaty, R. W. The analytic hierarchy process—what it is and how it is used. *Mathematical modelling* **1987**, *9*, 161–176.
76. Malczewski, J. *GIS and multicriteria decision analysis*; John Wiley & Sons, 1999.
77. Boons, F.; Lüdeke-Freund, F. Business models for sustainable innovation: state-of-the-art and steps towards a research agenda. *Journal of Cleaner Production* **2013**, *45*, 9–19.
78. Evans, S.; Vladimirova, D.; Holgado, M.; Van Fossen, K.; Yang, M.; Silva, E. A.; Barlow, C. Y. Business Model Innovation for Sustainability: Towards a Unified Perspective for Creation of Sustainable Business Models. **2017**.
79. Wirtz, B. W. Business model management. **2011**, *2*.
80. Donaldson, T.; Preston, L. E. The stakeholder theory of the corporation: Concepts, evidence, and implications. *Academy of management Review* **1995**, *20*, 65–91.
81. Evans, S.; Rana, P.; Short, S. W. Deliverable 2.6. Final set of tools & methods that enable analysis of future oriented, novel, sustainable, value adding business-models and value-networks. *University of Cambridge, Cambridge, UK, available at: http://www. sustainvalue. eu/publications/D2_6_Final_v2. pdf* **2014**.
82. Geissdoerfer, M.; Bocken, N. M. P.; Hultink, E. J. Design thinking to enhance the sustainable business modelling process – A workshop based on a value mapping process. *Journal of Cleaner Production* **2016**, *135*, 1218–1232.
83. Ayag, Z. An analytic-hierarchy-process based simulation model for implementation and analysis of computer-aided systems. *International Journal of Production Research* **2002**, *40*, 3053–3073.
84. Palma-Mendoza, J. A. Analytical hierarchy process and SCOR model to support supply chain re-design. *International Journal of Information Management* **2014**, *34*, 634–638.
85. Ayağ, Z.; Özdemir, R. G. A fuzzy AHP approach to evaluating machine tool alternatives. *Journal of intelligent manufacturing* **2006**, *17*, 179–190.

86. Wu, H.-Y.; Tzeng, G.-H.; Chen, Y.-H. A fuzzy MCDM approach for evaluating banking performance based on Balanced Scorecard. *Expert Systems with Applications* **2009**, *36*, 10135–10147.
87. Chang, D.-Y. Applications of the extent analysis method on fuzzy AHP. *European journal of operational research* **1996**, *95*, 649–655.
88. Hsieh, T.-Y.; Lu, S.-T.; Tzeng, G.-H. Fuzzy MCDM approach for planning and design tenders selection in public office buildings. *International journal of project management* **2004**, *22*, 573–584.
89. Zadeh, L. A. The concept of a linguistic variable and its application to approximate reasoning—II. *Information sciences* **1975**, *8*, 301–357.
90. Mon, D.-L.; Cheng, C.-H.; Lin, J.-C. Evaluating weapon system using fuzzy analytic hierarchy process based on entropy weight. *Fuzzy sets and systems* **1994**, *62*, 127–134.
91. Buckley, J. J. Fuzzy hierarchical analysis. *Fuzzy sets and systems* **1985**, *17*, 233–247.
92. Kaufman, A.; Gupta, M. M. *Introduction to fuzzy arithmetic*; Van Nostrand Reinhold Company, 1991.
93. Negi, D. S. *Fuzzy analysis and optimization*; UMI, 1996.
94. Zimmermann, H.-J. Fuzzy Control. In *Fuzzy Set Theory—and Its Applications*; Springer, 1996; pp. 203–240.
95. Chen, M.-K.; Wang, S.-C. The use of a hybrid fuzzy-Delphi-AHP approach to develop global business intelligence for information service firms. *Expert Systems with Applications* **2010**, *37*, 7394–7407.
96. Ren, C.; Dong, J.; Ding, H.; Wang, W. Linking strategic objectives to operations: towards a more effective supply chain decision making. In *Proceedings of the 38th conference on Winter simulation*; Winter Simulation Conference, 2006; pp. 1422–1430.
97. Taticchi, P.; Tonelli, F.; Cagnazzo, L. A decomposition and hierarchical approach for business performance measurement and management. *Measuring Business Excellence* **2009**, *13*, 47–57.
98. Quezada, L. E.; Cordova, F. M.; Palominos, P.; Godoy, K.; Ross, J. Method for identifying strategic objectives in strategy maps. *International Journal of Production Economics* **2009**, *122*, 492–500.
99. Quezada, L. E.; Palominos, P. I.; Gonzalez, M. A. Application of AHP in the Design of a Strategy Map. *iBusiness* **2013**, *5*, 133.
100. Quezada, L. E.; López-Ospina, H. A. A method for designing a strategy map using AHP and linear programming. *International Journal of Production Economics* **2014**, *158*, 244–255.
101. Amrit, C.; Daneva, M.; Damian, D. Human factors in software development: On its underlying theories and the value of learning from related disciplines. A guest editorial introduction to the special issue. *Information and Software Technology* **2014**, *56*, 1537–1542.
102. Curtis, B.; Krasner, H.; Iscoe, N. A field study of the software design process for large systems. *Communications of the ACM* **1988**, *31*, 1268–1287.
103. Joint Technical Committee ISO/IEC JTC 1/SC7 ISO/IEC 25010:2011 Systems and Software Engineering – Systems and software Quality Requirements and Evaluation (SQuaRE) – System and Software Quality Models 2011.

104. Towers Watson *Effective Model validation – Embedding Trust. Insights*. July 2014, pp. 1–6.
105. MxConnell, S.; Stuart, J.; Peloquin, M.; Tockey, S.; Nygren, M. *Construx Software Builders, Inc.* July 2008,.
106. Bozbura, F. T.; Beskese, A.; Kahraman, C. Prioritization of human capital measurement indicators using fuzzy AHP. *Expert Systems with Applications* **2007**, *32*, 1100–1112.
107. Bontis, N. Intellectual capital: an exploratory study that develops measures and models. *Management decision* **1998**, *36*, 63–76.
108. Bontis, N. Assessing knowledge assets: a review of the models used to measure intellectual capital. *International journal of management reviews* **2001**, *3*, 41–60.