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Modelling Business Indicators on a spatially enabled Decision Support System: Spatial Dashboard

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Resumo

O processo de tomada de decisão é um dos mais importantes aspectos de uma empresa. Um processo de tomada de decisão inteligente poderá trazer valor acrescentado a uma organização. Urge então a necessidade de investir em ferramentas de *Business Intelligence* como forma de suportar este processo de decisão. Na verdade, e num mundo dito globalmente competitivo, destacar-se-ão as empresas que melhores decisões tomarem, ganhando poder competitivo.

O Spatial Dashboard é um sistema de apoio à decisão com suporte espaço-temporal. Esta tese dá especial enfoque ao Scenario Manager, módulo onde são criados e geridos todos os cenários de negócio (ferramentas decisivas na tomada de melhores decisões). O Spatial Dashboard é baseado no Balanced Scorecard uma metodologia de Corporate Performance Management (CPM). A modelação de indicadores de negócio revela-se então crucial para um sistema que pretende fornecer vantagem competitiva a todos aqueles que dele fazem uso. A modelação destes indicadores funciona como agregador de conhecimento especializado que traduz de uma forma sistemática e detalhada a visão estratégica da empresa.

A avaliação do estado-da-arte de metodologias de CPM; a descrição da proposta e solução consideradas para resolver o problema de modelar indicadores de negócio de forma inteligente e a descrição de um caso de estudo, resultado da aplicação do Spatial Dashboard a um cenário de negócio hipotético, constituem, de grosso modo, o conteúdo principal desta tese. Ademais, as principais contribuições do trabalho desenvolvido no âmbito desta tese, bem como algumas sugestões para trabalho futuro estabelecem as considerações finais da mesma.

Palavras-chave

Sistemas de Apoio à Decisão, *Balanced Scorecard*, *Scenario Planning*, Cenários de Negócio, Indicadores de Negócio

Abstract

Making decisions is one of the most important basics of all organizations. Making those decisions correctly and wisely is what really creates value. Therefore, high-quality decision making is what most concern nowadays' organizations which explains the heavy investments that are being made in Business Intelligence systems. In fact, under a globally competitive environment, organizations that analyse and extract information from their data increase insight into markets, obtaining competitive advantage.

The Spatial Dashboard is a complex tool for enhancing decision-makers ability to take decisions, as it provides useful and multi-dimensional information with the support of spatial and temporal context. This thesis focus on a Spatial Dashboard's specific module concerned with the creation of 'what-if' business scenarios, the Scenario Manager. Along with the definition of business indicators comes its modelling under business scenarios. Having a comprehensive and thorough approach for modelling business indicators could be very helpful on clarifying cause and effect factors on business, which was achieved by using a graph model.

Throughout this thesis, an analysis on state-of-the-art of Corporate Performance Management methodologies is made since Spatial Dashboard relies on Balanced Scorecard a CPM approach, as well as it is described the proposal and the solution to address the problem of modelling business indicators in a comprehensive and useful way so that they could provide valuable and powerful real-time information to decision-makers. Moreover, a final case study is presented to evaluate Spatial Dashboard's Scenario Context effectiveness and some conclusions and future work considerations are drawn as final words.

Keywords

Decision Support Systems, Balanced Scorecard, Scenario Planning, Business Scenario, Business Indicators

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List of Acronyms

Acronym	Description
AHP	Analytic Hierarchy Process
AIS BSC	Balanced Scorecard of Advanced Information Services
BI	Business Intelligence
BSC	Balanced Scorecard
CPM	Corporate Performance Management
CVS	Concurrent Versions System
DM	Decision Makers
DP	Design Pattern
DSS	Decision Support System
ESI BITS	Balanced IT Scorecard
IAM	Intangible Asset Monitor
ICAO	International Civil Aviation Organization
IS	Information System
IST	Instituto Superior Técnico
IT	Information Technology
KPI	Key Performance Indicators
MVC	Model-View-Controller
OWA	Ordered Weight Averaging
PI	Performance Indicators
ROCE	Return-On-Capital-Employed
SD	Spatial Dashboard
SN	Skandia Navigator
SVN	Subversion
TDB	Tableau de Bord
TOC	Table of Contents
WLC	Weighted Linear Combination

1. Introduction

This document portrays the work developed under an MSc Thesis on modelling scorecard indicators on a spatially and timely enabled Decision Support System. A thorough description of implementation process, with all the stages this thesis went through, from context analysis to case study implementation, all the way through problem, proposal and implementation definition. On this introductory chapter it is described a brief description of this thesis statement and organization.

1.1. Thesis Statement

In this section, a brief overview of first chapters of this thesis is presented. A brief context will be given in order to provide the reader some background, followed by the problem needing a solution and, finally, the solution proposed to address it.

1.1.1. Context

Enterprise executives understand that accurate knowledge can mean improved business performance. Having access to an accurate, wide and available information centre could lead them to make better decisions. Effectively, making decisions is one of the most important basics of all organizations. Making those decisions correctly and wisely is what really creates value. Therefore, high-quality decision making is what most concern nowadays' organizations which explains the heavy investments that are being made in business intelligence systems [1][2].

In the Information Era, Information Technology (IT) came to aid the decision making process, allowing its users to introduce, evaluate and analyse data. For that reason, it is extremely desirable to evaluate how effectively these systems are, especially on helping business decision-makers.

Evaluating the IT function remains a challenge: well-known financial measures such as 'Return on Investment' (ROI), 'Internal Rate of Return' and 'Payback Period' have been demonstrated to be inadequate, both in explaining IT investment decisions and in assessing them [3]. Since the financial dimension alone was not enough to evaluate a corporate performance, others have been added and as a result many frameworks have emerged to analyse Corporate Performance Management (CPM).

Corporate Performance Management is a new generation of Business Intelligence systems which supports the monitoring and control of business operations. CPM solutions must be able to efficiently process business events, compute business metrics, detect business situations, and provide the real-time visibility of Key Performance Indicators (KPI) [4].

CPM is an area of Business Intelligence that has eagerly been developed over the past ten years. CPM solutions are usually adopted by companies that want to improve their business performance, optimize processes, reduce costs and understand the way their business are run internally. CPM solutions will bring desired benefits when correctly implemented and used within organizations. In fact, they could speed up response time and, thus, increase revenue; could be of great help managing risk, since it could provide the right information on the right time, easing the decision making process; and it could improve business processes by placing the customer on the spotlight, i.e., adopting strategies of built-to-order instead of built-to-stock, for illustration.

In order to achieve a higher level of performance measuring within companies, frameworks have been developed to outpace the traditional reliance on financial indicators to evaluate companies' performance. Whether some of them are more interested on providing a balanced view of the company or just focusing on Intellectual Capital they all made important contributions to this area of Business Intelligence. Despite the fact that each framework had been developed under specific economic and cultural circumstances they all provide an important turnover on the performance measuring field.

The Balanced Scorecard designed by Norton and Kaplan, the Intangible Assets Monitor created by Sveiby and the Skandia Navigator implemented by Edvinsson are frameworks developed to address the CPM requisite. These measurement systems can be used for control or for dialogue. As language for dialogue, metrics are excellent, because they force us to define relationships mathematically and to be stringent. Well designed indicators based in a coherent theoretical framework are like the words and the grammatical syntax of a language. It can help managers understand how the relationships between people and profit look like in their own company [5].

The following chapter provides the state-of-the-art of Corporate Performance Management. Starting with the description of this area, explaining its main motivation and going through three main frameworks that strive to address this business area, the state-of-the-art chapter will focus on this specific area. Finally a comparative analysis is provided amongst all the frameworks presented on Chapter 2.

1.1.2. Problem

Peter Drucker, the world-renowned business strategist, built his organisational theories on one overriding management principle: "*What you cannot measure, you cannot manage*." This is the basis of modern business management and performance benchmarking.

In fact, scorecard methods provide a very comprehensive and conveyable way of measuring business performance, hence, a better way to manage organizations. A properly constructed scorecard should tell the story of the business unit's strategy. It should identify and make explicit the sequence of hypotheses about the cause-and-effect relationships between outcome measures and the performance drivers of those outcomes.

However, most of these scorecard methods and frameworks tend to focus on strategy implementation and definition of the deliverable benefits but ignore the rapid changes on economy, industry and technology. Moreover, the way most scorecards presents the relevant information, usually through bi-dimensional tables and charts, is quite counter-productive, in a way that can limit the deepness and wideness of managers' analysis [6][7].

Having this situation in mind, the problem stated on Chapter 3 of this thesis is intrinsically related with this situation. In fact, this thesis challenge is concerned with providing a broad and helpful approach for modelling scorecard business indicators, in a way that they could provide valuable and powerful information to decision-makers, shortening their time-to-enlightenment, hence, enhancing their decision making process.

1.1.3. Solution

An effective approach was adopted to address the problem of modelling scorecard indicators on a spatially and timely enabled decision support system. The proposed solution was developed under an existent DSS, the Spatial Dashboard. The Spatial Dashboard is an innovative approach for defining, analysing and managing business performance using spatial and temporal dimensions.

Since the problem we want to address is very specific and it is inserted under the Spatial Dashboard context we mainly focus on particular subjects, as they are directly related with the problem we want to achieve. Given that, the main focus of this thesis will be:

- Creation and manipulation of business indicators
- Construction and management of business indicator's rules
- Definition of a graphical representation for the development of business scenarios
- Management operations amongst business scenarios
- Interface features for enhancing decision makers' performance on business scenarios definition

The proposal and solution statements are organized in four main sections with the intention of focusing the reader on the problem-solving task. So first of all, it is described an approach for the definition of these business indicators; on the following section it is presented our proposal for modelling them under business scenarios; the subsequent section defines our approach for managing these business scenarios, created in the meantime; and the last section provides some interface features for enhancing managers' performance when defining these business scenarios.

1.2. Thesis Organization

This thesis is organized in the following way:

Chapter 2 presents the *state-of-the-art* on Business Performance Management and particularly on Scorecard methods. A brief description of Business Performance Management is made along with the definition of its three main frameworks: the Balanced Scorecard, the Skandia Navigator and the Intangible Assets Monitor.

On **Chapter 3** is described the main problem this thesis strives to address.

Chapter 4 outlines the proposal for addressing the problem stated before, under the Spatial Dashboard approach. For that reason on this chapter a brief overview of Spatial Dashboard DSS is provided

The solution's implementation details of what had been proposed on previous chapter is described on **Chapter 5**.

A case study application of Spatial Dashboard, with focus on solution implemented under the scope of this thesis, is conveyed on **Chapter 6**. A results analysis to this case study application to the Spatial Dashboard is provided on Chapter 6 as well.

Finally, **Chapter 7** reveals a conclusion of this thesis with special focus on the main contributions of this thesis as well as a brief description of future related work that could be made.

2. State of the Art

This chapter outlines the existing solutions and proposals for using the spatio-temporal context in order to monitor and evaluate organizations' business performance. Corporate Performance Management is, therefore, one of the main scientific areas approached in this chapter. Some frameworks developed to address the Corporate Performance Management issue are summarized under this chapter as well.

2.1. Introduction

The new concept of Business Intelligence as we know it nowadays was first stated in Sun Tzu's Art of War. "*To succeed in war, one should have full knowledge of one's own strengths and weaknesses and full knowledge of one's enemy's strengths and weaknesses*." This Sun Tzu's well-known statement is the core idea behind modern Business Intelligence. Actually, a company should know itself better than any other, and should know its costumers, market, trends and competitors better than anyone else.

In fact, it is very interesting how much business and warfare are alike, especially on the challenges each area has to deal with:

- collecting data
- analysing data and make them useful information
- making decisions based on information analysed

Enterprise executives understand that accurate knowledge can mean improved business performance. Having access to an accurate, wide and available information centre could lead them to make better decisions. Effectively, making decisions is one of the most important basics of all organizations. Making those decisions correctly and wisely is what really creates value. Therefore, high-quality decision making is what most concern nowadays' organizations which explains the heavy investments that are being made in business intelligence systems [1][2].

In a more and more competitive global business environment, organizations struggle to gain advantage in many fronts towards their competitors, including this area of information technology. Effectively, companies which collect and analyse their data can better achieve insight into markets, and act in response of its costumers and markets' needs.

Today's organizations have to deal with a problem they've never experienced before; handling the huge flood of data produced by today's information systems. In fact, lack of data is a problem that companies are no longer experiencing. Extracting and understanding all information that data can provide is extremely desirable for decision-makers and could be a critical and important competitive advantage. Hence, the way which the information is displayed to the decision-maker can be decisive on the way the decision is made. Providing quality information will help managers make better decisions which will enhance organizational performance and bring additional value.

In the Information Era, Information Technology (IT) came to aid the decision making process, allowing its users to introduce, evaluate and analyse data. For that reason, it is extremely desirable to evaluate how effectively these systems are, especially on helping business decision-makers.

Evaluating the IT function remains a challenge: well-known financial measures such as 'return on investment' (ROI), 'internal rate of return' and 'payback period' have been demonstrated to be inadequate, both in explaining IT investment decisions and in assessing them [3]. Since the financial dimension alone was not enough to evaluate a corporate performance, others have been added and as a result many frameworks have emerged to analyse Corporate Performance Management (CPM).

Corporate Performance Management is a new generation of Business Intelligence systems which supports the monitoring and control of business operations. CPM solutions must be able to efficiently process business events, compute business metrics, detect business situations, and provide the real-time visibility of Key Performance Indicators (KPI) [4].

The neologism often used to refer to this new picture in BI is Corporate Performance Management, which can be defined as a set of processes that help organizations optimize business performance by encouraging process effectiveness as well as efficient use of financial, human, and material resources[8].

An intelligent use of CPM should be able to draw accurate representations of the world. In fact, it is supposed to convey a comprehensive view of business operation to its users. Hence, when addressing CPM solutions decision makers are mostly interested on getting some desired benefits[4]:

- Increasing revenue (through speeding-up response time)
- Managing risk (by providing the right information on the right time, easing the decision making process)
- Improving customer satisfaction (through improvement of business processes)

Despite the fact that CPM is a new generation of enterprise data management system that focuses on monitoring business operations, many frameworks have been developed throughout the years in order to address the management of business indicators created under a CPM solution. The Balanced Scorecard (BSC), the Intangible Asset Monitor (IAM), the Skandia Navigator, the Balanced IT Scorecard (ESI BITS) and the BSC of Advanced Information Services (AIS BSC) are some examples of frameworks that were considered on this chapter.

2.2. Corporate Performance Management

Corporate Performance Management (CPM) is a new approach to Business Intelligence that has eagerly made progress over the past ten years. Actually, during the last ten years the approach to business management has changed from both the technological and the organizational points of view:

- On the technology field we have recently assisted to the emergence of outsourcing. Outsourcing is being used to reduce fixed costs, mainly because no investments are necessary and only services are paid.
- On the organization field, companies are becoming more and more process-oriented.[9]

As companies started to engage customers and suppliers in order to synchronize all the business activities, they realized the importance to measure their business strategy through metrics. As a result, managers felt the need of continuously measuring their business process via KPIs. There is no reason for companies relying heavily on the traditional financial measures. In fact, these traditional measurements are no more certain or more real than non-financial measures, and new indices are necessary to achieve a balance between financial and non-financial measures.[10]

Under the CPM approach is important to understand that an organization is a well-structured entity divided under a hierarchy and organized mainly under three decision levels[8] (see Fig. 2.1):

- **Strategic**: the global strategy of the company.

- **Tactic**: usually divided under multiple divisions one of each controlling a set of functions. These functions should follow the global strategy defined by the upper level (the strategic one).
- **Operational**: composed by core activities. The decision power related to this level is usually limited to process optimization only if follows the tactic and strategic plans.

Fig. 2.1 - The CPM organization's three-level approach

When defining business process under a CPM approach it is important to note that even though a process identifies a set of logically related tasks, performed to accomplish a defined goal, they are usually orthogonal to the entire organization and commonly include tasks that must be executed by different levels. Therefore, there are two main concepts when defining these business processes under a CPM approach: *business rules* and *indicators*:

- In what *business rules* are concerned, the Event-Condition-Action will provide the best trade-off between effectiveness and simplicity.

- In what *indicators* are concerned, loads of proposals have come ahead to define the better approach to address this issue. Despite the fact that most of them have been widely accepted in the industrial context, the scientific community have been more interested on coping with the modelling and handling of indicators. Some works[8] in this direction have been carried out in the fields of budgeting and what-if analysis: while the first assumes a tree-based hierarchy between indicators, the second does not consider any predefined relationship between indicators, thus requiring the effects of correlations to be manually defined.

The crucial point of processes is that they focus on global strategy rather than on particular tasks. Given that, top-level strategy should be translated on single tasks and lower-level goals so that inferior levels could follow the corporate strategy as well. Under this approach, as could be seen under Fig. 2.2, company strategy and targets are translated on indicators that undergo the influence of company performance; all actions/decisions taken underneath lower-levels are aiming indicators targets defined on upper-levels; and, lastly, company performance is defined by whether or not indicators values are on target.

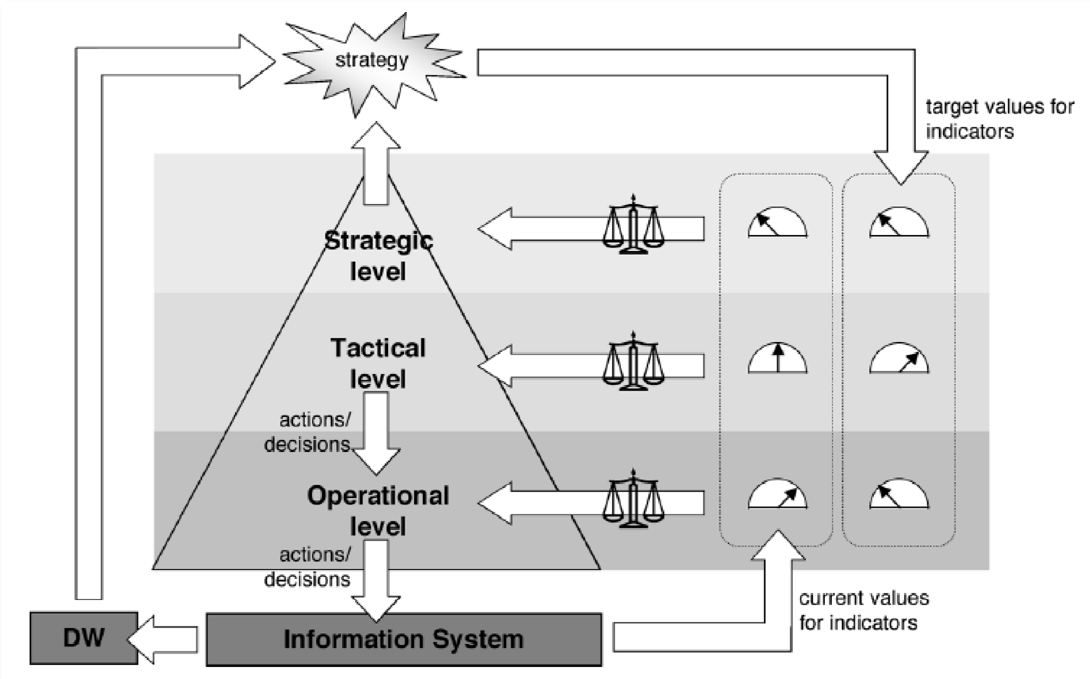

Fig. 2.2: The CPM approach (source: [8])

To summarize, CPM approach can be defined with four main characteristics:

- **Informative power**: if business rules and indicators are defined and selected according to company's business strategy it could turn data into information, shortening the time-to-enlightenment of decision-makers
- **Right-time**: data provided to CPM systems should be delivered on time; otherwise the information provided by the system will not arrive on time and will be useless to mangers. It is extremely important the collection and analysis of real-time data.
- **Light architecture**: KPI will change very often and it will be desirable to change them as business goes by, thus an easy change of KPI will be desired and, as a result, an overall light system's architecture should be attained.
- **Right process design**: it is necessary a full understand of business processes and the running business to design the business rules and KPI accordingly. Only then, the CPM system will provide accurate and reliable feedback based upon the indicators defined and selected. This design process has a leading role to guarantee the tenability and soundness of the system.

2.2.1. Frameworks

Throughout the years many frameworks have been developed in order to address the Business Performance Approach. Whilst some frameworks are more interested in attending to tangible assets others are more concerned with intangible assets. Either way, all of them deal with this issue and, in this section, is presented a brief overview of these frameworks.

2.2.2. The Balanced Scorecard

The Balanced Scorecard (BSC) was created in 1993 by the hands of Robert Kaplan, a professor at Harvard School of Business and chairman at Balanced Scorecard Collaborative (BScol), and David Norton, a PhD in Business Administration from Harvard University and President and CEO of BSCol. The Balanced Scorecard was first announced to a bigger audience through an article in Harvard Business Review.

The BSC has its origins on *Tableau de Bord* (TDB) an Information System (IS) created in France about 50 years ago [11]. The TDB has been used in France since then and it was with lot scepticism that French companies watched the rise of a new Corporate Performance Management system. In fact, the reaction to the BSC has not been very warm among French companies, or even among academics. The French resistance to the BSC could not be explained by technical issues alone. In fact, most French authors state that the BSC does not fit the French way of doing business, thus they consider the BSC inadequate to their way of managing firms[11]. This French reluctance to BSC is after all cultural. Actually, the local ideologies between France and the USA are very different from each other. In the United States, where people are assumed to be equal, management devices play a major role in creating hierarchies, making people obey, bringing legitimacy and reducing the feeling of uncertainty. In France, social hierarchy, obedience, legitimacy and security are mainly questions of education and honour, not of management devices. Consequently, the demand for management methods to create hierarchies, to make people obey and to legitimate managers is far from being the same in the two countries [11].

The aim of the TDB was to convey each company vision, strategy and business mission into a set of indicators and metrics throughout the definition of key success factors and key performance indicators to each and every company using the TDB. On the other hand, the main goal of the BSC is to unify in a multidimensional framework a company overall business performance throughout a set of defined indicators. Those indicators are called Key Performance Indicators (KPI) and are organized among four defined and wide areas (called perspectives). It is important to state that BSC is not static, i.e., all its Key Performance Indicators are defined by user according to the way each company runs its own business. Thus, BSC is, by definition, a logical framework for implementing and aligning complex programs of change and, indeed, for managing strategy-focused organizations. BSC ought to be used to ease the translation of strategy into action.

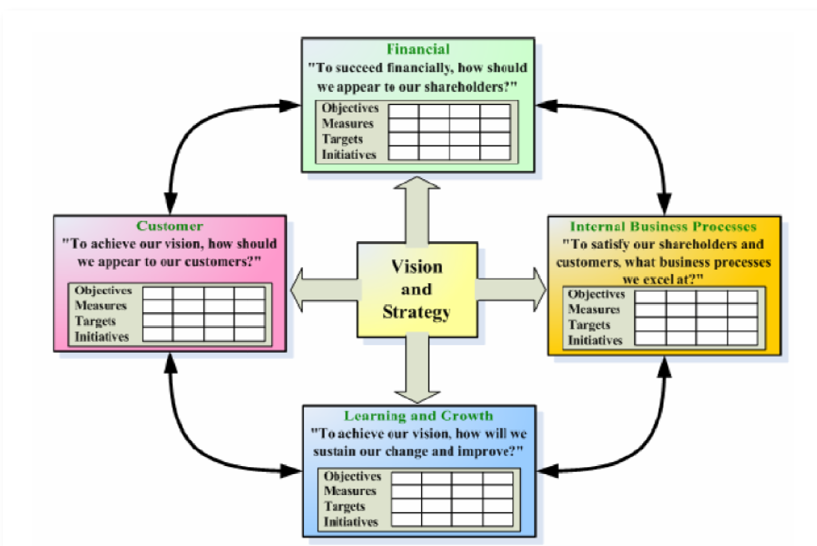

Fig. 2.3 – The standard BSC Perspectives (source: [12])

The BSC allows managers to analyse their corporate performance via four perspectives, as could be seen under Fig. 2.3. Having these four main perspectives, BSC provides the answers to the following questions:

- How do customers see us? (customer perspective)
- What must we excel at? (internal perspective)
- Can we continue to improve and create value? (innovation and learning perspective)
- How do we look to shareholders? (financial perspective)

The **customer perspective** is usually related to measurement of outcomes from the company strategy. The value of a company is usually related to their value to customers. However, customers' concerns tend to fall in four specific and well-known categories: time, quality, performance and service, and cost [13]. Putting BSC to work will simply be accomplished by the articulation of goals for time, quality, performance and service and then convert these goals into metrics. For instance, a high-quality goal could be measured using the defect level of incoming products; the delivery of a high standard service could be calculated via the accuracy of company's delivers, in order to infer on-time delivery and time-to-market, the time interval between an order request and its delivery could be measured.

The **internal business processes perspective** is, by definition, related with the internal processes defined by each company in order to attain corporate strategy and customer satisfaction. Guaranteeing customer satisfaction is one of the most important goals of every company; however, an excellent client fulfilment only comes with an excellent company strategy. In fact, managers should be focused on those critical internal processes that will facilitate customer needs, like factors that affect cycle time, quality, employee skills, and productivity[13]. Companies should also define what processes and competencies they must excel at and specify measures for it.

The **innovation and learning perspective** is usually related with processes designed to achieve long-term growth and people knowledge improvement amongst others. Keeping clients satisfied and processes optimized might be two of the key points in order to achieve competitive advantage towards opponent companies. However, the targets for success accomplishment keep changing. A company's ability to innovate, improve and learn ties directly to the company's value. That is, only through the ability to launch new products, create more value for customers, and improve operating efficiencies continually can a company penetrate new markets and increase revenues and margins – in short, grow and thereby increase shareholder value [13].

The **financial perspective** is mainly related to the profitability of a company, the tangible assets. Typical financial goals are related to profitability, growth and shareholder value. However, this specific perspective have been highly criticised in scientific community. Some critics fling the following question: 'Should managers pay attention to these backward-focus indicators, when they proved to be inadequate to reflect contemporary value?'. Others may say that these traditional financial measures do not improve customer satisfaction, quality, cycle-time and employee motivation. According to Kaplan and Norton these arguments are wrong for at least two reasons [13]:

- A well-designed financial control system can actually enhance rather than inhibit an organization's total quality management program.
- The alleged linkage between improved operating performance and financial success is actually quite tenuous and uncertain.

This framework translates the vision and strategy of a business unit into objectives and performance measures in four different areas: financial, customer, internal-business-process, and learning and growth perspectives. Kaplan and Norton state that a company strategy is a set of hypotheses about cause and effect[12]. The authors also declare that those cause-and-effect relationships should pass through all four perspectives of a BSC (see Fig. 2.4).

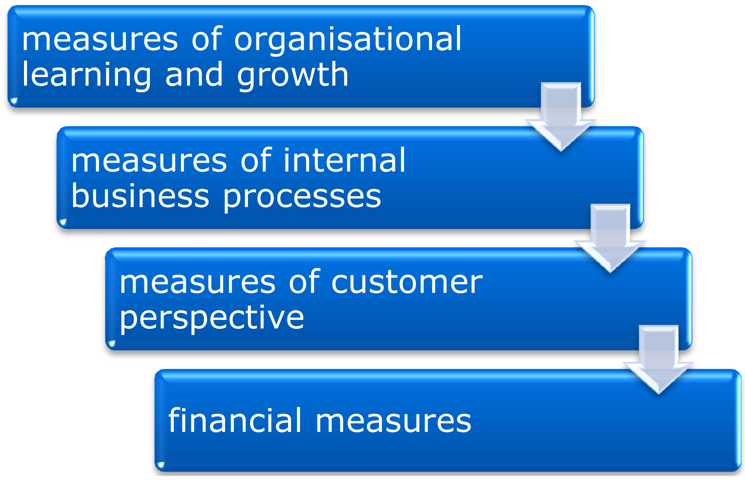

Fig. 2.4 - The causal-and-effect relationship amongst BSC perspectives

In reality, each strategic area should have both lead and lag indicators, yielding two directional cause-and-effect chains: lead and lag indicators apply horizontally within the areas and vertically between areas. This procedure implies that strategy is translated into a set of hypotheses about cause and effect [12].

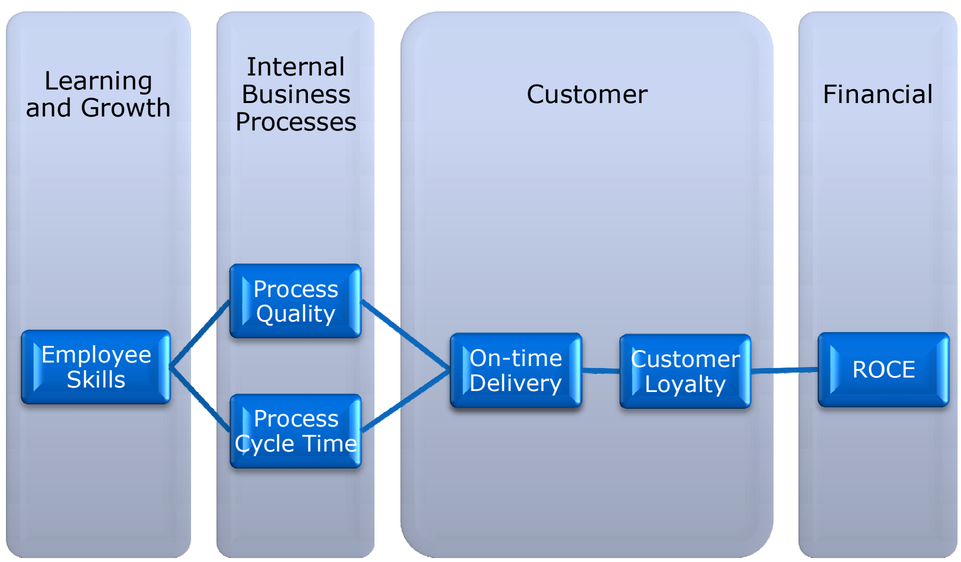

Fig. 2.5 – Corroborative example of cause-and-effect relationships under a BSC (source: adapted from [12])

With the purpose of illustrating these cause-and-effect relationships, Fig. 2.5 gives us an example where a definition of a simple financial indicator has, *de facto*, the so called cause-and-effect relationships. Let us conceive the idea of a company that wants to measure the return-on-capital-employed (ROCE) in the financial perspective. The driver of this indicator could be the repeat sales from existing customers, since it would be a result of loyalty among those customers. Thus, we have to include customer loyalty under customer perspective. ROCE and customer loyalty indicators are now connected through a cause-effect relationship. Consequently, analysis of customers' needs and preferences may reveal that on-time delivery is expected by customers. In order to improve this on-time delivery the company may need to achieve short cycle times in operating processes as well as levering the overall quality of processes. These two indicators fit in internal business processes perspective. Hence, only by training and improving the skills of their operating employees can organizations improve their processes quality and reduce respective cycle times, an indicator incorporated into innovation and growth perspective. All the way through this example we can observe clearly a chain of cause-and-effect relationships as a vertical vector through the four perspectives of the BSC.

The BSC assumes cause-and-effect relationships among the four areas of measurements at the strategic level implying the existence of a sort of generic model of performance. This assumption is essential because it allows the measurements in non-financial areas to be used to predict future financial performance, i.e., having all the indicators and perspectives connected a more comprehensive and coherent conclusion may be reached. This underlying feature of BSC is extremely important because it reduces the problem of the lack of future orientation of accounting data.

Apart from this observably cause-and-effect philosophy, the BSC is much more than a strategic measurement system, it is a strategic control system likewise. Throughout the bibliography [11][3][8][13][12][6][14], the BSC was considered useful for the following purposes:

- Clarify and gain consensus about strategy;
- Align departmental and personal goals to strategy;
- Link strategic objectives to long-term targets and annual budgets;
- Identify and align strategic initiatives;
- Obtain feedback to learn about and improve strategy.

However, the BSC is a somewhat complex framework and some measures should be taken in order to extract the best positive results from it, such as:

- The communication of the vision and the strategy to teams and employees (through executive announcements, town meetings, videos, brochures and newsletters);
- The translation of strategic objectives and measures into objectives and measures for teams and employees (through setting targets, aligning strategic initiatives with objectives and linking budgets with long-term plans);
- The creation of a link between rewards and performance measures (through strategic feedback and learning).
- Every measure selected should be part of a cause-and-effect relationship, representing company’s strategy and vision
- Lead indicators (indicators that drive performance) should be unique, since they reflect what's difference about company's strategy
- The creation of a link to financial indicators, because strategic goals ought to be translated into measures which ultimately link to financial indicators.

Finally, and as on what indicators are concerned, it is important to emphasize a particular feature of them under the BSC framework. The BSC indicators tend to focus on rewards, i.e., the BSC method strongly encourages the linking of rewards to performance measurement. The performance measurement system makes qualitative objectives like quality, customer service, personnel involvement, among others, quantitative ones. It helps differentiate the basis of rewards, which was previously limited almost exclusively to financial results, and it apparently does so without abandoning the invaluable objectivity of figures.

Succinctly, the BSC is a business performance management framework divided under four main perspectives. A new approach of cross-functional integration combining the financial, customer, internal processes and innovation, and organizational learning perspectives, helping managers to understand many inter-relationships they weren't aware of. This new insight and understanding into their own companies could help managers to go beyond the traditional notions of management and in due course improve decision making and problem solving.

Nevertheless, there are some drawbacks along with some advantages in this framework. As a result, it is presented below a short-list of the main advantages and disadvantages of this framework.

As **advantages** of the BSC we can observe it as a system which:

- Provides a balanced presentation of both financial and operational measures;
- Forces managers to focus on the handful of measures that are most critical;
- Brings together, in a single report, many important elements of each organization's competitive agenda, like customer orientation, short time responsiveness, quality improvement, focus on team work, innovation enhancement of both products and internal processes, and definition of a long-term strategy;
- Allows a clarifying and gaining consensus on strategy;
- Has the ability to give guidelines for better business conduct.

In what concerns BSC main **disadvantages** we can state that:

- Built upon Michael Porter's model (the five forces model) [15] the approach of the BSC works from the outside in, i.e., from the customers to the internal processes. Thus, this approach does not have a resource-based perspective working from the inside out.
- Among some of the suggested areas of measurements there is no cause-and-effect relationship. For instance, between customer satisfaction and financial performance there isn't any kind of direct relationship[14].
- There is no interaction between the levels, and the objectives at level N are an analytical sum of the objectives at level N-1.
- There is the latent idea of mono-responsibility. A system of shared responsibility isn't possible, thus there's no room for several persons being responsible.
- Everyone struggles for the same objectives. In fact, everyone is in complete control of the variables for which they are accountable.

2.2.3. Some BSC adjustments

Along with the BSC philosophy of clear communication of goals and priorities within the company comes a continuously learning and team working thinking. In effect, some authors support Kaplan and Norton's idea that the BSC isn't just a set of goals and measures, defining it as a three-stage framework [16]:

- **Design**: where the business model should be reflected in relationship between strategic goals.
- **Development**: where this corporate strategic measurement and management tool should be reflected under divisions, business units and functions, i.e., the development should be vertical, evolving all management teams and employees.
- **Deployment**: on this particular stage all management systems should be in line with corporate strategy. Thus, the BSC will help to drive strategic behaviour into everyday decisions and operations.

There were some attempts to adapt the BSC to Software Intensive Corporations creating two additional variations of this framework described, briefly, above:

- The **BITS**: the Balanced IT Scorecard (BITS) proposed by the European Software Institute (ESI): provides a new version of the four original perspectives (financial, customer, internal process, infrastructure and innovation) and adds a fifth one, the People Perspective [17].
- The **AIS BSC**: the BSC of Advanced Information Services Inc. (AIS BSC): considers the 'employee' element as a distinct perspective, thereby expanding the analysis to five perspectives (financial, customer, employee, internal business process, learning and growth) [18].

In a few words, these new approaches to the Balanced Scorecard (adapted mainly to the IT field) consider the following perspectives:

- **Financial Perspective**: How do our software processes and software process improvement initiatives add value to the organization?
- **Customer Perspective**: How do we know that our customers (internal and external) are delighted with our product?
- **Process Perspective**: Are our software development processes performing at sufficiently high levels to meet customer expectations?
- **Infrastructure and Innovation Perspective**: Are process improvement, technology and organizational infrastructure issues being addressed with a view to implementing a sustainable improvement program?
- **People Perspective**: Do our people have the necessary skills to perform their jobs and are they happy doing so?

2.2.4. The Intangible Asset Monitor

The Intangible Asset Monitor (IAM) was created by Karl Erik Sveiby; a Knowledge Management Professor at Hanken Business School (Helsinki) who has dedicated is research work on knowledge management and knowledge organizations.

The theories behind the IAM were first conceptualized in 1986-1987 in Sweden and have been used widely there. This framework is a method for measuring intangible assets and a presentation format which displays a number of relevant indicators for measuring intangible assets in a simple fashion. The choice of indicators depends on the company strategy. The format is particularly relevant for companies with large intangible assets.

The IAM can be integrated in a management information system. According to the author, the Monitor itself should not exceed one page and should be accompanied by a number of comments.

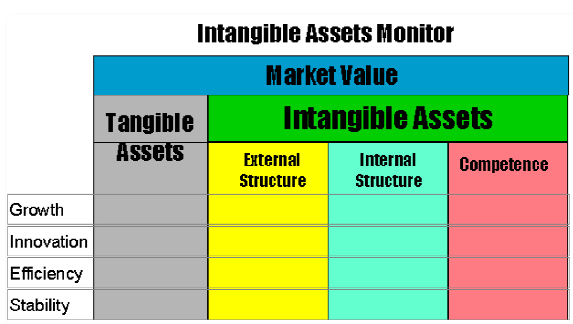

Fig. 2.6 - The Intangible Assets Monitor (source: [19])

As seen in Fig. 2.6, besides the financial perspective (Tangible Assets) there are three main Intangible assets considered in the IAM Framework proposed by Karl Erik Sveiby [5]:

- **Individual competence**: is people´s capacity to act in various situations. It includes skill, education, experience, values and social skills. People are the only true agents in business; all assets and structures, whether tangible physical products or intangible relations, are the result of human actions. Competence cannot be owned by anyone or anything but the person who possesses them. People tend to be loyal, if they are treated fairly and feel a sense of shared responsibility. That is why companies are generally willing to pay some kind of compensation to those who retire, or have to be laid off. Although such commitments are not recorded as liabilities in the balance sheet, they can be seen as pledges, like leasing or rental contracts, and thus a form of invisible financing of employee competence.

- **Internal structure**: consists of a wide range of patents, concepts, models, and computer and administrative systems. These are created by the employees and are thus generally owned by the organisation. The informal organisation, the internal networks, the culture or the spirit belongs to the internal structure as well.

- **External structure**: consists of relationships with customers and suppliers, brand names, trademarks and reputation. The value of these assets is primarily influenced by the way customers' problems are solved. As a result, a high level of vagueness is usually attached to these assets. Given that, the external structure is not particularly liquid, however, the economic value of a customer relation is no further invisible than the market value of a house or a car. In fact, the reason why such measures seems invisible to us is because there isn't any standard metric to it.

The internal structure area and the people area together constitute what we generally call the organization. Thus, when using the IAM one perceives the three Intangible Assets as real assets, instead of thinking them as *invisible* assets. Given that, the Monitor can be used to design a management information system or to make an audit.

This framework is then interested in indicators that point out change and knowledge flows, i.e. growth, renewal/innovation, efficiency/utilization and risk/stability measures.

Table 2.1 shows us a bunch of indicators examples to use under an IAM approach to business performance management. The intangible assets presented here are just a suggestion and not all of them will fit under any circumstance, under any company. On the contrary, they should be changed, adapted and adjusted to each company's reality.

External Structure Indicators	Internal Structure Indicators	Competence Indicators
	Indicators of Growth	
Organic Growth	Investment in IT Investments in Internal Structure	Competence Index Number of Years in the Profession Level of Education Competence Turnover
	Indicators of Renewal/Innovation	
Image Enhancing Customers Sales to new customers	Organisation Enhancing Customers Proportion of new products/services New processes implemented	Competence-Enhancing Customers Training and Education Costs Diversity

Indicators of Efficiency/Utilisation		
Win/Loss Index Sales per customer Profitability per customer	Proportion of Support Staff	Value Added per Employee Value Added per Professional Profit per Employee Proportion of Professionals Leverage Effect Profit per Professional
Indicators of Risk/Stability		
Satisfied Customers Index Proportion of Big Customers Age Structure Devoted Customers Ratio Frequency of Repeat Orders	Values/Attitudes Index Age of the organization Support Staff Turnover Rookie Ratio Seniority	Professionals Turnover Relative Pay Seniority

Table 2.1 – Intangible assets examples (source: [19])

As **advantages** of the IAM we can state that:

- It is based on the notion of people as an organization's only profit generators. In fact, living in a knowledge economy people should not be regarded as costs but rather revenue creators, sources of wealth creation.
- It considers an external structure area instead of a Customer area. Some services of public administration could find the definition of their customers a difficult task.
- It considers the notion of knowledge perspective of a firm.

On what IAM's **disadvantages** are concerned, the framework:

- Is not interested on giving a balanced view of the company to managers but rather the knowledge perspective.
- Is a Stock-Flow theory, like the traditional accounting theory. It is tempting to try to design a measuring system equivalent of double entry bookkeeping with money as the common denominator, but if we measure the new with the tools of the old, we will not "see" the new.

2.2.5. The Skandia Navigator

The Skandia Navigator (SN) created by Edvinsson and Malone as they were inspired by the methodology adopted by a Swedish company for its Annual Report: Skandia Insurance Ltd, nowadays a global provider of savings products.

The SN combines the two previous frameworks explained on this thesis, the Balanced Scorecard and the Intangible Assets Monitor. This framework has a remarkable *human focus* which came from the outstanding importance given by Skandia to Intellectual Capital. Thomas Stewart stated on Fortune 130 in 1994 that "*Intellectual Capital is something that you cannot touch, but still makes you rich!*"

According to Leif Edvinsson Intellectual Capital is [20]:

- supplementary information to financial information;
- non-financial capital;
- a debt item, not an asset item.

When Skandia Insurance Ltd created the first department of Intellectual Capital, they were creating the Intellectual Capital concept. It was initially defined as 'the possession of knowledge, applied experience, organisational technology, customer relationships, and professional skills that provides Skandia AFS with a competitive edge in the market'[20].

Focusing on intellectual capital, one takes delivery of an effective instrument to manage and develop one's company. Aware of this new reality in economy that came along with Intellectual Capital, Skandia Insurance Ltd started to feel the need of measuring new investments they were making, mainly on intangible assets. A society where a major proportion of the investment stream goes into these intangibles needs another mapping system.

In fact, it is evident that a major proportion of growth companies, such as Intel, Microsoft, General Electric, are valued way beyond book value, as could be stated on Fig. 2.7 where companies' book value is represented in dark blue and its market value is drawn in light blue. Observing the picture above (Fig. 2.7) may lead us to conclude that there is a kind of *ad hoc* analysis in economy that allows us to measure companies' value beyond their profit and loss statement.

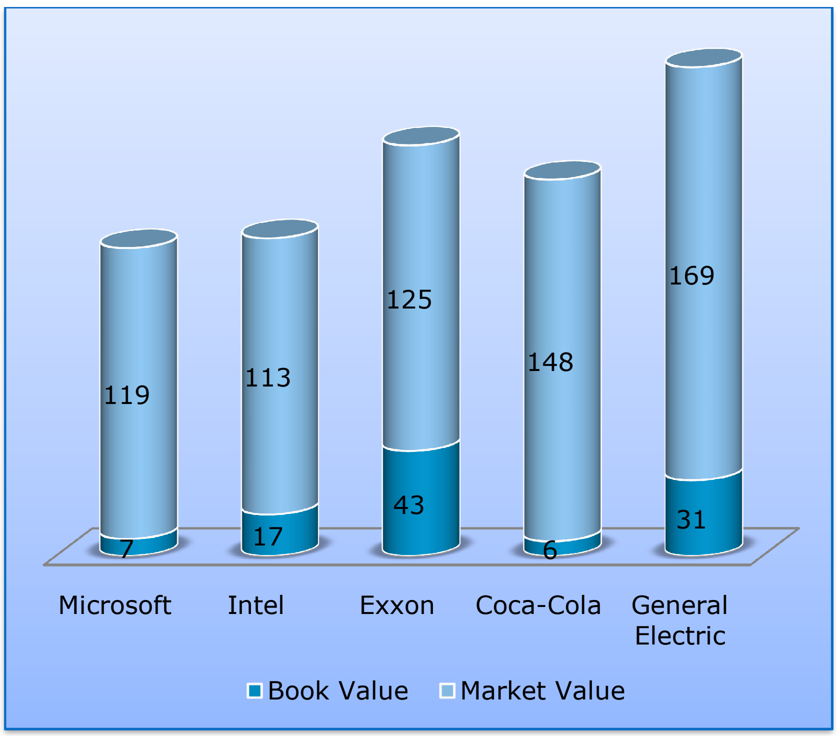

Fig. 2.7 – Companies Book value versus Market value (source: adapted from Fortune 500, April 26, 1997; theory: Tobins Q)

Once again, Skandia Insurance Ltd realized that intellectual capital had something more than just human capital. If truth be told, they could see that was something left behind when each employee goes home. These were, for instance, the costumer database, the concessions and the IT systems. So they've reached that out of human capital grows something else, which they called structural capital. Based upon these assumptions Skandia Insurance Ltd designed a well-defined tree structure of this new complex concept of Intellectual Capital. As seen in Fig. 2.8, they created a binary tree in which divided the intellectual capital between human capital and structural capital, as explained before. Under structural capital we find capital related to customer empowerment, which could be seen as external capital, and a more internal capital, named Organizational capital. All aspects related to corporate business processes is considered under process capital and Innovation capital is also considered. Under Innovation capital, the Skandia Scheme considers all the intangible assets and aspects of intellectual property are as well considered.

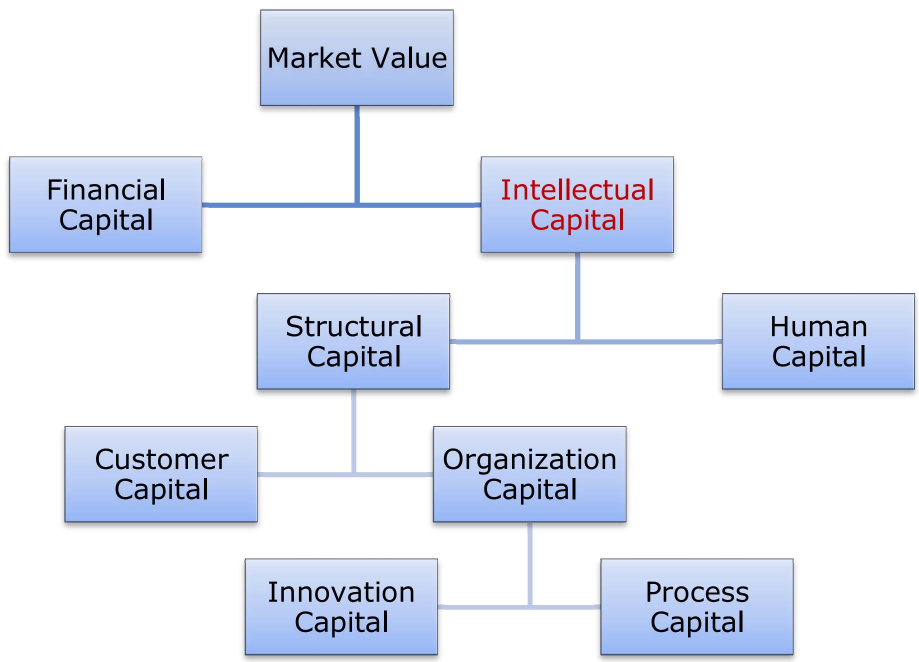

Fig. 2.8 – The Skandia Scheme (source: adapted from[21])

A more thoughtful observation under the Skandia Scheme (Fig. 2.8) could lead us to reach some interesting conclusions. Given this well-structured tree, human capital is much more volatile, and structural capital can be used as leverage for financing corporate growth. Consequently, the banks and venture capitalists, amongst others, are more interested in structural capital. Nonetheless, neither the human capital nor the structural capital is visible in the traditional accounting system.

Given all these new business areas concepts a new need had emerged, the need of reporting this intangible and intellectual capital. It was then created a one-page report of non-financial items. It had emerged the Skandia Navigator (Fig. 2.9). This metaphor of navigation constitutes a search for another language of dynamic reporting beyond management. This very simple metaphor emerges out of the need for a new balance between financial and non-financial issues. It is also a balance between information on past financial performance, information about today, including human resources and processes, and about tomorrow's renewal and development. It also takes into account the external operating environment. Summarizing all these dimensions into one reporting format leads to the Skandia Navigator.

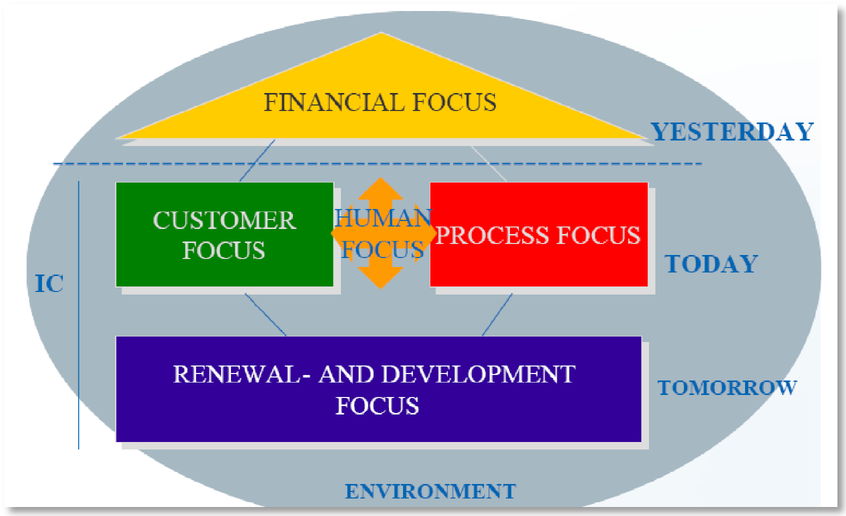

Fig. 2.9 - The Skandia Navigator (source: [21])

In a few words, this approach to the Skandia Navigator (SN) considers the following five areas:

- **Financial:** How can I affect the organization to work cost efficient?
- **Process:** What can I do in order to cooperate?
- **Renewal and Development:** How can I affect the way we look at renewal and development? How do I keep an open mind?
- **Human:** How do I make myself a please employee? How do I cooperate? How do I contribute to an attractive team?
- **Customer:** What can I do in order to make our customers happy when it comes to knowledge, availability, and professionalism?

As **advantages** of the SN we can pore over it as a system which:

- Was made to fill the gap between book value and market value, which is of fundamental importance for global trade.
- Is made not to distort the financial information, but rather supplement it.
- Focuses on intellectual capital, a useful indicator when benchmarking the company against their competitors.
- Is an excellent tool for evaluating the soft assets of an organization. Therefore, intellectual capital becomes at least as important as financial capital in providing truly sustainable earnings.

On what SN's **disadvantages** are concerned, the framework:

- The expanded leadership responsibility is clear
- The framework contains 91 different measurements[22]. That's a daunting number, and even assuming that companies will institutionalize the measurement of these indices and use considerable computing power to do so, it will remain a monumental task. Companies should focus on measures that matters most for them, otherwise, the use of SN could become cumbersome and miscarried.

2.2.6. Comparative Analysis

All frameworks presented, it is then useful to summarize all frameworks and compare them through some main aspects. The Table 2.2 was built based upon the main characteristics stated before in each description of each framework and aims to present a comparative analysis among all frameworks through the following main aspects: focus of each on intellectual capital, particularly on human, internal and external capital; tangible assets considered on each framework, as well as intangible assets regarded on each technique; the number of areas approached by every framework; the origins of each technique; their main focus and, finally, the main inspiration of each technique.

The Table 2.2 shows us that all the frameworks studied try to complete the financial perspective with some other assets extremely important on each and every company nowadays. The Balanced Scorecard framework could be applied in companies who want to achieve a balanced overview of their performance significance because the BSC is not designed specifically to measure and publish intangible assets, only to take a more balanced view on internal performance measurement. As for Intangible Assets Monitor (IAM) it could be used on knowledge companies, for the reason that IAM is based on the notion of a knowledge perspective of a firm, i.e., companies who struggles to totally adapt to their customers instead of simply providing them services or products.

			Balanced Scorecard	**Intangible Assets Monitor**	**Skandia Navigator**
Origin Country, date			USA, 1993	Sweden, 1986	Sweden, 1995
Origins			*Tableau de Bord*	-	Skandia Insurance Ltd. 1995 Annual Report
Areas Considered			4 (called perspectives)	4 (called assets)	5 (called focus)
Tangible Assets Considered			Financial Perspective	Tangible net book value	Financial Focus
Intangible Assets Considered			• Learning and Growth Perspective • Internal Business Perspective • Customer Perspective	• Human Competence • Internal Structure • External Structure	• Renewal and Development Focus • Customer Focus • Human Focus • Process Focus
Intellectual Capital	Human Capital		Learning and Growth Perspective	Human Competence	Human Focus
	Structural Capital	Internal Capital	Internal Business Perspective	Internal Structure	Process Focus
		External Capital	Customer Perspective	External Structure	Customer Focus
Main Focus			Balanced Company	Knowledge Company	Intellectual Company

Table 2.2 - BPM Frameworks Comparative Analysis (source: own design)

Despite the semantic and contextual differences among these three frameworks, which comes naturally out of their different historic backgrounds, they all present solutions with a special focus on intangible assets without forgetting, however, the financial category. This leads us to conclude that when choosing indicators to execute the company's performance analysis one should be aware that the best indicators are the ones which combine financial and non-financial metrics.

2.3. Summary

CPM is an area of Business Intelligence that has eagerly been developed over the past ten years. CPM solutions are usually adopted by companies that want to improve their business performance, optimize processes, reduce costs and understand the way their business are run internally. CPM solutions will bring desired benefits when correctly implemented and used within organizations. In fact, they could speed up response time and, thus, increase revenue; could be of great help managing risk, since it could provide the right information on the right time, easing the decision making process; and it could improve business processes by placing the customer on the spotlight, i.e., adopting strategies of built-to-order instead of built-to-stock, for illustration.

In order to achieve a higher level of performance measuring within companies, frameworks have been developed to outpace the traditional reliance on financial indicators to evaluate companies' performance. Whether some of them are more interested on providing a balanced view of the company or just focusing on Intellectual Capital they all made important contributions to this area of Business Intelligence. Despite the fact that each framework had been developed under specific economic and cultural circumstances they all provide an important turnover on the performance measuring field.

The Balanced Scorecard designed by Norton and Kaplan, the Intangible Assets Monitor created by Sveiby and the Skandia Navigator implemented by Edvinsson are frameworks developed to address the CPM requisite. These measurement systems can be used for control or for dialogue. As language for dialogue, metrics are excellent, because they force us to define relationships mathematically and to be stringent. Well designed indicators based in a coherent theoretical framework are like the words and the grammatical syntax of a language. It can help managers understand how the relationships between people and profit look like in their own company[5].

Managers that install new measurement systems for controlling the performance of their people put in risk destroying their source of revenue: their people. Organisations do not need more control, in fact, individuals need more creative space and they need systems that support a more open dialogue so they can contribute more to the strategy of their companies.

After a brief overview of these frameworks we can state that most of the things said are common sense but the challenge is to turn it into common practice.

3. Problem

Problem conceptualization is a complex, largely human-centred activity, supported by a range of relatively basic computational simulations of the problem domain. Moreover, evolutionary engineering design concerns the integration of population-based stochastic search, exploration, and optimization processes with complex, multivariate design problem domains [23].

Actually, there are five important aspects to have in mind when defining a problem[24]:

- The decision makers, who are facing the problem
- Those concepts the decision-makers can control
- Those facets of problem no one can control
- Environmental constraints, which can influence either positively or negatively the problem
- The possible outcomes, produced by the decision maker's choices and the problem's uncontrollable variables.

The problem space develops with information gained in a dynamical process followed by the establishment of a sufficiently well-defined problem domain. Throughout this chapter, the definition of the problem will be made in a three-step process: (1) the definition of the problem itself; (2) the context where this problem arises; and finally the main motivation for approaching this problem on this thesis, i.e., the main important reasons for addressing this issue.

3.1. Definition

The approaches mentioned above (on the State of the Art chapter) to address the Corporate Performance Management are proven multi-level management tools which help organizations through the monitoring and management of four (or more) areas which co-exist.

However, **most of these scorecard methods and frameworks tend to focus on strategy implementation and definition of the deliverable benefits but ignore the rapid changes on economy, industry and technology**.

The scorecard is a very different way of managing performance, unfamiliar to managers that use traditional large volumes of information, to make decisions. The introduction of a strategy model that constrains the volume of information used to improve the decision making process can be both a good concept and counter-intuitive to this scenario. In effect, experienced managers develop keen information analysis skills and resources to help them set aside tacit information indicative of performance levels. While this may initially be an easier solution for experienced managers to continue using locally, the lack of a common performance vocabulary that then exists across the organization results in the most significant performance-enhancing opportunities going undiscovered [7]. Actually, a recent survey shows that only 25 percent of managers inquired considered having enough information to aid their process of decision making [6]. **The way most scorecards presents the relevant information, usually through bi-dimensional tables and charts, is quite counter-productive, in a way that can limit the deepness and wideness of managers' analysis.**

These statistics are even worse on what comes to decision processes that relies heavily on spatial data, because most of these tools do not provide a strong geospatial feature to enhance spatial decisions. If truth to be told, there are a lot of questions companies need to answer based upon geographic context: where are the suppliers?, where are the customers?, where did accidents occur?, etc. Nonetheless, this spatial dimension is often neglected by performance management tools on the market nowadays [25].

This thesis main challenge is to provide a comprehensive and useful way of modelling scorecard business indicators, in a way that they could provide valuable and powerful real-time information to decision-makers, shortening their time-to-enlightenment.

3.2. Context

As the business ability to analyse data has definitely been outpaced by its ability to collect data, it is extremely important the way information is presented to decision-makers. This is commonly called visualization techniques, or in a business context it is called as Visual Intelligence. Even if we are interested in the way decision-makers are viewing indicators they define under a scorecard, or the way they co-relate those indicators to a spatial-context, what we are doing is, *in extremis*, defining the best way that indicators' modelling could be made.

Visual Intelligence is a process that provides information visualization technology to address the challenge of discovering and exploiting information. The integration of Data Warehousing, Information Visualization, Web and new Visual Interaction techniques will change and expand the paradigms of current work of humans using computers. *Visual Intelligence* will improve visual communication that takes place in all elements of the user interface and provide decreased time-to-enlightenment [1].

These Visual Intelligence tools introduce a brand new opportunity for decision-makers. It brings open and customizable visual data mining tools to their desktop. Advanced visualization methods provide an easy to use and economic way to build qualitative knowledge. An expedite way to turn data into powerful information and, therefore, business knowledge.

Humans think visually. Therefore, decision-makers could use their natural visual skills to explore data, and decide, in real-time, where further examination should be done. In this way, visualization techniques could be a very interesting tool to help decision-makers to navigate through floods of data and extract information from it. Having information on their hands, they can better create knowledge from it and make better and wiser decisions.

Visualization can be an important tool to address the problem explained on section above because the way information is presented to managers is what most limits their way of extracting knowledge and, consequently, make better decisions. From this point of view, the purpose of visualization is not to replace good solid quantitative analysis, but instead to allow the quantitative analysis to be focussed. Visualization should then allow the decision-maker to:

- Exploit the human visual system to extract information from data;
- Provide an overview of complex data sets;
- Identify structure, patterns, trends, anomalies, and relationships in data;
- Assist in identifying the areas of *interest.*

In fact, some companies started to address this problem using visualization. For instance, vendors such as Pilot Software are creating the foundations of 'second generation' scorecard systems that can, in addition to required reporting and data analysis features, support the identification of the relevant critical development issues[7].

3.3. Motivation

Despite the context given to the problem identified in this chapter, it might well seem insignificant or irrelevant if it does not look like interesting to solve, or seem already solved. This motivation section was written in order to avoid misinterpretation of the current problem in hands.

A properly constructed scorecard should tell the story of the business unit's strategy. It should identify and make explicit the sequence of hypotheses about the cause-and-effect relationships between outcome measures and the performance drivers of those outcomes. Every measure selected for a scorecard should be an element in a chain of cause-and-effect relationships that communicates the meaning of the business unit's strategy to the organization[12]. Understand and clearly recognize this cause-and-effect relationships is of extreme importance. The more effective this information is conveyed to the decision-maker the wiser and more conscious his/her decisions are made.

Moreover, existing reporting, planning and resource allocation processes must be re-engineered to support a more holistic performance paradigm of the scorecard; otherwise these processes become barriers to success.

One stage of scorecard development is creation of Key Performance Indicators (KPI). A KPI measures an aspect of the organisation thought to drive business performance. Collectively KPI are critical to developing a high-performing business and implementing a strategy. Ideally KPI are developed for a single, or a group of objectives. Developing KPI is an essential part of implementation of the business strategy. Organisations universally find it difficult to develop KPI aligned to objectives that are often intangible. Having an easier and intuitive way to define these KPIs and view their evolution and performance would enhance managers' decision process and will bring, as a result, competitive advantage to their companies.

3.4. Summary

The main focus of this thesis is to address a very specific problem arisen by nowadays' system's ability to produce massive floods of data, to transform raw data into useful information via a specific business intelligence tool: the Balanced Scorecard. The main challenge of this thesis is to provide a way of modelling scorecard business indicators in a helpful way for decision-makers.

In order to summarize this chapter in a more conveyable way the problem statement is overviewed on Table 3.1:

Statement	The most part of scorecard methods tend to focus on strategy implementation and definition of the deliverable benefits but ignore the quick environmental changes. Hence, modelling scorecard indicators will remain the main challenge of this thesis.
Main allied concepts	Key Performance Indicators (KPI), Balanced Scorecard (BSC), Corporate Performance Management (CPM)
Main areas to focus on to address the problem	Modelling scorecards indicators aided by common visualization techniques and BSC frameworks.

Table 3.1 - Problem summary table definition

4. Proposal

Throughout this chapter it is described the proposal to achieve the problem defined on the chapter above. To address the problem of modelling scorecard indicators on a spatially and timely enabled decision support system the proposed solution was developed under an existent DSS, the Spatial Dashboard.

The Spatial Dashboard is an innovative approach for defining, analysing and managing business performance using spatial and temporal dimensions.

Because this proposal is placed inside the Spatial Dashboard approach it is important to describe, in this chapter, a brief overview of Spatial Dashboard's architecture and then describe the proposal itself, merely to provide the reader a notion of proposal's background and context.

4.1. Context

On what describing the SD is concerned, it is important to describe it by two different perspectives: a conceptual and an architectural one. On conceptual description is explained the main theories behind the Spatial Dashboard as well as some of its features that support and embodies the Spatial Dashboard approach. On the architectural description is clarified the overall technologic architecture that supports the SD as an Information System and a brief description of this architecture is made.

4.1.1. Conceptual Description

As said before, the Spatial Dashboard is a decision support system spatially and timely enabled. It includes several of information types, allowing the decision maker to monitor and analyze business performance in a spatial and temporal context. Hence, this access to a more comprehensive and accurate source of information will potentiate his/her decision making process.

The Spatial Dashboard relies on the Balanced Scorecard framework. The BSC is a framework with proven value to approach the business performance management issue. In fact, the BSC measures the company value on all levels and follows the events from a close perspective. This enables a faster and punctual reporting, which is very useful for managers when taking decisions [26]. Moreover, of the generic frameworks presented on section 2 above, Kaplan and Norton's BSC framework has the largest market penetration and tackles performance at several levels, from the organizational level to the small business unit, and to the individual level [3].

Along with this reliance on the BSC concepts and structure, the Spatial Dashboard is also based upon geographic systems, in order to attain its spatial dimension. The Spatial Dashboard was developed in order to mitigate a flaw in the current CPM systems, as they, usually, only use the spatial dimension to report context, i.e., the geographic information is only used to present data over a static map image.

Together with this spatial dimension, the Balanced Scorecard also gives importance to the time dimension. Under a CPM's philosophy is extremely important that managers have a full access to past information, which is given by the up-to-date systems, but more important than that is the ability to rehearse business scenarios. The Spatial Dashboard also accomplishes this desired feature, since gradual changes to business context could be mapped as new business scenarios. These business scenarios are time-stamped and represented as dendrograms.

These business scenarios are the main concept of the Spatial Dashboard approach, since these are what managers and decision makers are interested on analyze and monitor. In a BSC approach, decision makers will choose a set of indicators on which they are interested in monitoring and then aggregate them under the appropriate perspective. In view of the fact that the BSC is the guiding framework of the Spatial Dashboard, when using the SD users will have to choose indicators to create their business scenarios as well. Nevertheless, the way they model these indicators and place them under the appropriate perspective is an innovative facet of the SD.

The SD uses a tree structure to create these business scenarios. In a BSC, the user usually chooses a set of indicators that are placed above each perspective. The four perspectives contribute, then, to evaluate the corporate performance as a whole. On the SD approach, the indicators are not placed independently under a chosen perspective. This tree structure is an aggregation of inter-connected Performance Indicators (the leaf nodes) into Composed Performance Indicators (the intermediate nodes) and finally into the four perspectives and the global performance node, ultimately. These tree structures can be created under any level (usually the Strategic, Tactic or Operational Level) and alternative versions of each tree could be created. By changing the way business scenarios are usually created under a scorecard approach, SD is levering the scorecard methods into another level.

These Business Trees provide methods to help a decision maker to structure and manage them so that they accurately reflect the business. At each tree level, the contribution of PIs to its parents should be defined. This contribution is the weight of that PI. The overall value of the Global Performance node is computed recursively having the weight of each PI. This tree structure reduce the cognitive overload that would happen if the manager would have to mentally create this structure in order to reflect organization's business philosophy.

The weight of each PI is defined using multi-criteria decision-making methods like Analytical Hierarchy Process, Ordered Weighted Average, Weighted Linear Combination and Tracked Weighted Linear Combination.

The Spatial Dashboard's business objectives at different organizational levels (strategic, tactic or operational) are mapped as Performance Indicators into a set of business scenarios in which the corresponding dendrogram is adopted to monitor, diagnose and evaluate performance.

4.1.2. Architecture Description

The Spatial Dashboard as far as it concerns its technological architecture was developed following Client-Server architecture. It is important to state that in Client-Server architecture the client is a software entity and so do the server, they are not hardware units. Basically this architecture is defined by evolving a software entity, the client, which executes a specific and well-defined request which, in turn, is fulfilled by another software entity, the server.

The Spatial Dashboard Client is, by then, a well-structured client within a three-layer architecture. Each layer has a specific functionality and follows the typical three-layer approach (data access layer, business logic layer and presentation layer) [27].

Fig. 4.1 represents an overview of Spatial Dashboard's Architecture three-layer architecture. Presentation, Modelling and Domain Layers make up the overall SD's architecture. On the following subsections is given a brief description of each layer and their main features and functionalities within the SD.

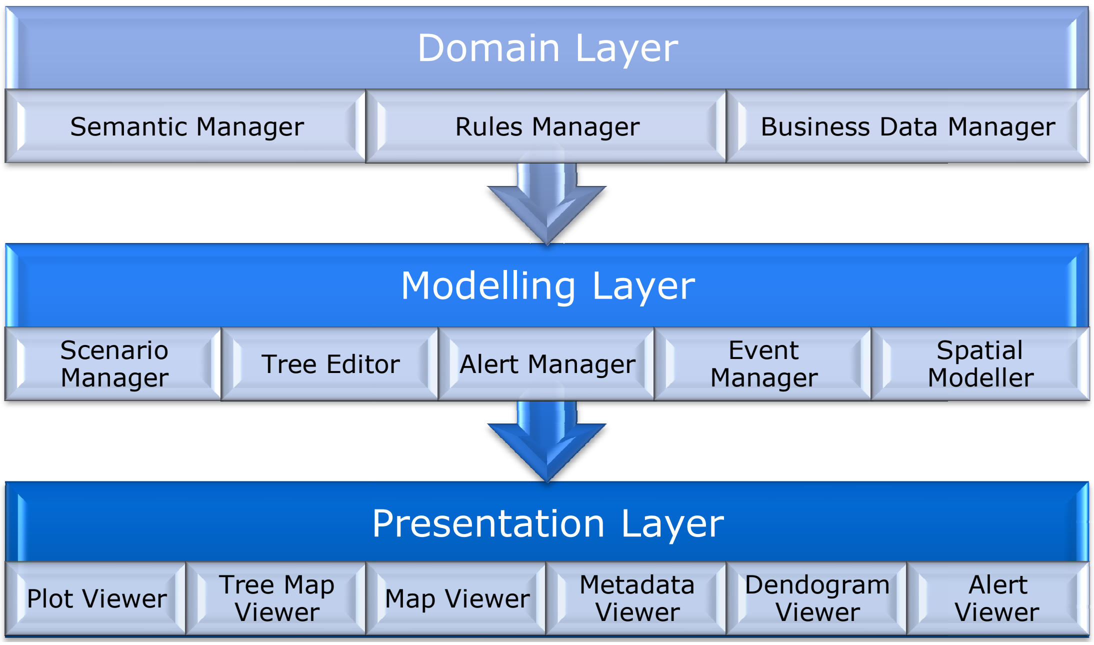

Fig. 4.1 - The Spatial Dashboard Architecture

4.1.3. Presentation Layer

The presentation layer is accountable for providing accurate views of data and information contained under the databases and data warehouses associated with the SD as well as supply visual information about the business scenarios modelled on the modelling layer. This layer contains six components: the Alert Viewer, the Map Viewer, the Tree Map Viewer, the Plot Viewer, the Metadata Viewer and the Dendrogram Viewer.

The Alert Viewer allows the user to watch if any of the indicators defined under the modelling layer has some active alert, i.e., when defining a business indicator the user sets a minimum and maximum threshold values between which the indicator's value should hang about. However, if any indicator's value outpaced or fall behind the score defined by user an alert should be triggered.

The Map Viewer enables users to analyze business indicators with spatial context using a map-based interface. This feature allows users to analyse a specified business indicator under its spatial context letting the user to see how the indicator has progressed over space and time dimensions.

The TreeMap Viewer represents all indicators of the business scenario currently in analysis in an innovative manner. Instead of displaying these business scenario indicators by way of gauges (commonly used with dashboards) the TreeMap symbolize the scores of indicators as rectangles in a defined and limited area. The area occupied by each indicator is directly proportional to its score[28][29]. This is a ground-breaking way of exhibiting indicators with extended visualization functionalities, i.e., use of pictograms for spatial indicators[30], different treemap approaches, colour-enabled, among others.

The Plot Viewer allows decision makers to analyse the evolution of a specific performance indicator through a precise time period. To analyse a PI under a defined time slice one just must use the time sliders in order to select the time period one wants to. This selection is made via timeboxes, which are rectangular query regions drawn directly into this two-dimensional graphic (the plot viewer) and then filters data according to the period selected. These timeboxes provide a very intuitive way of data selection and provide an expressive power on what information visualization is concerned [31].

The Metadata Viewer lets the user to observe relationships between KPIs and any metadata aggregated with them. It is also in this module one can attach metadata to an already existent KPI. For illustration, consider a KPI like 'Percentage of recycled waste' which, to a given industry, is regulated by law. If that law is changed it might be useful to attach the new law document to the KPI, because it could influence the KPI threshold values. Once again, consider that the 'Percentage of recycled waste' was levered by law; therefore, the KPI must be changed. For that reason, the attached documented law might explain why the KPI threshold values were changed.

The Dendrogram Viewer conveys the relationships amongst all the defined business scenario trees (also called dendrograms to short). These relationships amongst dendrograms are set whenever one scenario shares performance indicator(s) with another, creating a unique relationship among them. For this module only production scenarios are considered, since we are interested on observing the overall company's business health. All dendrograms evaluation contributes to a root node, the corporate performance node, which, in turn, put across organization's business circumstance.

4.1.4. Modelling Layer

The modelling layer is held responsible for enabling users to define overall business structure through business scenarios design. The Tree Editor, the Scenario Manager, the Dashboard Engine and the Spatial Modeller are the four modules that compose the Modelling layer.

The Tree Editor is a tree structure that allows the user to place company's business indicators under the appropriate perspective, level and business scenario. The user can define a hierarchical structure that reflects their current business construction. When defining this structured business scenarios, by placing business indicators hierarchically, the user must define each indicator weight on the overall business scenario, i.e., specify how much each indicator contribute for that particular business scenario.

The Scenario Manager is accountable for managing all business scenarios designed in the meantime as business runs by. By managing operations we mean, creating, renaming, deleting, setting to production, cloning and other related operations.

The Dashboard Engine is responsible for business scenarios validation and contains two modules, the Alert Manager and the Event Manager. The Alert Manager is a module which managers all the alerts defined on each business indicator. As said previously, whenever an indicator falls behind or outpaces the threshold defined for its score an alert should be trigger in order to warn the user of that specific circumstance. This alert is triggered due to the Alert Manager accountability for these triggering actions. The Event Manager, on the other hand, conveys important messages whenever a risk event is detected by the SD or even if it is reported by the user.

The Spatial Modeller allows geographic context association to each business scenario or indicator. Decision makers can create a spatial model to manage business instability. Moreover, as some business indicators are spatial and timely enabled they could watch the overall evolution of each indicator through space and time continuum.

4.1.5. Domain Layer

The Domain layer makes possible for users to access to different data sources and connect to the data provided by those data sources. These data sources may be relational databases, data warehouses or even operational spatial databases. The Domain layer contains three main modules: the Semantic Manager, the Rules Manager and the Business Data Manager.

The Semantic Manager module works as a tool for managers and decision makers reflect the overall organization's business view and knowledge through the use of indicators. A business indicator is the main concept of the Scenario Manager, by representing a piece of expertise knowledge these indicators give semantic to business data. When designing these business indicators one should define under which branch, level and perspective they should be placed.

The Rules Manager is accountable for providing an interface so that users could select comprehensive information to the creation of business indicators. Under this module users define and evaluate metrics that can be used on business indicators' design. Some business rules have only an informative nature, but others can include a formula to determine the indicator's value.

The Business Data Manager is responsible for data retrieval. This module enables the connection to different data sources, namely Data Warehouses, relational Data Bases and Geographical Data Bases. The Business Data Manager interacts with the Rules Manager and the Semantic Manager allowing these last to explore data using drag-and-drop functionalities, among others. The goal is to avoid decision makers to know the underlying database structure and to focus on the indicators they previously have created.

4.2. Statement

In order to address the problem of modelling scorecard indicators on a spatial and temporal enabled system, defined on Chapter 3 above, a proposal is defined all over this section. Since the problem we want to address is very specific and it is inserted under the Spatial Dashboard context we mainly focus on particular subjects, as they are directly related with the problem we want to achieve. Given that, the main focus of this thesis will be:

- Creation and manipulation of business indicators
- Construction and management of business indicator's rules
- Definition of a graphical representation for the development of business scenarios
- Management operations amongst business scenarios
- Interface features for enhancing decision makers' performance on business scenarios definition

The modelling of scorecard indicators is what is most concerned on this thesis. Therefore, the proposal statement is organized in four main sections with the intention of focusing the reader on the problem-solving task. So first of all, it is described an approach for the definition of these business indicators; on the following section it is presented our proposal for modelling them under business scenarios; the subsequent section defines our approach for managing these business scenarios, created in the meantime; and the last section provides some interface features for enhancing managers' performance when defining these business scenarios.

4.2.1. Business Indicators

A business indicator is an object that measures the performance of a given business activity or process. When defining this indicator the user must set which values are acceptable and which are not for it, i.e., a threshold must be set for the indicator's score value.

The Spatial Dashboard relies on the Balanced Scorecard concept, therefore, when designing these business indicators the user must be able to define on which perspective the business indicator should be placed. Moreover, since the Spatial Dashboard adopts a vertical solution, it is important to define in which level and branch (as in which business unit) the user wants to place their indicators.

The indicators' distribution amongst branches, levels or perspectives is justifiable because the organizational structure is a hierarchy of divisions, aimed at defining their duties and responsibilities, and is usually organized on three different levels, namely strategic, tactical and operational. Furthermore, a company's processes are, frequently, orthogonal to organizational structure and they usually include tasks carried out by different divisions and require decisions at different levels [8].

When defining business indicators one should be aware of three main concepts concerning the business indicator's semantic context:

- **Perspective**: based upon the BSC's concept the Spatial Dashboard should allow the user to place the created business indicator wherever it is more suitable. By default, the four perspectives (customer, internal business processes, innovation and learning and financial perspectives) of the balanced scorecard are provided, but, customization of the perspectives is provided as well. In fact, the BSC uses Michael Porter's model and builds on four pre-categorised areas of measurements. However, we should note that Kaplan and Norton claim that the four areas of measurements are not to be perceived as a constraining straitjacket and other areas may be added if necessary [11].

- **Level**: based on the fact that common organizations have their internal process typified under three levels the SD would allow the users to place their indicators under the level they belong to. This decision could be somehow controversial since some may think that users on tactical or operational level may not have the skills to evaluate business performance, while others may state that even on the tactical and operational levels the users of these systems are still decision-makers [8]. However, it is important to state that the same level of customization is given at this stage, i.e., the three main levels are provided, although the users can change them to their hearts' content.

- **Branch**: since conveying a business strategy to a whole organization is a very complex and hard task, it is of extremely importance that all members in the company understand their goals and ambitions. The key point of organizations' processes is that the focus is on the global business goals rather than on the single tasks. Of course, employees involved in processes must share the business strategy in order to synchronize their behaviour. This result can be achieved by translating the top-level strategy into multiple goals at the lower levels, each defined by a target value for a given indicator [8]. The overall business processes of a firm are usually divided into business units, small divisions, departments or sections, so that each of these division can better achieve their goals since they could be focused on each strategic objectives. The SD also allows the creation of single branches so that each of the users could be focused on their specific goals without concerning with others unrelated branches' aims.

Apart from defining its business semantic context one should also load other semantic information related with the business indicator one is creating. This semantic dimension has a very wide scope containing characteristics such as a unique name and description, a spatial context, an associated business rule or metric, an alert and a set of triggers. Since the scope of this thesis is more focused on the modelling of scorecard indicators for the construction of business scenarios we won't describe each of these specific business indicator's attributes.

4.2.2. Business Scenarios

In a rapidly-changing business environment, a flexible decision-making for the surrounding changes is required in companies. To accomplish such level of decision-making, *Scenario Planning* is proposed. Scenario planning is a framework of support for decision-making based on clarifying cause and effect factors in a target business, which are mostly achieved by using a causal structural graph model. On the causal structural graph model, a scenario designer sets a state to controllable nodes and evaluates a state of attended nodes by a scenario designer based on the links [32].

One of the common believes under this business scenarios approach is that the business world is predictable, and if we could only find the right tool we would be able to accurately predict the future, and then develop a strategy to guarantee our success. This approach focuses on rational analysis and largely relies upon data and information to communicate its message. This approach has undoubted attractions for managers, as it perpetuates the belief that it is possible to be in control of strategy, however, it is particularly ineffective when unpredictable events occurs, turning the strategy outdated [33]. Nevertheless, it is important to state that this notion of business flexibility and agility should not lead managers to think that none strategy is needed at all. In fact, the absence of strategy is fine if we do not care where we are going [34]. Scenario planning is an approach to strategy that takes the view that the business world is indeed unpredictable, but certain events are predetermined, thus, learning from it could be a competitive advantage.

Amongst the many tools managers can use to help on their decision-making task and strategic planning, business scenario planning or design comes like a very helpful tool due to its capability to capture a bunch of possibilities in detail. In fact, these business scenarios will simplify the avalanche of data into a limited number of possible states [35].

Having this approach in mind the Spatial Dashboard also addresses the problem stated on chapter 3 above making use of scenarios. On the Spatial Dashboard context, the business scenarios are created to support gradual business changes that occur among the business context, consequently, multiple representations of business context will represent multiple scenarios in the Spatial Dashboard. Throughout this section it is explained the proposal of business scenarios under the SD context.

A tree structure is our proposal for the creation of these 'what-if' scenarios, since it is the mostly common approach for this business scenario context [32]. Because of this graph-like business scenario implementation other implementation needs had come ahead, like the tree structure weighting and all the business scenarios' management operations like renaming, deleting and creating features, amongst others.

4.2.3. Tree structure representation

The tree structure is the way the problem of creating different business scenarios is addressed on the Spatial Dashboard. Despite the fact it has become common practice to create scenarios in a graph manner [32], the decision making process is intuitively hierarchical. Beneath a relatively wide organization these decisions need to be even more hierarchical so that the entire corporation is under control.

This tree structure stands for a business scenario, thus, there should be one for each business unit (or branch) on each level. Let us consider a very small company that has no need of having any branches besides the main corporate branch and considering all the default levels and perspectives. In this company will be, by default, three business scenarios: one for each level (strategic, tactical and operational) on the main branch. Of course, this company could, in the meantime, produce other scenarios, delete these first ones, create other branches and rehearse some other business contexts. All these operations should be supported by the solution developed and will be detailed on The Scenario Manager section below as it is related with managing scenarios.

By default each of these business scenarios will have a default root node along with four default perspective nodes (see Fig. 4.2). These four perspectives stand for the four known perspectives of the Balanced Scorecard: the client node (for the classic BSC's client perspective), the financial node (for the classic BSC's financial perspective), the processes node (for the classic BSC's internal business processes perspective) and the organization node (for the classic BSC's learning and growth perspective). The names of BSC's perspectives were shorten and simplified for an ease of use under a usability perspective, since no context-awareness is lost with the given names. Moreover, this module should have a certain level of customization allowing the user to change perspective names amongst other possibilities.

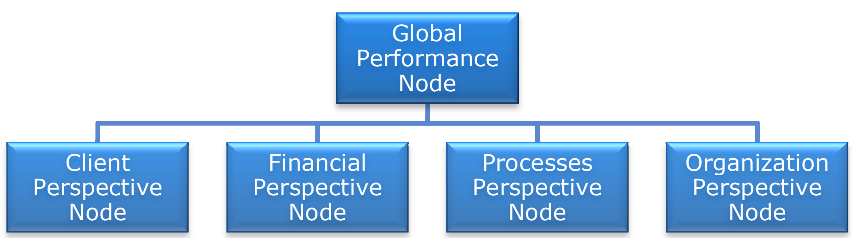

Fig. 4.2 - A business scenario tree example

This tree structure can be built by the user in a top-down or bottom-up manner: either by adding child nodes to perspective or composed nodes, or by creating independent sub-trees and then connect them together.

This tree structure contains two types of possible nodes: the inner nodes and the leaf nodes and both are associated with business indicators (explained on the section 4.2 above). The leaf nodes are related to business indicators, while the inner nodes refer to composed business indicators - created by aggregating other business indicators. There's a need of make a distinction between these two types of nodes because they are created on different contexts. Business indicators are created when decision makers are interested on evaluating performance of a business activity; they are, as said, a piece of expertise knowledge. Composed business indicators are, by definition, the result of composing business indicators, i.e., when creating a business scenario the user will import some of the business indicators but will need to create others to aggregate them, that's when composed business indicators are created.

There is also a special type of leaf node that is created when the user copies a node from one place (either a perspective on the same branch or from another branch) to another. This specific operation is called cloning nodes or indicators and is explained on the section 4.2.6 below.

4.2.4. Performance Indicators

These particular types of nodes are created based on business indicators (created on another module of the Spatial Dashboard, the Semantic Manager context). These types of nodes should maintain the same semantic characteristics when they were originally created.

These nodes have a well-defined value, since these nodes are connected to business indicators which, in turn, are designed by the definition of business rules, their value would be the matching business indicators' value.

Fig. 4.3 shows us an example of a possible combination between performance indicators and composed performance indicators. As depicted on Fig. 4.3 the performance indicators (drawn on light blue) are always leaf nodes, but not the only ones (note the teal blue node on the right which are a clone from another composed node).

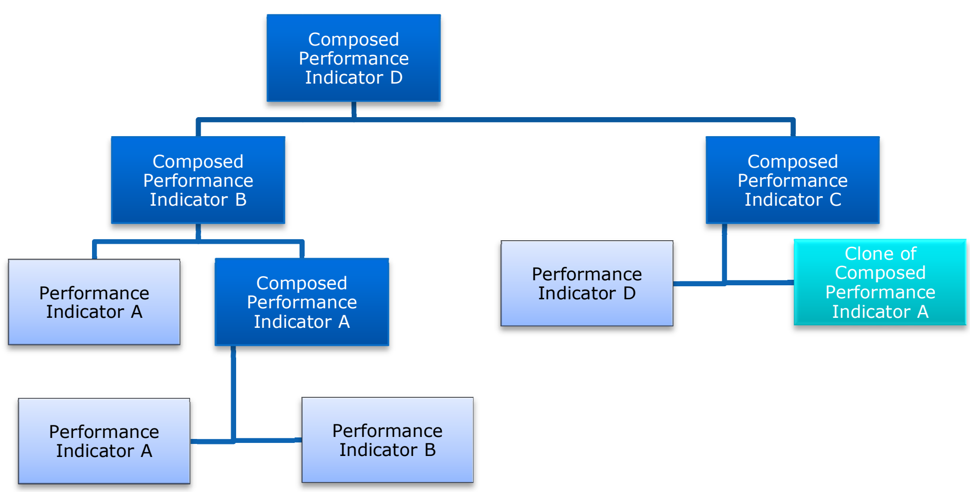

Fig. 4.3 – Example of a tree structure

4.2.5. Composed Performance Indicators

These composed performance indicators are created when the user wants do create an aggregation of indicators in order to create a more meaningful business scenario. These nodes differ from the performance indicators because they are not based on business rules, but instead they get their source values from already existing performance indicators or composed performance indicators.

The definition of performance indicators that contribute to a certain composed performance indicator is created whenever the user links them in the tree structure, i.e., by putting a performance indicator under a composed performance indicator the user is automatically linking them and defining the source value for the composed performance indicator.

As seen on the picture Fig. 4.4 the composed performance indicator (the dark blue node) has the contribution of the two performance indicators (the light blue nodes), i.e., the score value of the composed performance node is a balanced mathematical operation between the Performance Indicator A's score value and Performance Indicator B's score value. Of course this balanced mathematical operation is not just an average or other fixed operation. It is the user who decides which node has more contribution for the composed performance indicator on creation. The weighting methods are described in more detail on section 4.2.8 below.

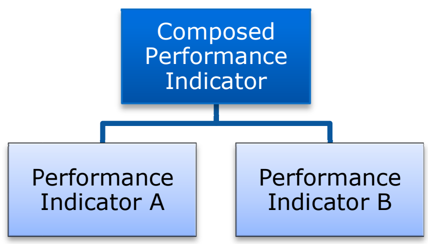

Fig. 4.4 – A composed performance indicator associated with two performance indicators

4.2.6. Cloned Performance Indicators

Creating new nodes can also be made from existing ones, i.e., users may create a copy of a certain node because that composed performance indicator it is also needed in another perspective, level or branch. Cloning a node corresponds to create a leaf node that is an exact replica of the original node. Changes on the original node value or semantic context are automatically reflected on all its cloned nodes. The composed performance node to which these clone nodes are, eventually, attached does not make a distinction between a cloned node or another node since all contribute with their weight to the parent-node's score value.

Moreover, the copy operation will not create a copy of the entire tree structure that may be associated with the original node; it will create a single node (visual distinctive, in order not to confuse the user) which points to the original node and cannot have children, like the leaf nodes. This approach to the creation of clones is justifiable because if instead of creating a single distinctive new node we create a new sub-tree structure of the original node, the user could change differently each of those sub-trees, which, *in extremis*, could be counter-productive.

The existence of nodes like these are justifiable because, as stated before, there are some processes and tasks inside a company structure that are orthogonal to organizational structure and usually demands that different divisions are involved requiring decisions at different levels [8]. These kinds of relations are the so called *cross-business* relationships proposed by Kaplan and Norton[13]. Thus, evaluating some particular task or business activity may be useful for different departments or business units under the same company, making this cloning feature justifiable.

4.2.7. Semantic Validation

In the Spatial Dashboard, the evaluation of the various performance indicators under a tree is a process which starts from the tree root node and recursively explores the tree:

- Composed performance indicators values are calculated using the linear combination of the values of their child performance indicators (the factors of the linear combination are the weights of the child nodes).
- Performance indicators values are the result of the evaluation of their matching business rules.

This method of evaluation has an immediate drawback, no cycles are allowed. Note that the introduction of cloning feature could make this possible, even under a tree structure. Therefore, if cycles exist on some business scenario, in extremis, the node evaluation would enter an infinite loop. In order to prevent these infinite cycles some validation should be made:

- All nodes above other node, up to the root, are not clones of this node.
- The node isn't a clone of any other node above it, up to the root.
- Node's children are not clones of any node above it.
- None of the nodes above one node are a clone of one's children.

Besides from this tree evaluation validation, there is also some other semantic validation on what copying and cloning of nodes is concerned. In fact, this validation is related with cloning nodes between different branches and levels.

Business strategic levels are commonly divided amongst three main levels: strategic, tactical and operational. Each of these levels has their duties and responsibilities, thus, different goals and aims to achieve. However, strategic level is usually concerned with selection of businesses in which the company should compete and with development and coordination of that portfolio of businesses. On the tactical level, strategic issues are about both practical coordination of operating units and about developing and sustaining a competitive advantage for the products and services that are produced. Finally, on the operational level, strategic issues are related to functional business processes and value chain.

Given that, the three levels have very different aims and different things to monitor and control. Because of this level restriction top managers will not be interested that corporate composed performance indicators would be cloned to lower levels, because they are meaningful where they were created. In order to avoid awkward cloning situations that would disturb the overall corporate performance management some semantic validations were created.

In fact, users at the tactical and operational levels are still decision-makers. However, these users have limited view of the company strategy, and only have to deal with the subset of indicators related to their specific tasks [8].

Along with this well-defined corporate hierarchy, there were defined a set of restrictions in order to avoid misplacement of indicators, i.e., cloning indicators where they should be from the very start:

- It's not possible to copy performance indicators to lower levels.
- It's not possible to copy composed performance indicators to lower levels.
- It's only possible to copy composed performance indicators between branches if the destiny branch is on an upper level than the source branch.

4.2.8. Weighting

Using the BSC as a guiding framework allows transporting all of its main concepts to the Spatial Dashboard. In fact, as it measures the company value on all levels and follows the events from a close perspective, the BSC enables a faster and punctual reporting, which is very useful for managers when taking decisions. However, the BSC has a very dreadful drawback: even though the BSC is structured logically to represent the series of causal links between the goals and drivers, it does not provide the support necessary to represent quantitatively how much each perspective contributes, either in relative or in absolute terms. In practice, the consolidation has to be carried out intuitively by the users of the BSC (making it dependent of user's interpretation which depends on their expertise and background) [3].

Therefore, in order to overcome this BSC's lacuna, the Spatial Dashboard addresses this issue by providing a tree structure with weighting evaluation methods. Besides, having this tree structure for designing and managing business scenarios it is bound to happen having composed performance indicators with several nodes underneath. Given these circumstances it is important to define how each child-node contributes to its parent score value.

It is stated above that a performance indicator value is the result that comes from the evaluation of its underlying business rule (defined on business indicator's creation). Though, how to determine the value of a composed performance indicator? A composed performance indicator value is computed by fetching the values of the performance indicators associated with its child nodes, and multiplying them by the weights that each child node have in respect to its parent node.

Since the user only defines the local contribution of a specific node regarding its parent node, in a bottom-up approach, the user only have to focus on the weight each node contribute to its parent. This way of setting weights is more intuitive since the user has no longer the need to know each node contribution to the root node (the global performance node). In fact, the global performance node's value is induced by a recursive evaluation of the tree, i.e., the aggregation of all these nodes regarding their weight and value is the global performance node's value.

This gradually bottom-up weighting process should make use of different weighting methods, based on multi-criteria decision processes:

- **AHP** – the Analytic Hierarchy Process is a complex decision making process that tries to reduce the hard task of prioritization. The achievement is done by simply reducing this evaluation to a pair wise comparison between elements. The AHP helps the analysts to organize the critical aspects of a problem into a hierarchical structure similar to a family tree. Therefore, the AHP not only helps the analysts to arrive at the best decision, but also provides a clear rationale for the choices made. The use of this method was adopted because AHP approach has been widely applied in various relative fields to solve decision-making problems with multiple hierarchies under the situation of uncertainty [36].

- **OWA** – the Ordered Weight Averaging is a based on a favourite ordering of the elements to be prioritized and on a distribution of each element's weight. The concept of decision strategy is used to distribute the weight: an optimistic strategy will give full weight to the preferred element and a pessimistic strategy will give full weight to the less preferred element. This type of aggregation method is justifiable because in many cases of multiple criteria decision the decision maker does not want to "and" or "or" each individual elements, because they work as a whole [37].

- **WLC** – the Weighted Linear Combination is a very simple algorithm that allows the direct assignment of weights to the elements to be prioritized. When assigning these values to each element it is important that the sum of the overall values is 1 or 100%. Given that, this method enables a trade-off between criteria, which means that criteria with a lower value can be counterbalanced by others with higher values.

These three aggregation methods are very different from each other; however, a full description of each is out of the scope of this thesis. The reader is, by then, invited to read some relevant bibliography in order to learn more about this particular subject [38][36][37].

Apart from the use on the business scenarios trees, these aggregation methods are also useful on what comes to set the weight each branch has to the overall corporation. On section 4.2 above it was stated that when designing business indicators one can place them wherever is more meaningful for the corporation. A definition of Spatial Dashboard's branches (or business units) was given at that time and it was declared that many branches may need to be created within a specific corporation context. It is obvious that not all branches has the same weight within a specific firm, hence, aggregation methods needs to be applied when creating branches.

4.2.9. The Scenario Manager

With the creation of so many different business scenarios, a managing functionality was needed. The Scenario Manager is a module that immediately comes ahead along with the definition of these needed business scenarios. In fact, if we just consider a small company with only the main branches (explained on section 4.2 above) and the default levels considered on a company (strategic, tactical and operational) we will have three business scenarios, just for start. If companies start to create more branches, and alternative versions of each scenario, then a Scenario Manager is more than needed.

Since this proposal is placed under the Spatial Dashboard a Business Scenario will have, apart from its tree structure scenario context, a spatial context. A base cartography could be added to one scenario. The reason why this cartography is added to each scenario and not to the whole project is because the base map and the business context change over time, thus, a need of changing a specific business scenario may be needed.

Nowadays, a growing number of business management software vendors are offering simulation capabilities to extend their modelling functions and enhance their analytical proficiencies. Simulation is promoted to enable examination and testing of decisions prior to actually making them in the "real" environment. In fact, simulation is positioned as a means to evaluate the impact of changes and latest happenings in a model environment through the creation of 'what-if' scenarios. Since simulation approximates reality, it also permits the inclusion of uncertainty and variability [39][40].

The Scenario Manager will also be accountable for managing the creation of test scenarios. A test scenario will be created whenever a decision maker feels the need of designing a 'what-if' scenario without reflecting those changes to actual data and values therein created.

This difference between scenarios creates a need of differentiating them in two diverse types:

- **Test Scenario**: A test scenario is a hypothetical scenario to simulate a specific situation perceived by decision makers. There can be multiple test scenarios for each branch but only one scenario per branch can be in production, for the same time slice. After all experiments the decision maker can set a test scenario to production by specifying the period of time when s/he wants the scenario to be active. Validation of time period's overlapping is taken, so that, for the same branch there aren't two scenarios on production state.

- **Production Scenario**: A production scenario is created when a user sets a test scenario to 'go-live' state. When creating these production scenarios, a pop-up window should request for the definition of the time interval on which the production scenario is applicable. These production scenarios are the ones SD's Presentation layer (see section 4.1.3 above) is concerned about. On this layer it should be possible to view the overall score value of the business scenario set to production as well as the evolution of each Composed Performance Indicator within the business tree.

4.2.10. Enhancing with Interface features

The CPM systems define a new approach to management requiring that information is constantly fed into the systems so that these performance indicators are always related with the most up-to-date data enhancing the decision making process.

In fact, this freshness of information is required for CPM systems because they are not supposed to operate in real-time but rather in right-time, i.e., information is fresh enough to be useful for decision making [8].

Along with these data freshness requirement comes a simple user interface condition, since the decision-makers do not have, usually, time and skills for interacting with complicated front-end interfaces [41].

The subject of usability was concerned on this thesis (in spite of not being its core topic) because recent studies have found that idiosyncratic aspects of user interfaces influence, in fact, their productivity when they are faced with different systems and interfaces [42].

These typical questions of usability are usually seen under games or websites context. Typical research questions concerning user experience goals are, for instance:

- the dependency between aesthetic impression and apparent usability of a user interface [43];
- the influence of the colours in a graphical user interface on the mood and performance of users [42];
- the relation between hedonic quality and attractiveness [44].

However, business users, who interact with software applications several hours a day, are a very interesting target for studying the effect of usability on their performance skills. Moreover, user acceptance is extremely important on what comes to evaluate the success or failure of a certain software project.

The main question needing an answer is if more attractive user interfaces on business management software are preferred than less attractive interfaces. While Tractinsky stated that *what is beautiful is usable* [45], Lindgaard and Dudek, on the other hand, showed that this relation between appeal and perceived usability does not exist for all types of interfaces [46]. Additionally, it is important to note that, usually, business management software are highly interactive, effective for data entry and efficient on what comes to search for relevant information and perform actions with the business objects modelled in the software [42].

Having this in mind, an ease of user interaction was one of the concerns regarding the Spatial Dashboard, not the most important among all, but since decision makers prefer attractive and usable interfaces it was a subject that urged to be concerned. Thus, an overall attractive design, drag-and-drop operations, the ubiquitously use of mouse, a tree structure with expand and collapse features, an explorer for searching previously designed Performance Indicators and the possibility to apply filters on existing lists was some of the features addressed on the Spatial Dashboard:

- **An overall attractive design**: since hedonic aspects have an important influence on software attractiveness and user acceptance is an important side of successful software, the Spatial Dashboard will address these usability requirements. Actually, the interfaces available to the DM must present easy and simple ways of exploring multidimensional information and without exposing specific technical features. To achieve this, they must be stripped of technological know-how and, together, extremely comprehensive, efficient and easy to learn. To create a successful user interface it is necessary to understand how the DM thinks and works. We must realize that users do not actually use algorithms, data structures, networks, functions or subroutines, even if some of them are technical professionals and this is typically the domain in which they work. Instead, DM push buttons to choose options, make selections from menus, give commands and manipulate controls [47].

- **Use of mouse**: the burden the systems place on the consciousness of the user is a very important factor on what comes to user-interaction. Users interacting with graphics systems are best served when the system virtually disappears from their consciousness leaving only their work and its ramifications to claim their attention [48][49]. 'Seeing and pointing' enhanced devices (like mouse) are much more effective than traditional ones (like keyboard) that lead the user depending on remembering a specific command [47]. Therefore, this proposal tries to be much more mouse oriented. In fact, we try to include a series of mouse operations to ease the burden of modelling new indicators:

    - Drag-and-drop operations;
    - Mouse context-menus;
    - Zooming operations;

- **List view filters**: with the creation of business scenarios comes the idea of managing them. Creating, deleting, renaming, and cloning scenarios are features that ought to be managed somehow on the proposed platform. In a wide organization it will come the need of creating loads of scenarios, thus, the creation of filters comes along. Since the list of all scenarios is, *de facto*, a list, a filter was created to these lists to enhance user performance when managing business scenarios. Filtering data is a *must-have* feature, in fact, on Ben Shneiderman's *visualization seeking mantra* the filtering facet is considered one of the seven high-level user needs, along with overview, zoom, details-on-demand, relate, history and extract features [50].

4.3. Summary

The modelling of scorecard indicators is what is most concerned on this thesis. Therefore, the proposal statement is organized in four main sections with the intention of focusing the reader on the problem-solving task. At the outset, it was described an approach for the definition of these business indicators, which is the main concept regarding this thesis; on the following section it was presented our proposal for modelling them under business scenarios; the subsequent section defined our approach for managing these business scenarios; and the last section provided some interface features for enhancing managers' performance when interacting with the system.

Business indicators are objects that measures the performance of a given business activity or process and in this thesis was defined how its definition was addressed under the Spatial Dashboard. These business indicators are then placed under business scenarios, which follow a tree structure design. This business trees are based upon *scenario planning* context which is a framework of support for decision-making based on clarifying cause and effect factors in a target business. These cause-and-effect relationships are mostly achieved by using a causal structural graph model [32].

Since on tree structure representations several nodes are placed under others, weighting methods must be provided to the user, so that he could perform a better representation of business view and strategy on those business scenarios. Along with this creation of multiple scenarios it was realized the need of managing scenarios (create, delete, rename and clone operations amongst others), thus, the Scenario Manager was proposed.

Moreover, some usability features were added to the Spatial Dashboard since it is believed that usability can shorten decision makers' time-to-enlightenment [48]. On Table 4.1 is provided a brief summary of this chapter in a more formal way.

Problem to address	Modelling scorecard indicators in a spatially and timely enabled DSS (the Spatial Dashboard)
Main visualization technique of support	Tree structure representation (graph)
Main concepts approached	Visualization Scenario Planning Multi-decision criteria Business Indicator Balanced Scorecard
Main module changes proposed to the system (SD)	The Tree Editor The Weighting Manager The Scenario Manager
Main interface features to support usability	Drag-and-drop operations Mouse context-menus Zooming operations Filtering operations Ubiquitous use of mouse

Table 4.1 - Proposal summary table definition

5. Implementation

This chapter presents the implementation details and processes for addressing the Problem stated on Chapter 3 above with the given Proposal, described on chapter 4 above.

The Spatial Dashboard approach has been developed by final year students at Instituto Superior Técnico, on INESC-ID. Given the problem stated on this thesis, concerning the modelling of BSC's indicators on the Spatial Dashboard, this chapter, like the development process, will focus on the middle layer of Spatial Dashboard: the Modelling layer (see section 4.1.4 above).

Given that, a more detailed view of this module is given here on Fig. 5.1, since the implementation was mainly focused on three modules of the Spatial Dashboard's Modelling Layer.

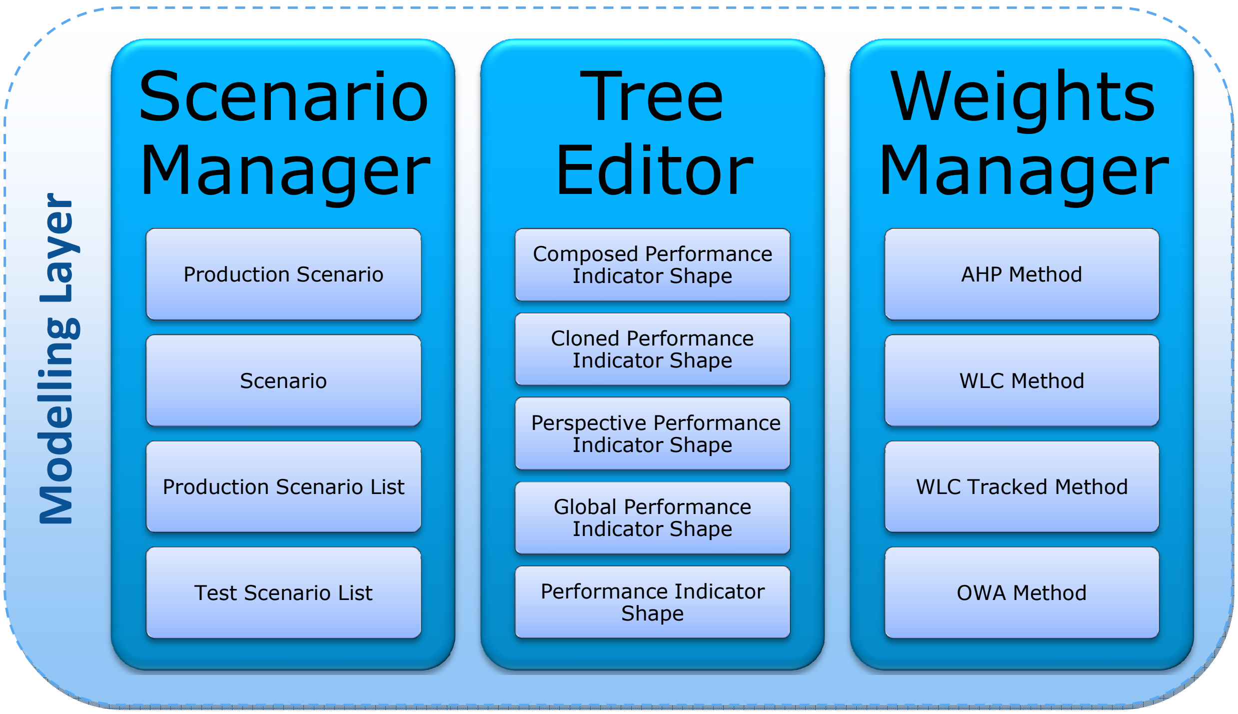

Fig. 5.1 - Detailed View of SD's Modelling Layer

Throughout this chapter, apart from the implementation details, it is also described the implementation's methodology, the main technologies used to put the solution into action, quality assurance and the documentation process.

5.1. Methodology

Through the last year, four final year IST students were evolved on developing the Spatial Dashboard. Since all four students were working on the Spatial Dashboard, developing some new features and improvements, an overall collaborative work and effort was not only useful but necessary. In fact, the interdependency among all modules made the need of collaborative tools and methods in order to achieve an ease and a straightforward development process.

Since the start of the prototype development a few tools and methodologies were adapted in order to avoid a counter-productive development process.

At the outset, there were regular progress meetings with the project manager (Professor Gabriel Pestana), usually weekly or twice a month, or whenever the development team or the project manager feels the need of one. Since the project we were all evolved had a very large dimension and developing features were intrinsically connected, a huge effort of constant communication was necessary among all developers. Apart from it, a very good specification and well-designed classes were necessary in order not to compromise each other's work.

Given that, there were several methodologies and tools adopted, with the intention of surpassing productivity:

- Communication;
- Issue tracking;
- Refactoring;
- Continuous integration;
- Concurrent version control system;
- Design patterns;
- Software quality.

In order to provide a more thorough description of each one of these methodologies an appendix (see chapter 9.1) was written with a more detailed explanation of those topics mentioned above.

5.2. Technologies

The Spatial Dashboard was developed using the .NET Framework 2.0 [51] using C# as the chosen language. The development environment selected was the Microsoft Visual Studio 2005, since maintaining the project as a whole solution was required.

The geographic and geospatial information is managed via ESRI 9.1 tools [52], used for that specific purpose. ArcGIS Engine, ArcSDE and ArcObjects were the main frameworks used to address the spatial context. ArcGIS Engine provides application programming interfaces with detailed documentation and high-level visual components to build an ArcGIS application. ArcSDE has as primary role to act as the database access engine to spatial data, its associated attributes, and metadata stored within a relational database management system. Finally, ArcObjects are platform independent software components that provide services to support GIS applications.

The business data was stored under a Microsoft SQL Server 2005 database [53]. The Microsoft SQL Server 2005 interacts with the spatial database engine (ESRI ArcSDE) that acts as a gateway for managing geodatabases in conventional relational database management systems.

Since the Spatial Dashboard is a complex solution evolving different programming challenges not all features needed were provided from the Microsoft .NET 2.0 framework. As an example, and given the interface requisites of easy, attractive and hedonic user front-end, dockable windows control was something that has arisen. To achieve this goal, open-source dockable windows from Weifen Luo [54] were adopted.

Apart from these technologies mentioned another framework was needed to convey the Dendrogram Network Viewer in an appropriate manner. Since conveying the relations between dendrograms was a task needing a multidimensional environment, the Irrlicht .NET CP [55] tri-dimensional engine was the chosen framework to address this requisite.

5.3. Implementation Details

In this section is presented the implementation of what was presented on proposal chapter (see chapter 4 above) in order to address the problem stated before (see chapter 3 above). This section gets across all the implementation facets of business indicators, business scenarios and some interface features used to enhance usability and user's task achievement.

5.3.1. Business Indicators

Business indicators are the basic model objects of the Spatial Dashboard. They are defined on the Domain Layer, specifically on the Semantic Manager module (see Fig. 4.1). The Semantic Manger implements the Balanced Scorecard concept and allows the user to define specific business indicators in line with the company strategy and vision. Since the definition of business indicators themselves is out of scope of this thesis, we will just give a brief overview of its definition, because they are important for the business scenarios, which are, in fact, the main scope of this thesis.

It is on Semantic Manager module that users define the hierarchic construction of levels, branches and perspectives. By default, there are three levels (the strategic, the tactical and the operational), on which there are one main branch (the main branch for that level) and four perspectives (the client, the financial, the processes and the Organization perspectives).

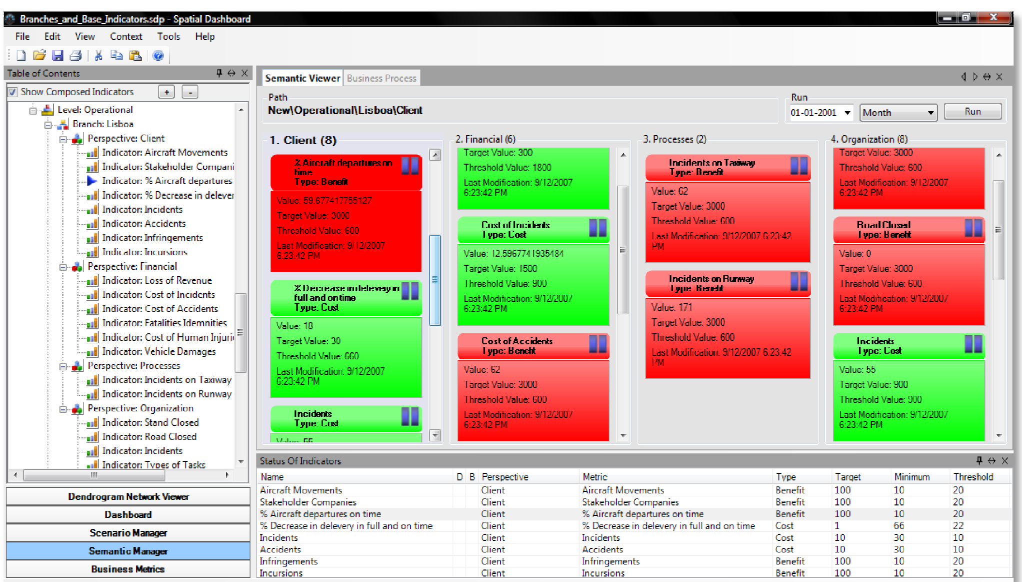

Fig. 5.2 - The Spatial Dashboard's Semantic Manager (screenshot)

Fig. 5.2 shows us the look and feel of Spatial Dashboard's Semantic Manager. On the bottom left corner we could see the Semantic Manager context selected. Under the Spatial Dashboard, changing the context (to Dendrogram Network, or Dashboard, or Scenario Manager, or Semantic Manager, or Business Metrics) will change the controls placed on the Spatial Dashboard, i.e., forms are displayed according to the context currently in use. The Semantic Manager reflects an implementation of the BSC. Therefore, on the centre there are four swim lanes, one for each perspective defined, creating the Semantic Viewer. On the left there is the Table of Contents and on the bottom is presented a grid with all Business Indicators defined and its main attributes.

The colour of business indicators conveys its state. Indicator's colour goes from green to red passing through yellow, following a colour scale (see Fig. 5.3).

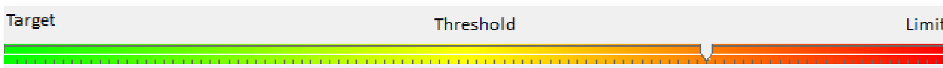

Fig. 5.3 - The Spatial Dashboard's colour scale

The colour of a business indicator is defined by the evaluation of its business rule. When defining a business indicator one must set the business metric that business indicator is assigned to. Along with that, user must set the business indicator type (benefit, cost or on-target) and the minimum and maximum values accepted for that business indicator. Its colour is defined according to business type and its business metric evaluation. The final colour outcome according to a business indicator is better understood on Fig. 5.4.

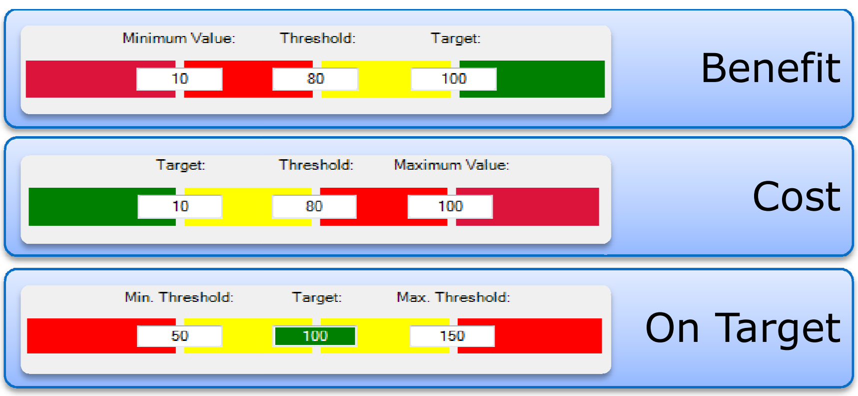

Fig. 5.4 - Business indicator's colour definition

On the Table of Contents is possible to see what Business Indicators were created and under which level, branch and perspective they were placed. It is also on this control that user manages levels, branches and perspectives.

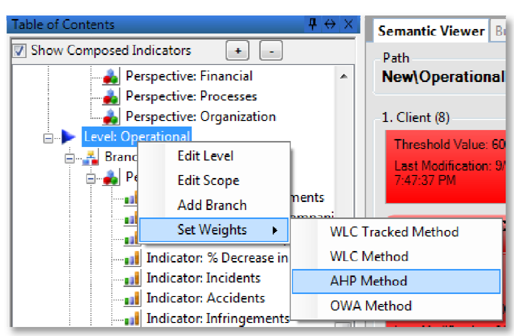

Fig. 5.5 - Mouse right-click over a Level on Semantic Manager TOC (screenshot on detail)

Fig. 5.5 depicts what happen when the user right-clicks over a level. The user can edit a level (change its name and description or its hierarchic level), edit a scope (changing the default perspectives and levels, see Fig. 5.6), add a branch (inserting another business unit under the level being edited) and setting branch weights (weighting the branches under a specific level through the provided methods: AHP, OWA, WLC and WLC Tracked methods). Because polymorphism was used in order to apply weighting methods to level branches and nodes under a specific business scenario, the weighting methods are explained further (see section 5.3.3).

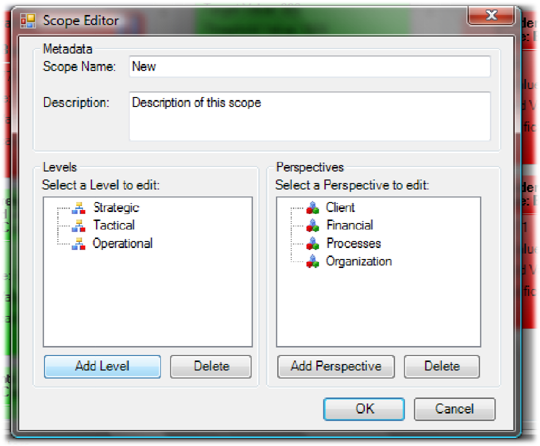

Fig. 5.6 - Scope Editor form (screenshot on detail)

The Semantic Manager is a useful tool for decision-makers reflecting their vision and strategy into business indicators. Each and every business indicator created can be seen under a certain level's branch's perspective. A business indicator evaluates the status of a business activity or process and for that reason concentrates the core knowledge of decision-makers for that specific business activity or process. A business indicator conveys the user knowledge and business overview when defining it.

When creating a new business indicator one should set important attributes, so that, the indicator best describes what one wanted to convey when describing it. Thus, user must define a description, a set of alerts, a business area, a spatial dimension and context, a metric and a set of triggers.

As seen under Fig. 5.7 the definition of a business indicator is divided in different properties the user must describe in order to better express his/her business view.

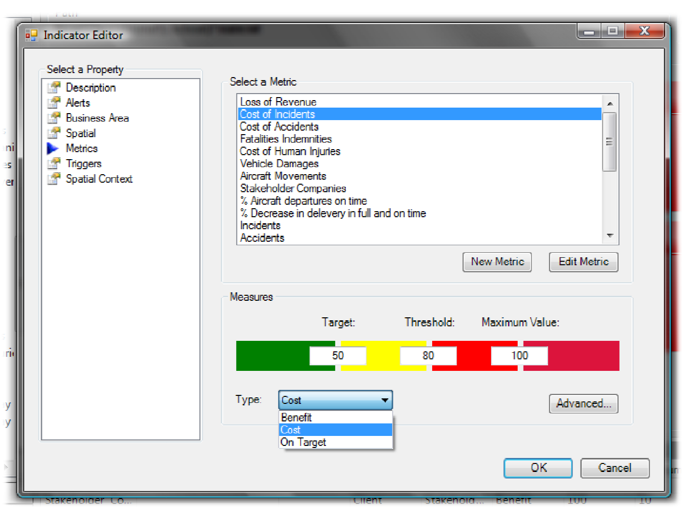

Fig. 5.7 - Indicator editor form (screenshot on detail)

The *Description* property lets the user to set his/her description for the business indicator. The *Alerts* property allows the user to set messages when the indicator reaches decisive score values, like the minimum value accepted for that business indicator. The *Business Area* is where the user sets to which business activity that indicator is related to. The *Spatial* property allows the definition of geographic layers to that specific indicator. The *Metrics* property lets the user to choose which pre-defined metric is connected with this indicator or create a new one, set the threshold values for the business indicator's score and define the type of indicator (benefit, cost, or on target). The *Triggers* property endows the definition of triggers to the business indicator being created. Finally, the *spatial context* provides the definition of spatial restrictions to the spatial area where the indicator is defined.

By this way, the business indicators' definition should best convey managers' view of their business processes and, thus, the company as a whole.

The status of indicators grid (see bottom of Fig. 5.2) conveys all the business indicators defined in a concise manner. The name, description, perspective, type, metric's name and metric definitions (maximum, minimum and threshold score values) are given for all the indicators defined. It is a 'quick-access' grid in order to provide the user an immediate glimpse over the indicators' status.

5.3.2. Business Scenarios

On chapter 4 above business scenarios were presented as a way to address the problem stated previously (see chapter 3 above). In order to manage these business scenarios a specific context was created under the Spatial Dashboard. The Scenario Manager context was developed in order to allow the definition of 'what-if' scenarios by decision makers so that they better could convey their organization's business strategy.

Fig. 5.8 shows the Scenario Manager context on the Spatial Dashboard, the selected context on the bottom left corner. On this context is possible to drawn business scenarios on the Tree Editor (at the centre); managing scenarios for a specific branch, the Scenario Manager (the right table of contents with the filter-lists for test and production scenarios); and the overall performance indicators and composed performance indicators dispersed over a level-branch-perspective tree structure (the left table of contents).

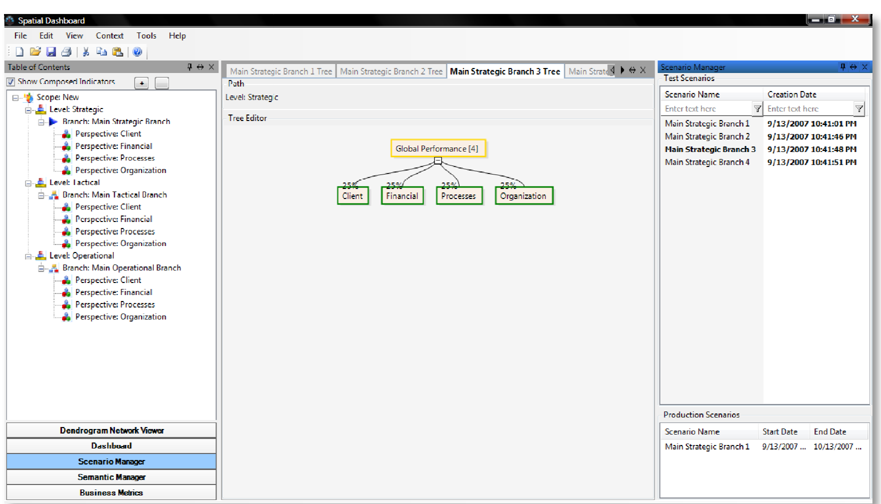

Fig. 5.8 – The Spatial Dashboard's Scenario Manager Context (screenshot)

Throughout this chapter it is described, in detail, the specific implementation process and options for each characteristic of this Spatial Dashboard's context: the tree structure implementation; the creation of performance indicators, composed performance indicators and cloned performance indicators; the tree structure semantic validation and, at length, some interface features developed to enhance usability and user's efficiency when executing tasks.

5.3.3. Tree Structure

According to some literature [35][32] read under the scope of this thesis, representing scenarios through a graph-like manner is the best way to represent business scenarios. In fact, this way allows visual interaction shortening the time-to-enlightenment of decision makers.

The implementation of this tree structure, called the Tree Editor, made use of an open source library, specifically developed to deal with tree structure manipulation. The Lithium Control was the tool used to implement the business scenarios as a graph-like representation.

The Lithium Control Library [56]is a generic diagramming, graph-drawing and graph-layout tool for .NET. As main features provided we could find: automatic tree's layout both horizontally and vertically; the standard add/delete/edit mouse actions; various types of connections; the traditional rectangular connections, the default straight line, Bezier connections; flexible import/export of XML data using .Net's XmlSerializer class and expand/collapse branches amongst others. Not all features provided by the Lithium Control library were used, since some of them were not related to the scope of this thesis.

Fig. 5.9 depicts a business scenario for a certain company defined for a certain business unit (or branch) called Porto. Here is presented the first scenario for that branch, hence, the 'Porto 1' business tree.

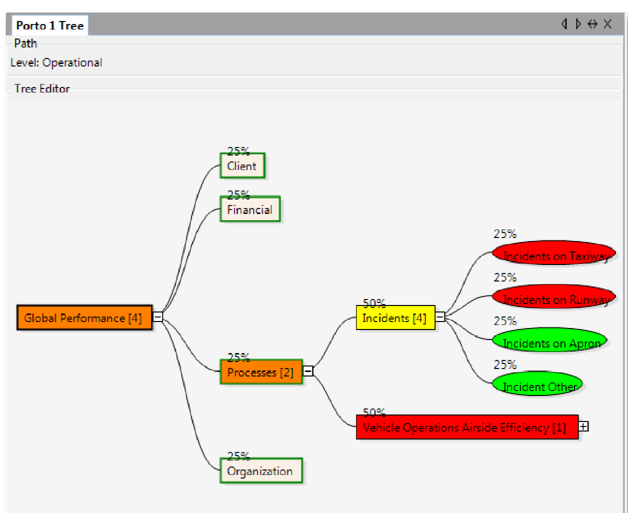

Fig. 5.9 - A Spatial Dashboard's Business Scenario (screenshot on detail)

By default, a business scenario contains a global performance node which, in turn, contains all the perspectives defined on the Semantic Manager Context. These perspectives are aggregated to this global performance node since each one of them will contribute with their score to the final global performance node's score value.

As seen under Fig. 5.9 the overall score value of each node could be perceived by its colour, i.e., whether the node is a performance indicator, a composed performance indicator, a cloned performance indicator, a perspective node or even the global performance indicator they all are filled with some colour after the tree evaluation. This colour represents the state of the node.

The node colour is defined according to its node's type. The performance indicators nodes (designed on the Tree Editor as ellipses) are the representation of business indicators (defined on Semantic Manager) on business scenarios. Therefore, its colour is defined according to its score value, i.e., these indicators will have exactly the same colour they have when they were defined under the Semantic Manager context (see section 5 above). The composed performance indicator, cloned performance indicator, perspective and global performance nodes will have their colour defined according to the colour of their descendants, i.e., an average is computed amongst the score value nodes and their contribution for its parent node.

The 'Incidents' node on Fig. 5.9, for instance, assumes the yellow colour because it has a contribution of 25% of its four child performance indicator nodes. Since two of its child nodes have solid green as colour and the other two have solid red as colour the result is solid yellow.

Knowing the colour and score value of all nodes is an important information to provide to decision makers since that can easily get a business scenario's overall perspective and outcome, hence, enhancing their decision making process. Tree evaluation was implemented in order to address this requisite. Tree evaluation is a process that starts from the tree root node (the global performance node) and recursively explores the tree. The composed performance indicators values are computed by using the linear combination of its performance indicators value. On leaf nodes, the performance indicators nodes value is calculated from the evaluation of their business rules.

Fig. 5.10 shows the context-menu popped up when the user right clicks the mouse over the Tree Editor content. Three different options are displayed: adding a composed performance indicator which pops up another form for the creation of the composed node (see section 5.3.5 below); setting the layout of the current business scenario, i.e., displaying the tree vertically or horizontally; and applying some zoom operations as seen under Fig. 5.10.

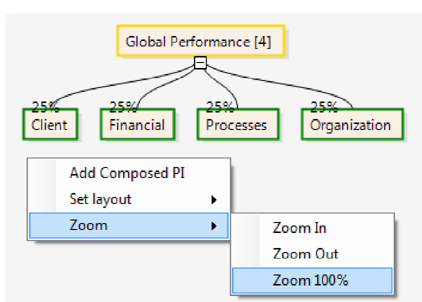

Fig. 5.10 - Tree Editor's mouse right click outcome (screenshot on detail)

As seen throughout this thesis section, the creation of different types of nodes is possible under the same business scenario tree. Each type of node has its own design and properties. In fact, each business scenario could have up to five different types of nodes:

- **The global performance node**: placed on business tree's top assumes a rectangular shape outlined by a yellow bold line to be distinguished amongst the other nodes. Its colour is determined by tree evaluation.
- **The perspective nodes**: placed under the global performance node, represents all perspectives defined by user on Semantic Manager Context. It has a rectangular shape outlined by a green bold line to be distinctive amongst other types of nodes. Its colour is defined using a linear combination of its child nodes score values.
- **The performance indicators nodes**: when business indicators, defined on the Semantic Manager context, are used on business scenarios they are seen as performance indicators node. This is just an object name detail, but of extremely importance when implementing this feature. These nodes are ellipse-shaped outlined with a black thin line and its colour is defined according to its business rule.
- **The composed performance indicator nodes**: these are the core type of nodes under the Scenario Manager context. They are created to aggregate other nodes in order to create a business scenario. These nodes are designed as simple rectangles outlined with a black thin line and its colour is filled by evaluation of its child nodes.
- **The cloned performance indicator node**: created when a user deliberately creates a clone of a node under the same scenario, or when a user uses the same node under different branches and levels. Designed as rectangles with rounded corners and outlined with a bold red line, this special type of nodes are easy prominent amongst others.

5.3.4. Performance Indicators

When creating business scenarios decision makers are bound to use business indicators previously defined on Semantic Manager context so that their business scenarios could better perform an overall overview of the company's strategy.

On the Spatial Dashboard we try to ease the process of integrating business indicators on the business scenario context. Since the creation of business indicators and the creation of business scenarios are made on different contexts (the Semantic Manager for business indicators creation and The Scenario Manager for business scenarios creation) a common structure where these indicators were shared was a need that came up ahead. In order to pull off this need a tree structure of all indicators was created and shared between the two contexts: the Table of contents (TOC). This TOC is mutual between the two contexts and lets the user to instantiate business indicators on business scenarios, via drag-and-drop operations. This TOC is depicted on Fig. 5.11 on the left side of it.

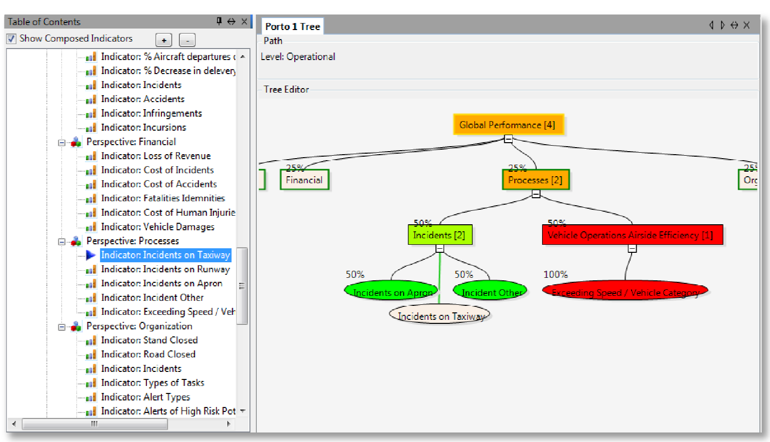

Fig. 5.11 - Creation of performance indicator on Scenario Manager (screenshot on detail)

Fig. 5.11 shows a typical creation of a performance indicator on a specific business scenario tree. On the example depicted here the indicator 'Incidents on Taxiway' created previously on Semantic Manager context was selected and dragged into 'Porto 1' scenario Tree under the composed performance indicator 'Incidents'. As could be seen, when the user drags one indicator into a business scenario and until s/he drops it, a bold light green line is traced from the performance indicator to the nearest composed indicator. This is a very helpful way of letting the user know where to is s/he placing the performance indicator.

Moreover, these nodes receive an ellipse shape outlined by a thin black line so that the user can easily perceive where these types of nodes are. The colour of these particular nodes is filled with the same colour these business indicators have on the Semantic Manager context, based upon their business rules and metrics (see section 5 above to better realize on what is based the colour of business indicators).

The use of an open-source library allowed us to implement features and enhanced usability details that would have been impossible with commercial or closed libraries. In fact, the implementation of drag-and-drop operations was implemented from scratch since the lithium library only provides graph design and manipulation tools. Furthermore, the zooming and scrolling operations were also modified in order to deal with large trees which without these operations would have been extremely cumbersome.

5.3.5. Composed Performance Indicators

Composed performance indicators are created whenever decision-makers feels the need of aggregating business indicators in order to better reflect company's strategy and vision. The creation of these nodes could be achieved using two different ways:

- 'Add composed PI' option on the tree editor's context-menu of a specific scenario (see Fig. 5.10)
- 'Add child' option on the composed PI's context-menu (see Fig. 5.12)

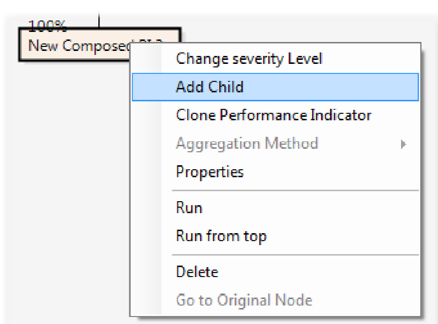

Fig. 5.12 - Composed PI's context-menu (screenshot on detail)

If the user chooses to add a child on a composed performance indicator (like depicted on Fig. 5.12 or on Fig. 5.10) the action will be the creation of a composed performance node with a default name ('New Composed PI') right under the selected node.

These nodes acquire a rectangular shape outlined by a thin black line and its colour are defined by tree evaluation, i.e., they get a linear combination of its child colours depending on their weight contribution. Furthermore, these nodes' name is followed by a number in rectangular brackets (i.e.

[…]). These numbers stand for the number of child nodes the parent node has. On Fig. 5.11 the indicator 'Incidents' has two child nodes before the addition of the 'Incidents on Taxiway', thus, its representation is 'Incidents [2]', meaning that it has two child nodes, so far.

The Composed PI's context-menu (shown on Fig. 5.12) provides multiple choices to user. It allows the user to add children nodes; to clone that particularly node (more information on this operation can be seen under section 5.3.6 below); to access its properties; to run it in order to compute its colour and score value; to delete it if it is no longer needed; and to change the node's severity level.

The severity level is a property of every business scenario tree nodes allowing the user to set the level of importance (thus, severity) given to that specific node. As a result, if one sets a severity level to 1 that would mean an indicator of extremely importance for the overall business of a certain company (profit, for instance). Therefore, no matter how distant this node is from the root tree it will have a vital place on the Tree Map view on Dashboard context (see section 4.1.3 above to read more about Tree Map view).

The user can then edit the created node by right-clicking it and choosing the 'Properties' option (seen on Fig. 5.12). When choosing this option one is interested on changing some composed performance indicators node's options like (as seen on Fig. 5.13):

- Changing its description
- Define messages for yellow, red and emergency alerts
- Define the corresponding business area
- Define its Spatial Context

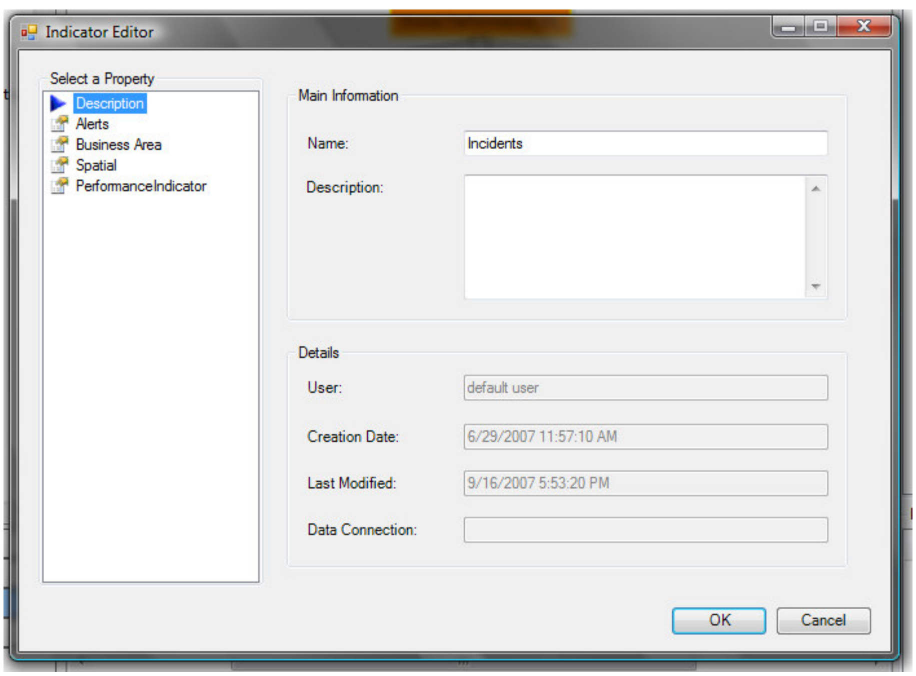

Fig. 5.13 - Composed Performance Indicator editor form (screenshot on detail)

5.3.6. Cloned Performance Indicators

The need of creating nodes from other existing nodes was visible, since on a business environment many processes are orthogonal to a company structure and many business indicators can be needed on different perspectives, levels or branches [8]. In order to accomplish this need cloned performance indicators were created.

A cloned performance indicator is, basically, an exact copy of other composed performance indicator node. This operation creates a new node on the tree and the user is accountable for placing it under the node which is more suitable for it.

Creating cloned performance indicators can be reached via two different ways:

- Choosing 'Clone Performance Indicator' option under a specific Composed PI's context-menu (see Fig. 5.12), which creates a new cloned node under the same business scenario tree (as portrayed under Fig. 5.14).
- By drag-and-drop a Composed PI from the TOC into another business Scenario tree (as depicted under Fig. 5.15).

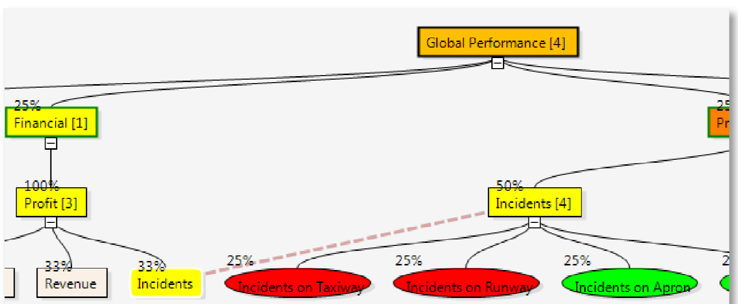

Fig. 5.14 - A Cloned PI under the same business scenario tree (screenshot on detail)

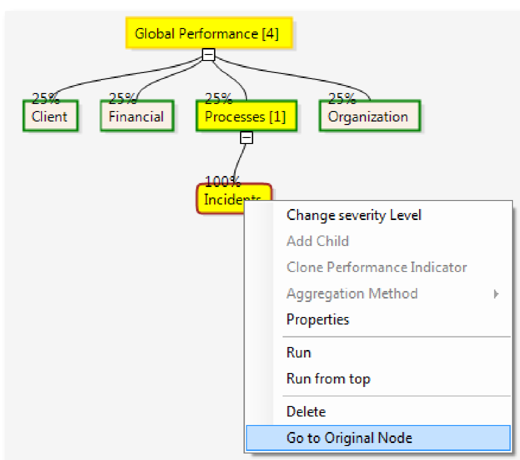

Fig. 5.15 - A Cloned PI on a different business scenario tree (screenshot on detail)

These Cloned nodes are visual distinctive from others as they have a rectangular with rounded corners design and they are outlined by a thick red line. This gives important visual feedback to the user. Apart from this visual uniqueness given to these nodes, it was also important to know the original node of a certain cloned node. Since there are two ways of creating cloned nodes two different approaches were developed to achieve this desired feature.

Fig. 5.14 depicts a cloned node created on the same business scenario tree. As could be seen on the picture above a thick dashed red line is designed from the cloned node 'Incidents' (under 'Profit' node on 'Financial' perspective) to 'Incidents' original node. This line is drawn whenever the user hovers the mouse pointer on the cloned node and the cloned node is placed under the same business scenario tree of its original node. Hence, the user knows exactly the original node of that cloned node, letting him/her to perceive the overall structure underneath the original node.

Fig. 5.15 depicts a cloned node on a different business scenario tree from its original node. This is achieved whenever the user drag-and-drops a composed performance indicator node from the TOC into a different scenario. When a cloned node is created this way, it is still possible to navigate to its original node. On every occasion one right clicks over this type of cloned nodes an option 'Go no original node' will appear as active on the context-menu. Note that this option isn't always available, i.e., is only active on cloned nodes (realize the difference between the context-menus of Fig. 5.15 and Fig. 5.12).

Finally, the colour of these nodes and its score values are always the same of their original nodes. This is achieved because these nodes objects have an internal reference to the original node; consequently, it is always possible to know the original node's score value and colour.

5.3.7. Semantic Validation

When creating tree structures for these business scenarios is important to verify some constraints. We've seen that the Spatial Dashboard claims to be an orthogonal solution to a company, therefore, many strategic indicators defined on the upper levels should not be placed on the operational business trees.

What is more, the creation of the cloned nodes could lead to infinite loops whenever the tree would be evaluated; this issue had to be mitigated as well.

Fig. 5.16 shows the semantic validation whenever the user tries to place a composed performance indicator under a simple performance indicator. As could be seen, the node 'Exceeding Speed' is closer to 'Incidents on Runway' than 'Incidents', but since it is not possible to create connections to leaf nodes, the connection line is drawn to 'Incidents' node.

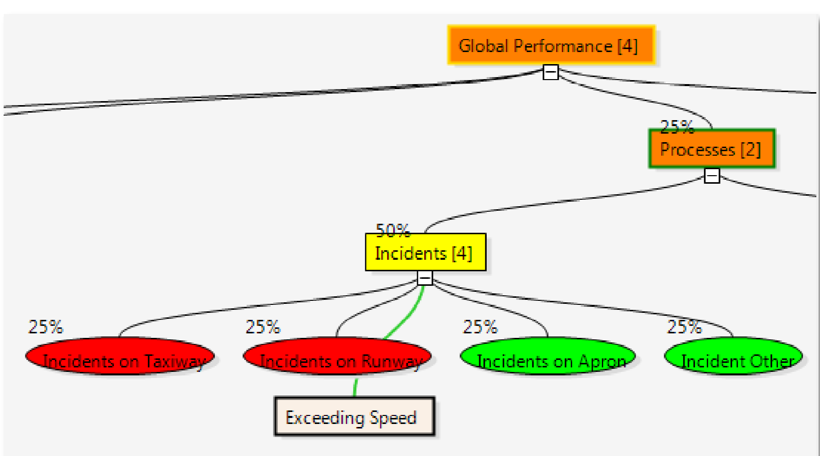

Fig. 5.16 - Placing nodes under Performance Indicators validation (screenshot on detail)

The implementation of this feature is simply achieved by having a seeking algorithm (the one that seeks parents for one node when the user is dragging a node through the tree structure) that ignores simple performance indicators.

Fig. 5.17 depicts the semantic validation whenever the user tries to place a cloned performance indicator under another cloned node (‘Vehicle Operations Airside Efficiency’) or under its own original node (‘Incidents’). As could be seen, the node ‘Incidents’ with the rounded corners is extremely close to ‘Vehicle Operations Airside Efficiency’ and also close to its original node and none green line of attachment is drawn, because no allowed connections are available.

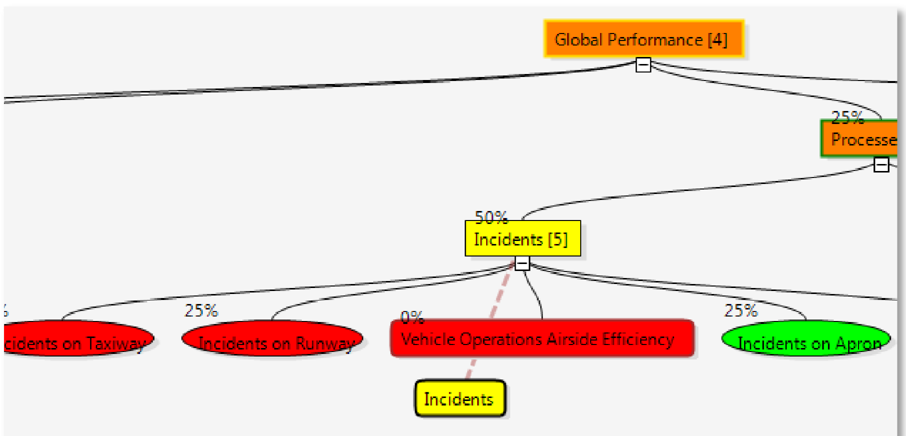

Fig. 5.17 - Placing cloned nodes under its original node or another clone validation (screenshot on detail)

The implementation of this feature is simply achieved by having a seeking algorithm (the one that seeks parents for one node when the user is dragging a node through the tree structure) that ignores cloned performance indicators or the original node of the cloned node being dragged.

Fig. 5.18 portrays the semantic validation executed whenever the user tries to place a defined upper level performance indicator (composed or not) on a lower level business scenario. On this example below the composed performance indicator ‘Profit’ defined on the strategic level was being placed under the ‘Porto 1’ scenario on the operational level (as seen under the ‘Path’ label above the Tree Editor). Because this is a semantic validation, a message is displayed to the user (‘can’t copy Indicator to lower level.’) in order to let him/her know the operation is forbidden.

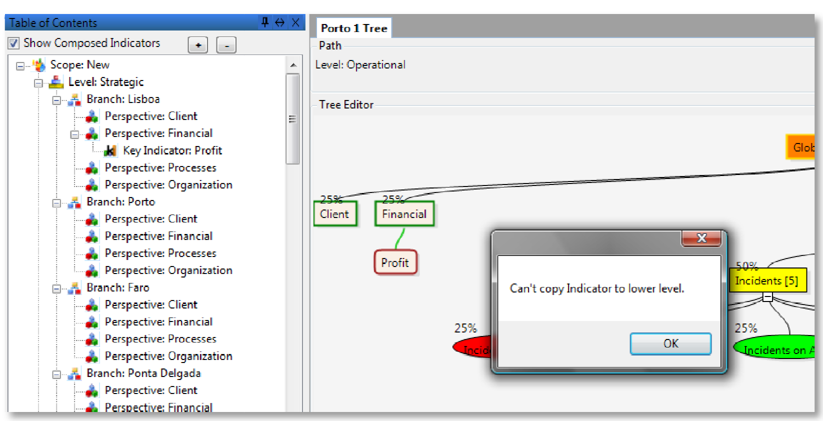

Fig. 5.18 - Placing upper level nodes into lower level business scenarios validation (screenshot on detail)

This implementation feature is simple achieved by having the drag-and-drop handler method to perform the test if the destiny business tree is on a lower level than the source, if it is the message is shown and the indicator is not placed on the lower level business tree.

5.3.8. Weighting

Having multiple nodes under a Composed Performance Indicator node, or having multiple branches under a certain level, or even having multiple perspectives defined was something that could be achieved given the high level of customization implemented on the Spatial Dashboard and, particularly, on the modules on the scope of this thesis.

Having this multitude of nodes, branches and perspectives one issue comes ahead: how to tackle all of this nodes and setting which one is more important or which contribution each node, branch and perspective has for the overall business scenario or company's business strategy?

As a way of overcoming this issue weighting methods were implemented. Weighting methods will allow the user to set the contribution of each node or branch to its parent's entities (parent-node or level). The weighting methods is very easy accessible, by just right-clicking a level or a parent-node the user will have access to an option of 'Set Weights' (for setting branches' weights of a specific level, see Fig. 5.5) or 'Aggregation Method' (for setting child nodes' weights of a specific Composed PI, see Fig. 5.12), on which four different weighting methods are provided:

- WLC (Weighted Linear Combination) Method
- WLC Tracked Method
- AHP (Analytic Hierarchy Process) Method
- OWA (Ordered Weight Averaging) Method

Since this weighting methods were to use in different contexts polymorphism was used, so that the weighting methods could use either node objects (for child-nodes weighting) or level objects (for branches weighting). Moreover, in order to achieve a high level of customization this weighting module made use of Abstract Factory Design Pattern (see 9.1.6 below) in order to ease the addition of others weighting methods. For this purpose, an abstract class (WeightingMethod) was created and the weighting methods (like OWA, AHP and WLC) inherit this class and implement their specific algorithm.

In addition, it is important to state that there is not any kind of conflicts amongst the different weighting methods and it is possible to use any of them under the same business structure or beneath different business levels. A minor implementation detail has to do with memorizing the previous weight state when setting the weights, i.e., if some weights have already been defined by user, but then s/he wants to make some corrections using the same weighting method, the last distribution of weights is recorded so that the user restarts from the point s/he left it.

Furthermore, another implementation detail was developed, when introducing values to set weights for each node or branch the weighting method automatically computes the weight of other nodes based on the values already defined. For instance, on the WLC Method if there are four nodes to set weights to, if we just put values on the first three, the fourth will assume a weight of 0% because no value was set (see Fig. 5.19).

The implementation of each method needed its algorithm method and the user-interaction screen where the user sets its weighting values for the nodes or branches being set.

Fig. 5.19 depicts a weighting method that normalize all weights given the relation ratio user wants to reproduce on the nodes. On this particular example, a user was defining the contribution of each perspective to the Global Performance node on a specific scenario.

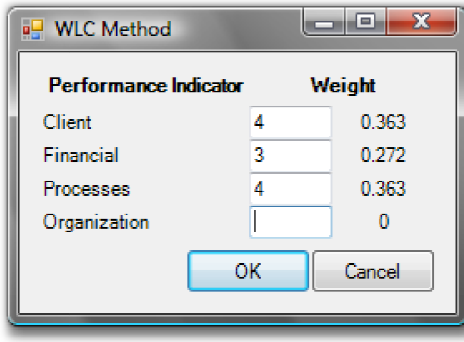

Fig. 5.19 - The WLC Method interface (screenshot on detail)

Fig. 5.20 shows a variation of the WLC Method where the weights are defined using tracking bars. When tracking a particular node or branch to a higher value others will automatically decrease their values in order to avoid inconsistency. This method is particular useful to watch the impact each node or branch has on others, however, it is much less accurate than its peer due to the complexity of setting exact values when using a track bar. On this particular example, again, a user was defining the contribution of each perspective to the Global Performance node on a specific scenario.

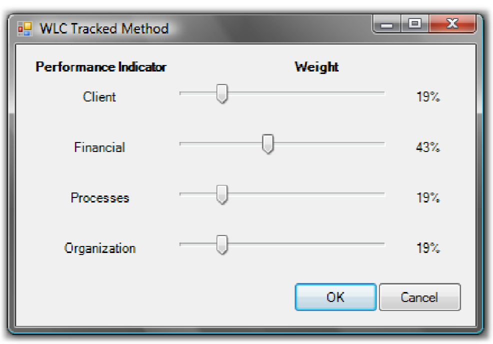

Fig. 5.20 - The WLC Tracked Method interface (screenshot on detail)

Fig. 5.21 illustrates a weighting method where the user can order the list of nodes or branches being weighted and define a pessimistic or optimistic strategy for the more preferred node or branch. Thus, a pessimistic strategy will give less weight to the most preferred element whereas an optimistic strategy will give more weight to the most preferred element. By definition, an average strategy will give exactly the same weights to all elements on the list. On this particular example, again, a user was defining the contribution of each perspective to the Global Performance node on a specific scenario.

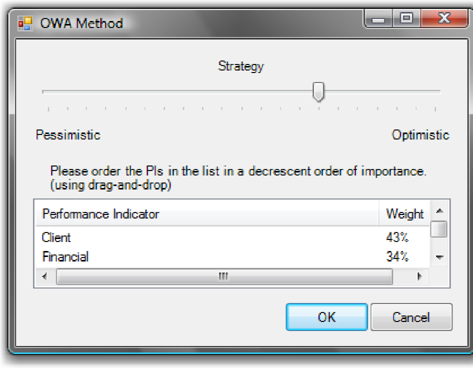

Fig. 5.21 - The OWA Method interface (screenshot on detail)

Fig. 5.22 demonstrates the implementation of AHP weighting method. The AHP method is a complex multi-criteria decision method that reduces the complexity of multiple choices to a pair wise comparison. On this method the user selects two elements to which s/he defines a relation ratio, i.e., which element is more preferred than other. For instance, on the example below the user is simple defining that the Financial node is four times preferable (has more importance) than the client node. The other elements are equally preferable. As a result, this would represent on a distribution of 17% for client, 33% for financial, 25% for processes and 25% for organization elements.

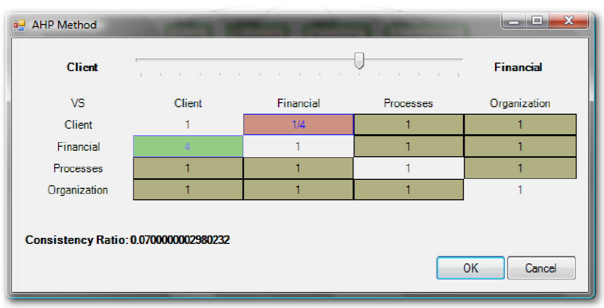

Fig. 5.22 - The AHP Method interface (screenshot on detail)

5.3.9. The Scenario Manager

Given the possibility of creating manifold business scenarios on specific branches will potentiate the need of managing them, i.e., renaming, creating and deleting nodes, for instance. In fact, scenarios galore on the Spatial Dashboard, since they are a useful tool to create 'what-if' situations enhancing the decision making process.

As stated before (see section 4.2.9 above of Chapter 4 - Proposal) there are two types of scenarios; thus, two scenarios to manage: the test scenarios and the production scenarios. Given that, the overall interface of Scenario Manager will be two list-views containing all the test and production scenarios for the current selected branch (on the left TOC). All managing operations will be accessible via context-menus, specific for the scenario we want to manage.

With a Test Scenario is possible to rename it; to set as active (activating it on the Tree Editor); to set as production scenario; to clone it (creating a new scenario with the same business tree as the original scenario); delete it and setting its base cartography (its geographic context) (see Fig. 5.23).

On what comes to Production Scenarios, it is only possible to remove scenarios, or changing its settings via Scenario Manager. Since they are on production their operations are much more limited, which is reasonable given the fact that they are already on production state (see Fig. 5.25).

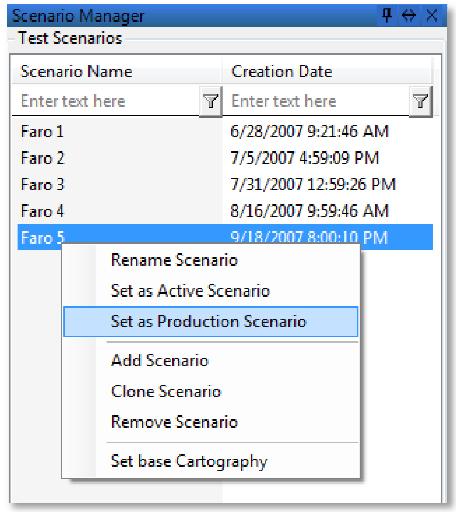

Fig. 5.23 - Test Scenario List and context-menu of Scenario Manager (screenshot on detail)

Fig. 5.23 shows the Test Scenarios list-view control on the Scenario Manager component. The list-view presents all the test scenarios created on that branch and its creation date. When right-clicking on a specific test scenario a context-menu will pop up portraying all the possible managing operations with this kind of scenarios.

The spatial context is also set on test scenarios, so that decision-makers could experiment different contexts and situations. The spatial context is important to give spatial and visual feedback on each business scenario tree evaluation.

Choosing 'Set as Production Scenario' option on the context-menu of test scenarios' list will set the currently selected scenario into production state. In order to complete this task successfully the user must set the production start date and its end date (see Fig. 5.24).

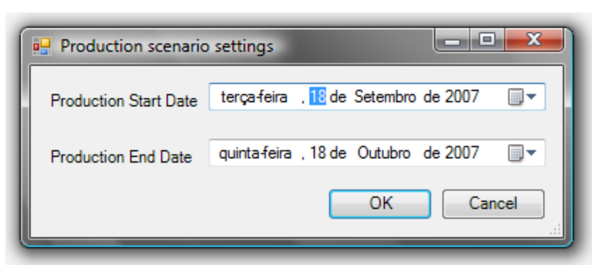

Fig. 5.24 - Production Scenario interaction form (screenshot on detail)

After setting a test scenario into production state, the scenario name will become visible on production scenarios' list as seen under Fig. 5.25. Once a business scenario is set into production state the previous managing operations are no longer allowed. With a production scenario the user can only change its start and end date and remove a production scenario from the list of scenarios.

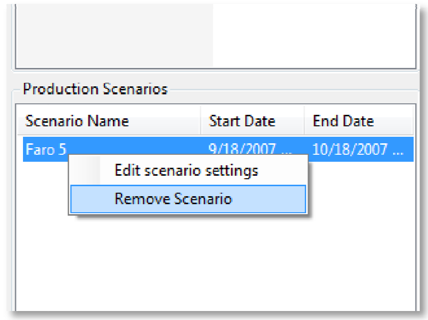

Fig. 5.25 - Production Scenario List and context-menu of Scenario Manager (screenshot on detail)

Additionally, when one is setting a business scenario into production state one has to bear in mind that no overlapping production scenarios for the same branch should be defined. Having business scenarios on the same branch that partly covers each others will undergo into a misleading situation: having different business scenarios being computed on the same time-slice period, thus, giving their score contribution to the corporate performance score. Since this situation is undesirable a date validation snippet algorithm was implemented to avoid overlapping production scenarios.

Fig. 5.26 conveys the outcome of date validation expressed on last paragraph. For this specific situation the user were trying to set another business scenario that overlaps three other business scenarios already on production state (Porto 1, Porto 2 and Porto3 scenarios).

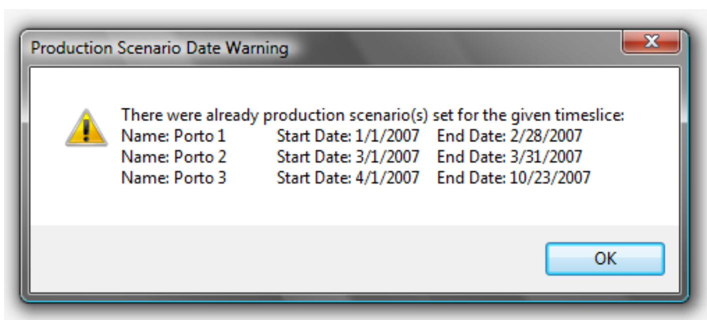

Fig. 5.26 - The Production Scenario's Date Warning (screenshot)

Given this myriad of scenarios it might be useful for the user to see 'on-the-go' which scenarios are currently set on production. For that reason, when the user clicks on a level, under the TOC (see Fig. 5.27), the business scenario trees displayed on Tree Editor are only the Production Scenarios. If no production scenarios are set for any branch of that specific level the user is informed that 'No production scenarios were set for this [that] level'.

5.3.10. Interface features

As seen under Proposal chapter on section 4.2.10 above some interface features and overall product attractiveness could, in fact, enhance productivity when one interacts with a high-quality interface.

With the intention of achieving a hedonic interface for the Spatial Dashboard that potentiates usability and, thus, enhance decision making, some interface features were developed:

- **Context-awareness**: in order to let the user know at all times on which context is s/he located under the SD a context menu was developed. Moreover, as a way to convey an immediate object representation for their late use, icons were use to distinct different objects, thus, on the Table of Contents levels, branches, perspectives and indicators have different icons (see Fig. 5.27).

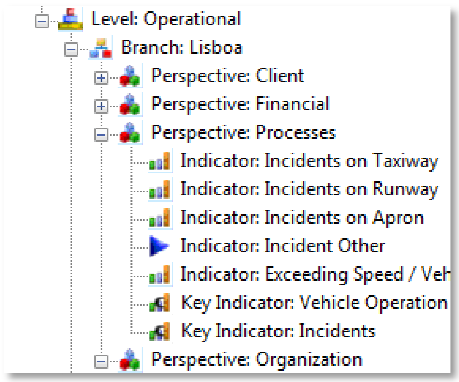

Fig. 5.27 - The Spatial Dashboard's icon feature on TOC (screenshot on detail)

- **Mouse operations**: drag-and-drop was a feature developed to place indicators from one business scenario tree to another. The user just has to drag a desired indicator from the TOC into the business scenario s/he was creating. Additionally, in spite of defining complicated keystrokes sequences or commands to execute some tasks, context-menus were widely used. To access it, one just has to right-click over a certain object one is interested on executing. After the mouse right-click a context-menu with associate options will pop up (see Fig. 5.12, Fig. 5.15 and Fig. 5.23 for illustrative purposes).

- **Expand and Collapse features**: dealing with large amounts of information has an immediate drawback: managing large amounts of information. On a typical Spatial Dashboard interaction it may happen that the amount of information created by the user is, apart from necessary, excessive for a specific task or purpose. Thus, expand and collapse chunks of information may be of great help for the user. This feature was implemented on Tree Editor, because business trees may become cumbersome and in those situations it might be useful to collapse some branches (see Fig. 5.9 and note that the node 'Vehicle Operations Airside Efficiency' has a 'plus' sign on its end, this means that its child nodes were collapsed to achieve an uncluttered image). Additionally, this feature was also implemented on TOC with two buttons that collapse all the levels to its branches or expand all the tree structure. This might be useful to find a specific indicator or branch (see Fig. 5.28).

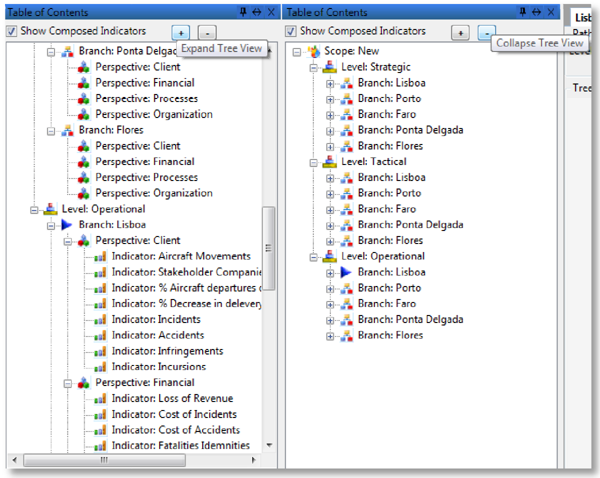

Fig. 5.28 - The Spatial Dashboard's TOC - Expanded (on the left) and Collapsed (on the right) view (screenshot on detail)

- **Usability features**: dealing with large business trees and with a myriad of business scenarios to manage brought new interface features that ought to be implemented:

  - **Layout**: when creating large business trees it might be useful for the user positioning the tree whether vertically or horizontally. If the user right-clicks the Tree Editor content there is an option ‘Set Layout’ (see Fig. 5.10 context-menu) that lets the user to choose the more appropriate layout (see Fig. 5.9 and Fig. 5.11 and observe the layout differences between the two screenshots).

  - **Zooming**: it is also possible to zoom in and zoom out under Tree Editor’s content (see Fig. 5.10)

  - **Filtering**: under a branch it is possible to create the number of scenarios the user wants and founds necessary to better convey business strategic and vision. All scenarios created for a certain branch are presented in a list on Scenario Manager. Due to the amount of scenarios one might create a list-view-filter was developed from scratch. On Fig. 5.29 is presented a non-filtered list (on the left) and a filtered list with the given scenario name and creation date arguments (on the right). Moreover, by clicking on the ‘funnel’ icon is possible to set some filtering options like:

    - Defining the data type we are filtering, i.e., if we are filtering a string, a number or a date.
    - Defining the text alignment by column, i.e., if we want to centre, right or left align the column’s text. This option might be useful for overall comparison purposes. On the example below, for instance, one might be interested on comparing the scenario numbers, thus, aligning it to the right turns to be quite handy.
    - Defining filtering option to be case-insensitive, i.e., when filtering objects the filter should ignore case and just compare the words despite uppercase or lowercase letters.
    - Clear the filter currently being applied, i.e., clears the text on the filter text-box and lists all the objects on the list, since no filter is being applied.

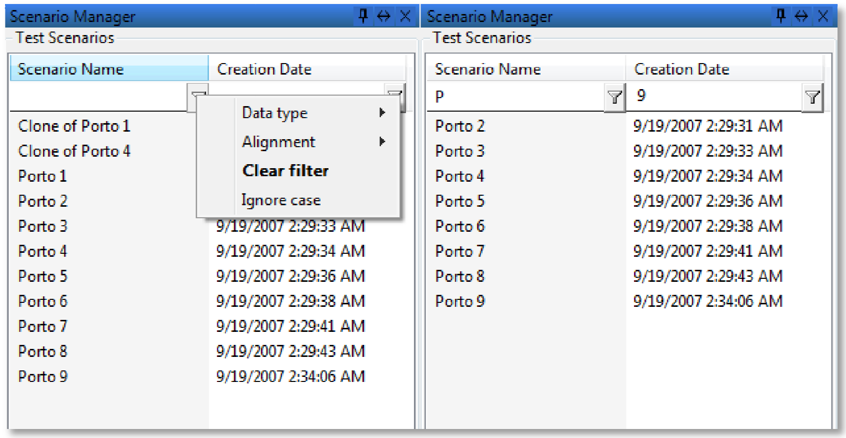

Fig. 5.29 - The Scenario Manager Filtering option - filtered on the right (screenshot on detail)

- **Tabs**: given this myriad of test and production scenarios decision makers might find useful to compare scenarios under the same branch. Because of that, Tab feature was implemented on the Tree Editor, since splitting up the screen in two (the two scenarios under analysis) would be counter-productive because with large business trees viewing the content of both trees would become extremely unmanageable. As seen under Fig. 5.30 there are a lot of scenarios defined under this branch. The scenario under analysis ('Clone of Porto 1 Tree') has its tab lighter and written in bold fonts, the remaining scenarios are still accessible but their tabs are some sort of faded away, meaning that they are not currently active.

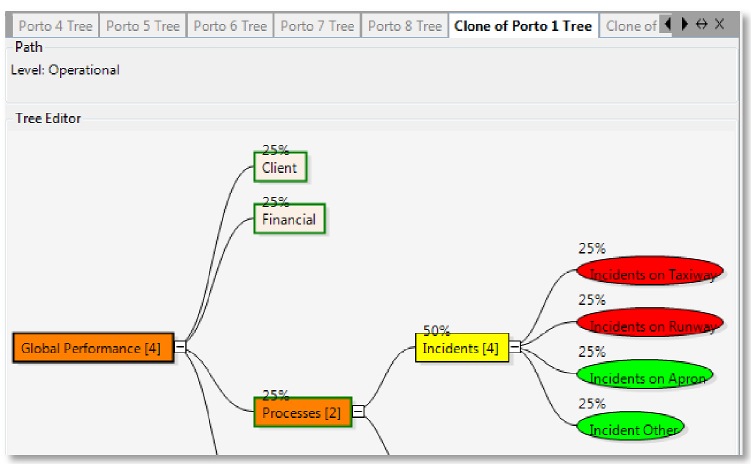

Fig. 5.30 - The Tree Editor tab feature (screenshot on detail)

5.4. Summary

Throughout this chapter it was explained the implementation details concerning the implementation of new features on the Spatial Dashboard, regarding the scope of this thesis: modelling scorecard indicators.

Apart from these features presented on this chapter, some other features were added to the Spatial Dashboard since it was a collaborative work. Given that, some programming methodologies and techniques were adopted, like *extreme programming* practices, refactoring code, use of design patterns.

Given the problem stated on this thesis, concerning the modelling of BSC's indicators on the Spatial Dashboard, this chapter focused on three specific modules of the SD under the Modelling layer: the Scenario Manager, the Tree Editor and the Weights Manager (see Fig. 5.1).

All the way through this chapter, was presented the implementation of what had been presented on proposal chapter (see chapter 4 above) in order to address the problem stated before (see chapter 3 above). This section gets across all the implementation facets of business indicators, business scenarios and some interface features used to enhance usability and user's task achievement.

Table 5.1 outlines the implementation of proposal described previously:

Reference Models	Three-tier architecture Client-Server architecture
Technologies	.NET ESRI (geographic context) C# Windows Forms Project
Frameworks	Lithium Library Weifen Luo Irrlicht .NET CP
Design Patterns	Model-View-Controller: Tree Editor Singleton: Scenario Manager and TOC Abstract Factory: weighting methods Observer: managing SD's events
Interface features	Context-menus Dockable windows Tree Structure representation Expand and collapse feature Filtering options Zooming facet Tab implementation

Table 5.1 - Implementation summary table definition

6. Case Study

This chapter describes the use of a case study in order to best describe usefulness of the Spatial Dashboard approach on a very specific and real context. The airport business was the industry selected to describe the application of Spatial Dashboard to a specific business area.

The main issues addressed on this Case Study chapter are related to airport safety management. The reason why the Airport Safety Management industry is addressed on this thesis has to do with the fact that this is a continuation of a project conducted last year, the Airport Network for Mobile Surveillance and Alerting (AIRNET) project.

6.1. Introduction

The continuous increase of airport traffic intensified the number of accidents and incidents related with aircraft movements. Faced with emergency situations, airport decision-makers have limited knowledge of the overall traffic situation. Therefore, ground movement hazards are more bound to happen. The AIRNET project contributes to the solution of this problem by developing a new low-cost and modular platform for safety management on airport surface movements[57] [58].

The scope of AIRNET is restricted to an airport's airside area. This area has a very strict control due to security and safety reasons. Thus, people and vehicles must follow a demanding protocol to go through this area. From the ground surface movements point of view, the airside can further be segmented into the movement area (which includes manoeuvring and apron areas), for aircraft circulation and where vehicles are also authorized to circulate subject to very restrictive rules, and peripheral and service roads just for vehicle circulation.

The key innovation proposed by AIRNET is to further advance airport safety and improve the efficiency of operations for ground surface movements. Therefore, AIRNET should be able to provide answers to questions that are central to airside safety, namely prevention of future incidents/accidents[57]:

- What is happening or when did it happen?
- Where are the areas that need the most attention?
- What do I need to do about something that had happened?
- Why is it happening? Who is responsible and who is involved?

Critical metrics (for instance, number of incidents, number of accidents and their severity level, amongst others) can reveal cause-and-effect relationships and alert the decision-makers to problems in airport, requiring their instantaneous attention and action. Given that, it is extremely important that AIRNET strengthens performance data from the diverse sources into a coherent surveillance system that users can rely on.

6.2. Approach

In order to better implement and test this case study, we need to create a set of safety airport related business indicators to better convey a realistic scenario. However, before starting to explain the business indicators created within this case study a brief overview of Airport Safety Management is made through this section. Moreover, a brief description of on what was based this definition of indicators is made as well. Finally, the description of business indicators is made.

6.2.1. Airport Safety Management

In the airport industry, accidents are rare, but there other incidents may happen more frequently. However, ignoring the less severe events can increase the number of more serious incidents. An accident is defined as an event during operations that results in a fatality or serious injury to an individual or substantial damage to an aircraft. An incident is defined as an event associated with the operation of an aircraft that affects or could affect the safety of its operation.

Along with this safety events operation under the airport industry, another interesting fact is that the fees paid by an airline to the airport operator are based on the amount of time each aircraft stays on land. Running operations the more efficiently that is possible is great for both the airline company and the airport, especially because both of them want more passengers travelling around the world, using their airports and their aircrafts.

Stakeholders of this industry work together to achieve a well coordinated process in order to outcomes the more possible profit for all the stakeholders involved on the process. However, whenever things go wrong and some incidents or even accidents occur, they all try to thrust aside their responsibility on the given incident/accident. The main reason for this behaviour is because as in any other industry incidents are costly, producing profit losses.

Consider a ground accident on an airport. Right after the accident it is common practice in this industry that each and every stakeholder starts to blame each other, making others more accountable for the accident. In this situation it is useful to have a tool that can show what really happened, combining the various factors involved in order to discover the real reason behind the accident.

For instance, an accident is caused by one aircraft. In these cases, usually, the responsibility for the accident falls over the airline company. But what if the airline could raise reasonable doubt over the fact that the pathway where the accident occurred was faulty, and show that it wasn't the first time an accident happened on that precise location? These accident scenarios could be simple solved if not only the accident, but all in-land operations of the airport were monitored and spatially enabled.

6.2.2. Creating airport business indicators

In order to test this concept, we created a set of indicators, following the airport traffic rules and indicators set by the international organization that regulates the civil aviation sector: International Civil Aviation Organization (ICAO) [59]. This organization develops the principles and techniques of international air navigation and fosters the planning and development of international air transport to ensure safe and orderly growth. It is responsible for standards and recommended practices and also defines the protocols for air accident investigation.

The security procedures referred above are based upon rules defined by the ICAO and include items such as:

- Minimal distances between crafts
- Prohibition of entry of certain vehicles in some areas
- Maximum velocities in certain areas

The main procedure consisted in the creation of airport safety management indicators according to ICAO regulations and using the AIRNET data. The AIRNET data that we had access was few and it was a representation of a data warehouse in a relational database.

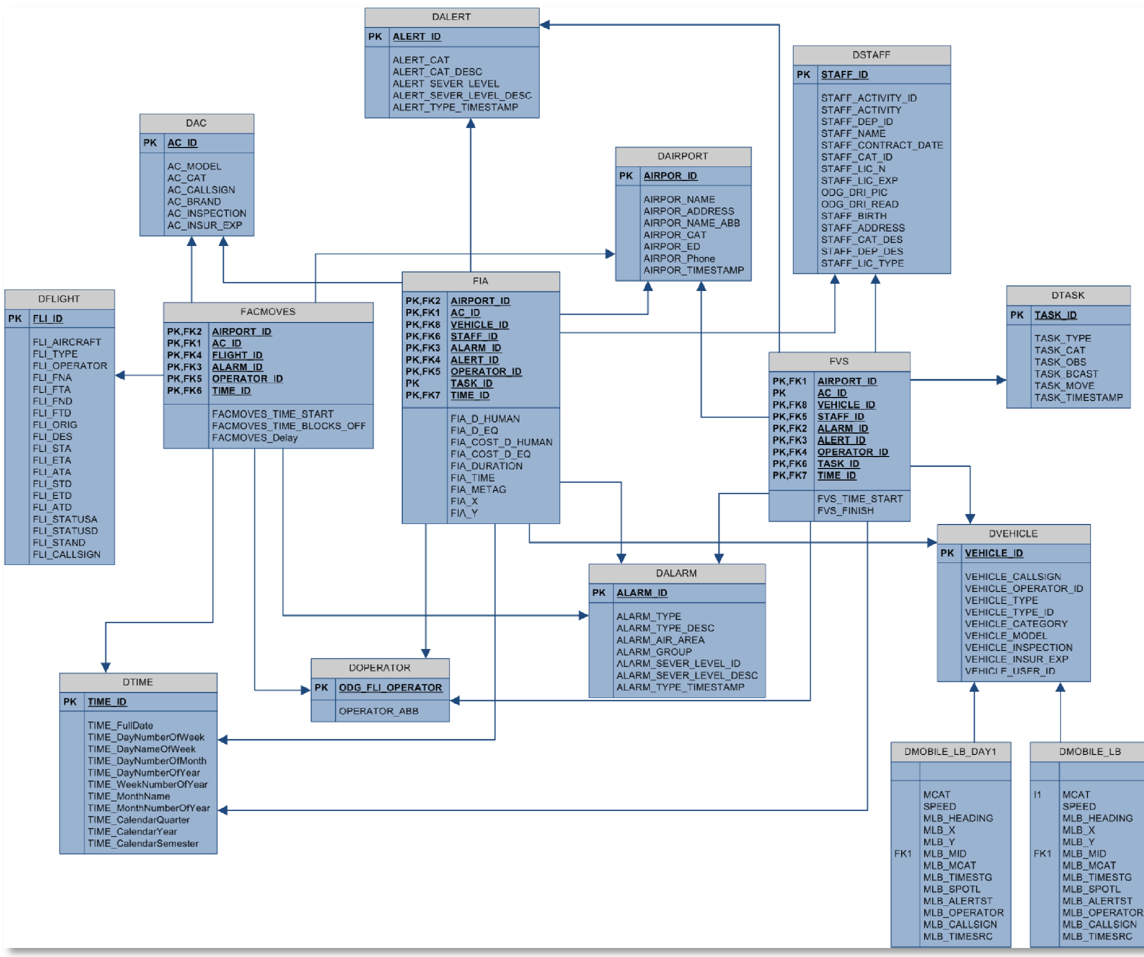

Fig. 6.1 – AIRNET's Database Relational Model

Fig. 6.1 portrays the case study data warehouse relationships between fact and dimension tables. The relationship between these tables meant to convey a multidimensional database that supports this case study. The main goal with these relationships is to provide sources for safety performance indicators in order to let them better convey airport safety performance, thus, data is related with airport safety culture and strategy.

Given that, the data warehouse has three fact tables (FIA, FACMOVES and FVS) and ten dimension tables (DAC, DAIRPORT, DALARM, DALERT, DFLIGHT, DMOBILE_LB, DOPERATOR, DSTAFF, DTASK and DTIME):

- **FIA** (Airport Incidents and Accidents): Provides information about the extent and financial impact of an incident or accident. It measures the total damage in equipment and differentiates human damages/injuries from fatalities.
- **FACMOVES** (Aircraft movements): It measures the total time an aircraft is on the ground and the total infringements it caused since the approach until it is parked at the assigned stand, or since blocks-off until the take-off
- **FVS** (Airport Vehicle Services): It measures the total time an activity (operational service involving a vehicle) took.
- **DAC** (Aircraft): This dimension defines the technical characteristics of an aircraft, including the airport airside areas where the vehicle is authorized to circulate.
- **DAIRPORT** (Airport): The Airport dimension provides information about the airport movement area (also called airside area). This is a restricted access area under the jurisdiction of the airport authority and where most of the airport safety rules apply.
- **DALARM** (Airport Alarm): Define the type of alarm situations. An alarm message corresponds to administrative infringements (e.g., driving license expired; vehicle inspection date expired; user not logged on, amongst others).
- **DALERT** (Airport Alert): Define the type of Alert situations, namely the types of alerts for each airport area and the level of severity (e.g., Panic Alert, clearance level, Conflict/Infringement messages).
- **DFLIGHT** (Flights): Describes the information about the flights, including flight type on arrival/departure (regular/charter), origin or destination, and other flight related information.
- **DMOBILE_LB** (Mobiles movements): Describes the activity of the vehicles/aircrafts in a daily basis. This is a spatial dimension used to monitor in a continuous way the mobiles ground movements (i.e., mobile's position for every second). This is a snowflake dimension which is related with the Aircraft and Vehicle Dimension.
- **DOPERATOR** (Airport Flights Operator): this dimension contains all the flight operators available on the airport.
- **DSTAFF** (Airport staff): Provides personal data about the employees
- **DTASK** (Airport Tasks): Describes the information about the type of tasks for airport operations
- **DTIME** (Time): the time dimension

Based on the data we had access and the airport safety background stated on paragraphs above, the definition of business indicators was the following:

- The definition of Performance Indicators followed the ICAO's guidelines and specifications
- It was mainly focused on principles and techniques of international air navigation and fostered the planning and development of international air transport to ensure safe and orderly growth.
- It followed the four main perspectives organized by AIRNET projects stakeholders:
    - Financial Perspective;
    - Customer-stakeholders Perspective;

- Internal Processes Perspective;
- Aerodrome Environment-Community Perspective.

Despite the data we had access was few, a case study was created in order to perceive the usefulness of Spatial Dashboard as a whole and the new features added, especially the ones concerned on this thesis. Therefore, a case study appliance to the Spatial Dashboard is described on section 6.3 below.

6.3. Prototype appliance procedure

For this case study analysis we assume that a specific airport company wanted to implement a Corporate Performance Management solution and for that purpose used the Spatial Dashboard as an orthogonal solution. Since the data we has access was based on AIRNET project we assume that company was the ANA Aeroportos (a Portuguese airport company), in a way to better convey this case study purpose under the Spatial Dashboard.

The first thing we had to create was the internal structure of business units (branches) for this company. According to what seems to us ANA Aeroportos business units' division, we decided to organize their branches under the following structure (see Table 6.1below):

Branch Name	Level	Description
Ana Aeroportos	Strategic	Handles all the strategic decisions under ANA Aeroportos.
Lisbon	Tactical	Tackles with corporate decisions under the Lisbon branch of ANA Aeroportos, which are in line with the ANA Aeroportos business vision and strategy.
Oporto	Tactical	Tackles with corporate decisions under the Oporto branch of ANA Aeroportos, which are in line with the ANA Aeroportos business vision and strategy.
Algarve	Tactical	Tackles with corporate decisions under the Algarve branch of ANA Aeroportos, which are in line with the ANA Aeroportos business vision and strategy.
Azores	Tactical	Tackles with corporate decisions under the Azores branch of ANA Aeroportos, which are in line with the ANA Aeroportos business vision and strategy.
Lisbon	Operational	Deals with all the operational decisions of Lisbon branch of ANA Aeroportos.
Oporto	Operational	Deals with all the operational decisions of Oporto branch of ANA Aeroportos.
Algarve	Operational	Deals with all the operational decisions of Algarve branch of ANA Aeroportos.
Azores	Operational	Deals with all the operational decisions of Azores branch of ANA Aeroportos.

Table 6.1 - Case Study's branch organization for the Spatial Dashboard

Since the data we had access is only related to operational processes, the case study will focus on a very particular branch of ANA Aeroportos, the Oporto branch. In fact, AIRNET data was collected on Oporto airport, thus, we will focus on the operational branch of Oporto airport on this case study.

In a real example scenario, all branches of ANA Aeroportos will figure here, the decision-makers of each business unit will define a set of performance indicators to monitor and then create them on the Spatial Dashboard. On this case study and after the creation of our business units we will create a set of indicators, on which we are interested to monitor.

In order to provide a more thorough description of each business indicators and their business metrics an appendix (see chapter 9.2) was written with a more detailed explanation of its business metrics and relationships with raw data.

The creation of business indicators is done on Semantic Manager (see section 5.3.4 above) and is depicted on Fig. 6.2.

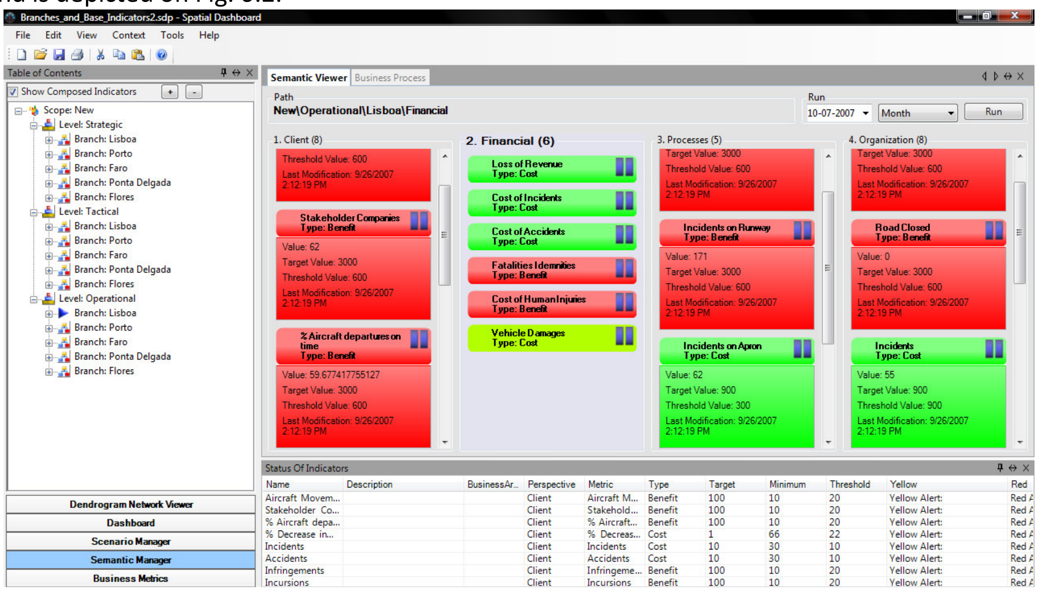

Fig. 6.2 - The Semantic Manager: business indicators for Oporto Airport business unit

After creating the business indicators it is important to create the business scenarios for the Oporto business unit as portrayed on picture Fig. 6.3.

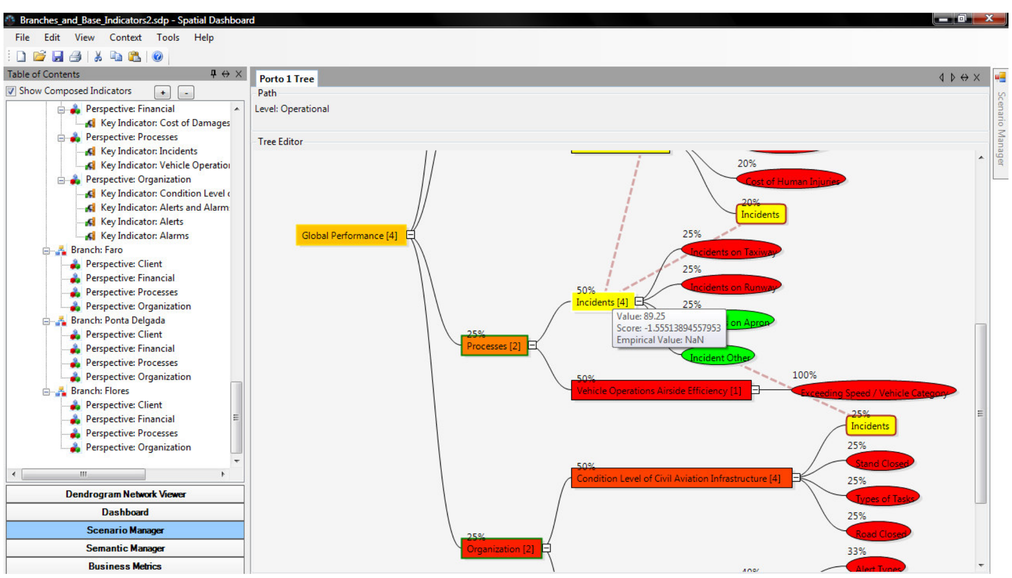

Fig. 6.3 - The Scenario Manager: a business scenario for the Oporto branch

Fig. 6.3 shows the creation of a wide business scenario tree for the Oporto operational business unit. For this scenario we created different Business Indicators and Composed Business Indicators and placed them under the more suitable perspective. On Fig. 6.3 it is clear that the Composed Performance Indicator 'Incidents' was cloned and placed under all the other three perspectives. Given a business indicator like 'Incidents' on an Airport business context it is clear that is an indicator orthogonal to the all airport business unit.

In fact, if many incidents occur the financial outcome of an airport will suffer from it, since the airport will have to pay all the personal and material damages that came with those incidents.

Additionally, these incidents also take some credit on customer perspective. Actually, if some serious incidents occur, whether they are accidents or not, and if they have some sort of projection on mass media, customers will start to create a general sense of untrustworthiness towards the airport, which, in turn, will have a severe impact on airport's revenue.

Finally, on what comes to Organization perspective, 'Incidents' is an important indicator to monitor the 'Condition Level of Civil Aviation Infrastructure', for instance.

Given that, and just as an example, the 'Incidents' indicator corroborate, in a conveyable way, the need of having Cloned Performance indicators. In fact, if this type of node does not exist, we would have to create all the tree structure existing beneath the 'Incidents' node in each perspective.

6.4. Results

The case study presented throughout this chapter tried to convey a real situation where the Spatial Dashboard could be applied. The case study took place in a Portuguese airport and all data we had access was collected by the AIRNET project, on which we were not directly involved.

This case study allowed us to perceive the usefulness of Spatial Dashboard on a real business context:

- The need of cloning indicators was corroborated by indicators which were needed on different perspectives and business units
- The need of managing business scenarios was also perceived with this case study, because during the creation of these business trees some 'what-if' situations needed to be tested and rehearsed.
- The overall ease of use and the ubiquitous use of mouse were very handy when creating these business scenarios.

However, this case study had some characteristics which did not allow us to evaluate all of Spatial Dashboard's potentialities. The case study presented here was based on data collected under AIRNET project and we only had access to 21 days of business data. Thus, we created a very simple case study and since data were related with the Operational business level we could not go any further.

Given that, it would be very helpful to test the Spatial Dashboard in a real and complex business scenario context. Creating a scenario where strategic data were created with the support of strategic decision-makers in a real environment would be invaluable.

Finally, it is important to state that there were some attempts of getting this important data, to evaluate Spatial Dashboard in a more methodical and authentic way. Negotiations with ANA Aeroportos and Portuguese Navy were started during the last year. In fact, some presentations were prepared to these entities, but they end up being post-pone frequently. This had made the process of testing the Spatial Dashboard under a realistic environment much harder.

6.5. Summary

In a globally competitive environment, benchmarking is a widely accepted means to analyse business performance against objectives and to evaluate achievements relative to peer performance. Airports worldwide have adopted financial and quality of service benchmarking as a management tool to enhance efficiency, improve service and drive down costs. The Spatial Dashboard is a DSS which tries to be a useful tool on helping its users to make better choices based on useful information provided in an appropriate manner.

The case study used to evaluate the effectiveness of Spatial Dashboard on a real environment was to apply the Spatial Dashboard to an airport business context. For this purpose, the AIRNET project's data on Francisco de Sá Carneiro in Oporto was provided and used to test real business scenarios.

The case study followed a normal procedure: the data were collected and the provided to us, we analyse it, after that we started to conceptualize a possible business structure organization in branches and business units and then started to create business indicators according to ICAO's guidelines and specifications. The Table 6.2 provides in a more succinctly way the scope of this case study.

Scope	Airport Safety Management
Data	AIRNET Project ICAO's Guidelines
Main Business Indicators created	Loss of revenue, Cost of incidents, Cost of accidents, Cost of human injuries, Vehicle damages, Aircraft damages, Aircraft movements, % aircraft departure on time, Number of accidents, Number of incidents, Number of infringements, Number of incursions, Incident on Runway, Incident on Taxiway, Incident on Apron, Amongst others.

Table 6.2 - Case study summary table definition

7. Conclusion

In the Information Era, Information Technology (IT) came to aid the decision making process, allowing its users to introduce, evaluate and analyse data. For that reason, it is extremely desirable to evaluate how effectively these systems are, especially on helping business decision-makers.

A properly constructed scorecard should tell the story of the business unit's strategy. It should identify and make explicit the sequence of hypotheses about the cause-and-effect relationships between outcome measures and the performance drivers of those outcomes. Every measure selected for a scorecard should be an element in a chain of cause-and-effect relationships that communicates the meaning of the business unit's strategy to the organization[12]. Understand and clearly recognize this cause-and-effect relationships is of extreme importance. The more effective this information is conveyed to the decision-maker the wiser and more conscious his/her decisions are made.

Having this situation in mind, the problem stated on Chapter 3 of this thesis is intrinsically related with this situation. In fact, this thesis challenge is concerned with providing a broad and helpful approach for modelling scorecard business indicators, in a way that they could provide valuable and powerful information to decision-makers, shortening their time-to-enlightenment, hence, enhancing their decision making process.

This thesis provided a solution for the problem stated previously throughout modelling scorecard indicators via a more structured and conveyable way. This way of modelling business indicators was this thesis main contribution, hence, on section 7.1 is provided a brief overview of this thesis' main contributions.

7.1. Main Contributions

Throughout this thesis was described an approach for the definition of business indicators; after that it was presented our proposal for modelling them under business scenarios; the subsequent part defined our approach for managing these business scenarios; and the last piece provided some interface features for enhancing managers' performance when interacting with the system.

Business indicators are objects that measures the performance of a given business activity or process and in this thesis was defined how its definition was addressed under the Spatial Dashboard. These business indicators are then placed under business scenarios, which follow a tree structure design. This business trees are based upon *scenario planning* context which is a framework of support for decision-making based on clarifying cause and effect factors in a target business. These cause-and-effect relationships are mostly achieved by using a causal structural graph model [32].

Since on tree structure representations several nodes are placed under others, weighting methods must be provided to the user, so that he could perform a better representation of business view and strategy on those business scenarios. Along with this creation of multiple scenarios it was realized the need of managing scenarios (create, delete, rename and clone operations amongst others), thus, the Scenario Manager was proposed.

Moreover, some usability features were added to the Spatial Dashboard since it is believed that usability can shorten decision makers' time-to-enlightenment [48].

The case study used to evaluate the effectiveness of Spatial Dashboard on a real environment was to apply the Spatial Dashboard to an airport business context. For this purpose, the AIRNET project's data on Francisco de Sá Carneiro in Oporto was provided and used to test real business scenarios.

The case study followed a normal procedure: the data were collected and the provided to us, we analyse it, after that we started to conceptualize a possible business structure organization in branches and business units and then started to create business indicators according to ICAO's guidelines and specifications.

7.2. Future Work

The main focus of this thesis was to provide a proposal for modelling scorecard business indicators under the Spatial Dashboard, a DSS. Nevertheless, there is some future work that could be done. Some may be made in order to improve the already existing features of the Spatial Dashboard, other may fell out of this thesis' scope and be considered as related work. However, a brief list of possible future work is presented below:

- **Develop a web-based architecture for the Spatial Dashboard**: instead of having client-server architecture, a web-based architecture would be developed for the Spatial Dashboard. This new architecture would provide an easier access to this software maximizing the cooperation between decision-makers and enhancing the real-time feature so much needed on these systems. Having this system and its information available at all times will potentiate strategic planning since every user could introduce expertise pieces of knowledge whenever and wherever they found useful.

- **Allow different views on TOC**: the TOC provides a tree explorer representation (see Fig. 5.7) following a rigid structure of Level → Branch → Perspective. If the user wants to find a well-known indicator, s/he has to found it under that tree structure representation. Despite the fact that a filter and expand/collapse features had been implemented, it would be useful if the user could perform different views of indicators created. For instance, instead of that rigid structure he could organize the view in Perspectives, letting him/her know every indicator within a very specific Perspective.

- **Case study in a real business environment**: case studies to evaluate Spatial Dashboard effectiveness in a real environment are needed. Having access to large amounts of real data, real decision-makers operating and making decisions with the support of the Spatial Dashboard and some usability tests with real decision-makers will add a great insight into what really concerns genuine business managers.

- **Adding common functionalities under DSS**: some common features like reporting, ease of commenting and ability to share messages and opinions when analysing decisive data and making decisions could be of a great assistance to decision-makers. In fact, most of nowadays DSS support these features as they enhance collaborative work and commitment, levering the process of decision making into another level: where all people gets involved and no information is lost.

- **Using spatial component beyond its contextual role**: on the current Scenario Manager the spatial context is only there to give geographical background feedback to users, since the real spatial dimension is applied for every Business Indicator defined under the Semantic Manager. However, it would be of great value if decision makers could add another spatial dimension layer, i.e., adding a spatial context beyond the single cartographic context. By means of this feature the user will be setting that all business indicators under that specific business scenario are confined to that spatial dimension. If indicators would have a spatial context of their own, the result would be the intersection of both spatial context, thus, spatial validation would be needed here.

- **Implement searching functionalities**: despite the fact that no large real data were used as a case study, some testing has been made in order to test Spatial Dashboard's scalability. With these tests another characteristic came ahead related with Spatial Dashboard usability. When creating large business scenarios more business indicators and metrics are needed, therefore it might happen that the TOC may appear cluttered with data and it might be difficult to search, at the naked eye, for a specific indicator. For this reason, and in order to avoid miscarrying tasks under the Spatial Dashboard it might be useful to implement search functionalities. An ubiquitous search, orthogonal to all SD's contexts would be of a great help, allowing the user to find business indicators, business metrics, business scenarios, maps, spatial layers, amongst other objects within the Spatial Dashboard.

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9. Appendixes

9.1. Spatial Dashboard's developing methodology

Through the last year, four final year IST students were involved on developing the Spatial Dashboard. Since all four students were working on the Spatial Dashboard, developing some new features and improvements, an overall collaborative work and effort was not only useful but necessary. In fact, the interdependency among all modules made the need of collaborative tools and methods in order to achieve an ease and a straightforward development process.

9.1.1. Communication

Several meetings were made throughout the year with all the development team so that issues could be undermined and correct implementation of requirements monitored. Having the features in line with the Spatial Dashboard concept and approach was a very important matter; as a result, communication assumed a very important role accomplishing that. Apart from these meetings a project management tool was adopted to ease this communication and cope with some particular characteristics of project. Basecamp [60] software for project collaboration (from 37signals Corporation) was adopted for some project management tasks. We decided to adopt a collaborative tool because project management is nowadays more concerned with tracking project work processes and efficient and effective sharing of information and knowledge, among project contributors. High-levels of collaboration are essential for distributed project success [61]. In fact, projects usually fail because of lack of clear communication.

We adopted a web project collaboration tool, because we wanted a collaborative tool that would allow us to access it from everywhere anytime. As seen under Fig. 9.1, this tool allows its users to change messages among them, to create to-do lists, managing milestones and deadlines, and leaving messages on the write board. Fig. 9.1 depicts an example of two messages left by two different users concerning assets on the Spatial Dashboard project: one concerned with code quality and other related with the plot viewer and metadata.

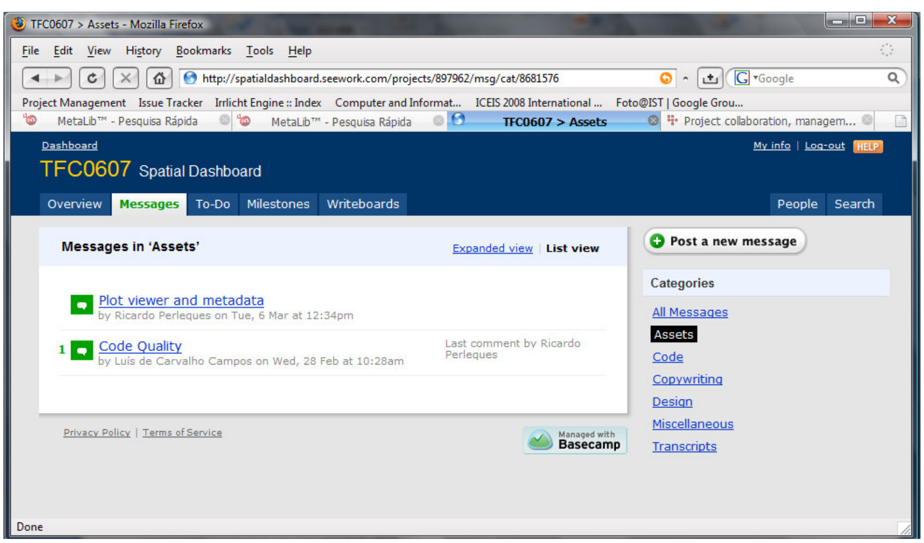

Fig. 9.1 - Basecamp Project Collaboration Software (source: [60])

9.1.2. Issue tracking

This methodology had only been raised up after a month or two the project started. After successive team meetings where many things were suggested and accepted there was a need of not only documenting it but also put some pointed issues on a list, so that not once was lost. We found this need because there were some issues that were successfully postponed, due to their low level priority and, sometimes, they were outpaced by others more recent low level issues. In order to mitigate this problem we decided to create a track issue. Track issue came in order to prioritize the issues needing to be solved and to avoid issue lost. Instead of doing like full-size development teams, an issue database was not created to address this issue [62][63]. Following the same line of thought that guide us to choose Basecamp over other stand-alone solutions; we decided to use Google Docs & Spreadsheets (from Google Corporation) [64] because Basecamp features didn't support a complete and good feature for addressing issue tracking. We created a spreadsheet with several tabs where we could record the issues, assign priorities, timestamp them, dole out to a special developer, consign a difficulty level and fill in a description field.

Fig. 9.2 portrays the issue tracker implementation by means of Google Docs & Spreadsheets web tool from Google Corporation. On this issue tracker implementation several tabs were created regarding different scopes: the *Issue Tracker tab* is the issue tracker itself where main issues or improvements were recorded; the *Pareto Issues tab* stands for small and unimportant issues that were reported more like nice-to-have features than in fact issues (the name comes from the Pareto Principle also known as 80-20 rule or the law of the vital few; the issues placed here were the ones that would demand a 80% effort and would only add 20% value to the overall system); on the *Old Issues tab* are placed all the solved issues, i.e., they are no longer issues; the *Tech Log tab*, the *Knowledge Base tab* and the *Things to Explain tab* are tabs created in order to aid development tasks, i.e., helpful IDE features and functions, classes description and main functions, amongst others.

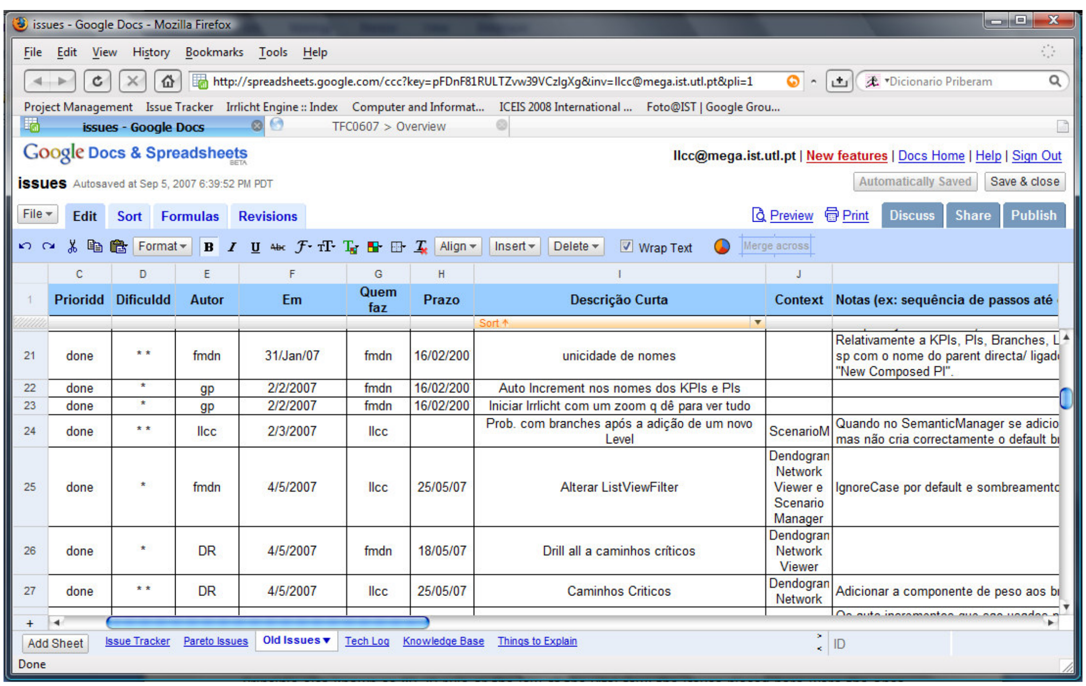

Fig. 9.2 – Issue tracker implementation using the Google Docs & Spreadsheets (source: [64])

9.1.3. Refactoring

Since the development task related with this thesis evolved integration on an already existent system (the Spatial Dashboard) refactoring was something that arisen. Refactoring is an activity of continuous re-designs of a program unit to take advantage of programming techniques, especially object-oriented design and design patterns, to make the programs more reusable, simpler, and more efficient [65]. Refactoring was something experienced on different stages of the development task. Either initially when some minor changes to the Spatial Dashboard were needed or throughout the implementation of new features, refactoring was something we have been put through. In fact, taking advantage of polymorphism, using inheritance, rearranging classes' code, employing design patterns was some of the object-oriented and pattern-oriented programming techniques used to achieve programming units that are more reusable, simple and maintainable.

9.1.4. Continuous integration

Continuous integration is the concept of integrating new code into existing code and then utilizing the testing techniques defined by Extreme Programming [66]. Using this concept, when new code needed to be integrated into old one, a series of tests were performed in order to guarantee that the new functionality as a whole is relentlessly tested and sound. Therefore, the release of the change was only done when it is tested and everyone knew about the new functionality at time of release. In order to make this concept of continuous integration effective several key practices have been adopted [67]:

- **Maintain a single source repository**: as explained on section 9.1.5 below an open source repository was chosen so as to achieve this practice of continuous integration.
- **Automate the build**: a complete solution of projects was adopted to achieve this practice. In fact, that projects and solution management was carried by a specific IDE, the Microsoft Visual Studio 2005 (more details on technologies are given on section 5.2 above).
- **Everyone commits every day**: by doing so, commit conflict errors are avoided. In practice it's often useful if developers commit more frequently than that. The more frequently one commits, the less places one has to look for conflict errors, and the more rapidly one fixes conflicts.
- **Keep the build fast**: the whole point of Continuous Integration is to provide rapid feedback [67]. Therefore, building the project as a whole for testing purposes should be something fast in order not to waste useful periods of time.
- **Make it easy for anyone to get the latest executable**: anyone involved with a software project should be able to get the latest executable and be able to run it: for demonstrations, exploratory testing, or just to see what changed this week [67]. Therefore, a Setup Project was created so that an executable could be created whenever each one found more appropriate.
- **Everyone can see what's happening**: Continuous Integration is all about communication, so you want to ensure that everyone can easily see the state of the system and the changes that have been made to it [67]. The use of comprehensive comments when committing the sources and the communication

of new releases via Basecamp project management tool (see section 7 above) contribute for accomplishing this practice that everyone evolved in the project can see what was happening.

- **Automate deployment**: like written previously on this section, a project for automate deployment was created under the whole solution. The creation of an automatic installation file (.msi) was something we strive to achieve.

9.1.5. Concurrent Version Control System

The Spatial Dashboard project was a collaborative work amongst four final year students. Apart from the communication need and all the extreme programming practices, a concurrent version control system to keep track of all changes on sources was needed. A Subversion system was adopted, the TortoiseSVN from Tigris [68]. Subversion was created on 2000 to replace the classic system of CVS (Concurrent Versions System). Subversion manages files and directories, and the changes made to them, over time. This allows you to recover older versions of your data, or examine the history of how your data changed. In this regard, many people think of a version control system as a sort of "time machine" [69]. With this concurrent version control system all developers had to maintain its code compilable and tested on each commit made.

9.1.6. Design Patterns

As a quality assurance part of the implementation process several design patterns were applied when development of certain features were needed. Design Patterns (DP) [70][71] are presented as a means of encapsulating the experience of programmers in a form that is easily communicated to other programmers in all domains regardless of their expertise within computer science. In fact, their use can bring some advantages because [72]:

- They encapsulate experience.
- They provide a common vocabulary for computer scientists across domain barriers.
- They enhance the documentation of software designs.

Given that, on The Spatial Dashboard the main design pattern used were:

- The **Model-View-Controller** (MVC): this architectural DP presents a solution commonly used under computer science, separate data (model) and user interface (view). Therefore, changes made to user interface will not affect data handling, and data can be reorganized without changing the user interface. Moreover, by decoupling data access and business logic from data presentation and user interaction an intermediate entity is needed: the controller [70]. This DP was used on Tree Editor (see 5.3.3 above) because it was important to separate the tree nodes from its actual data (the performance indicators created a layer above, the Semantic Manager).

- The **Singleton**: this DP is used to restrict instantiation of a class to one object. Is particularly useful when just one object is needed to coordinate actions across a system [70]. This DP was used on the Scenario Manager (see 5.3.9 above) and on TOC (see 5.3.4 above), because we just need one instance of these objects on the Spatial Dashboard.
- The **Abstract Factory**: this DP provides a way to encapsulate a group of individual factories that have a common theme. In normal usage, the client software would create a concrete implementation of the abstract factory and then use the generic interfaces to create the concrete objects that are part of the theme [70]. This DP was used on Weighting methods (see 5.3.8 above), i.e., an abstract class was created (the weighting method abstract class) and all the other concrete methods inherit this class which has all the fields, properties and methods all the concrete methods should have in order to perform a successful distribution of weights.
- The **Observer**: is a design pattern used to observe the state of an object in a program. It is related to the principle of implicit invocation. This pattern is mainly used to implement a distributed event handling system [70]. Since the Spatial Dashboard has many contexts and changes recorded on one context has implications on others, some notifying classes and events were needed in every module of the Spatial Dashboard.

9.1.7. Software Quality

It is well known that software maintainability is one of the most important concerns and cost factors of the software industry. Since this project is to be continued, in the future by others, there is a strong need of good documentation. To achieve a high level of maintainability a well-documented application is needed. Therefore, the Spatial Dashboard was documented accordingly, using the C# standards of code commenting, employing a clear and a simple language and writing the comments in English (easing the access to a wider audience). Easing the maintainability of a software application is a step ahead on gaining software quality.

However, not only from maintainability is software quality made of. In fact, according to ISO 9126 software quality should also be concerned with functionality, reliability, usability, efficiency and portability [73]. The reason why the ISO 9126 was chosen as guidance to evaluate software quality is because the software engineering community has defined and chosen it as a worldwide standard. Because, the ISO model is by no means better than Boehm's Model or Dromey's Model, they just have different approaches. In fact, producing an overall assessment of software quality isn't an easy task [74].

On the Spatial Dashboard, we were more concerned on the following software quality's characteristics:

- **Functionality**: correctness of conveyed data is a crucial part of the Spatial Dashboard. If incorrect data is misinterpreted by users, who are going to take decisions based upon that information, the whole software as a decision support system is counter-productive.
- **Usability**: decision-makers are not, usually, IT experts. Thus, user interface was something we were keen when developing new features to the Spatial Dashboard (see section 4.2.10 above).

- **Portability**: the software as a whole is well-structured in modules enhancing the possibility of changing one of the modules by other, according to developers' heart's content.
- **Maintainability**: as said before, this was some of the concerns since the Spatial Dashboard, as a project, is to be continued by other final year students.

9.2. ICAO – Case Study Guidelines

In order to test this concept, we created a set of indicators, following the airport traffic rules and indicators set by the international organization that regulates the civil aviation sector: International Civil Aviation Organization (ICAO) [59]. This organization develops the principles and techniques of international air navigation and fosters the planning and development of international air transport to ensure safe and orderly growth. It is responsible for standards and recommended practices and also defines the protocols for air accident investigation.

We followed the guidelines for creating indicators based on the following tables:

- Financial Perspective;
- Customer-stakeholders Perspective;
- Internal Processes Perspective;
- Aerodrome Environment-Community Perspective

9.2.1. Financial Perspective

KPI	PI	Business Rule	Obs.:
	$Passenger accommodations (F_PA) - (Month, QRT, Year)	Passenger accommodations = sum (each passenger * accommodation price coeficient)	values specified by the user (for demo propose)
	$aircrafy delays ( )(Month, QRT, Year)	aircrafy delays = sum (delay each aircraft * parking price coeficient)	**parking price coeficient** --> value specified by the user (for demo propose) **delay each aircraft** = value derived from Dimension Flight (DFLIGHT) and fact table AC Movements (FACMOVES)
	loss of market share (F_LMS) (Month, QRT, Year)		value specified by the user (for demo propose)
	loss of revenue (F_LR) - (Month, QRT, Year)		value specified by the user (for demo propose)
$cost of damages_H (F_CD-H) - (Month, QRT, Year)	# cost of incidents (F_CI) - (Month, QRT, Year)	cost of incidents = #incidents * fixed cost	fixed cost --> value specified by the user (for demo propose) #incidents --> Data derived from fact table Airport Incidents & Accidents (FIA)
	# cost of accidents (F_CA) - (Month, QRT, Year))	cost of accidents = #accidents * fixed cost	fixed cost --> value specified by the user (for demo propose) #accidents --> Data derived from fact table Airport Incidents & Accidents (FIA)
	$Fatalities indemnities (F_FI) - (Month, QRT, Year)	Fatalities indemnities = (each fatality * indemnity coeficient)	values specified by the user (for demo propose)
	$cost of Human injuries (F_HI) - (Month, QRT, Year)	Human injuries = (injuries * cost coeficient)	values specified by the user (for demo propose)
$cost of damages_Eq (F_CD-EQ) - (Month, QRT, Year)	$vehicle damages (F_VD) - (Month, QRT, Year)	Cost of the damage = # damage * fixed cost	fixed cost --> value specified by the user (for demo propose) #damage --> Data derived from fact table Airport Incidents & Accidents (FIA)
	$aircraft damages (F_ACD) - (Month, QRT, Year)	Cost of the damage = # damage * fixed cost	
		OBS.: because of simplification the Business Rules where only specified for the PIs, however in the real world each PI or KPI may be constrained by one o more Business Rules.	

Table 9.1 – Financial Perspective Guidelines

9.2.2. Customer-stakeholders Perspective

KPI	PI	Obs.:
	# aircraft movements (C_ACM) - (Day, Month, QRT, Year))	Data derived from fact table AC Movements (FACMOVES)
	# stakeholders companies (C_SC) - (Day, Month, QRT, Year)	Data derived from Dimension Stakeholders (DSTAKEHOLDERS)
	% aircraft departure on time (C_ACDT) (Day, Month, QRT, Year)	Data derived from fact table AC Movements (FACMOVES)
	% decrease in delivery in full and on time (C_DFT) - (Month, QRT, Year)	Data derived from fact table Vehicle Services (FVS)
# Safety Level (C_SL) - (Month, QRT, Year)	# incidents ( ) - (Day, Month, QRT, Year)	Data derived from fact table Airport Incidents & Accidents (FIA)
	# accidents ( ) - (Day, Month, QRT, Year)	
	# infringements ( ) - (Day, Month, QRT, Year)	values specified by the user (for demo propose)
	# incursions ( ) - (Day, Month, QRT, Year)	

Table 9.2 – Customer-stakeholders Perspective Guidelines

9.2.3. Internal Processes Perspective

KPI	PI	Obs.:
# accidents (IP_A) - (Day, Month, QRT, Year)	# accident Apron (IP_AA) - (Day, Month, QRT, Year)	Data derived from fact table Airport Incidents & Accidents (FIA)
	# accident TWY (IP_ATWY) - (Day, Month, QRT, Year)	
	# accident RWY (IP_ARWY) - (Day, Month, QRT, Year)	
	# accident Other (IP_AOTHER) -(Day, Month, QRT, Year)	
# incidents (IP_I) - (Day, Month, QRT, Year)	# incident Apron (IP_IA) - (Day, Month, QRT, Year)	Data derived from fact table Airport Incidents & Accidents (FIA)
	# incident TWY (IP_ITWY) - (Day, Month, QRT, Year)	
	# incident RWY (IP_IRWY) - (Day, Month, QRT, Year)	
	# incident Other (IP_IOTHER) - (Day, Month, QRT, Year)	
# Incursions (IP_INC) - (Day, Month, QRT, Year)	# Apron incursions (IP_INCA) - (Day, Month, QRT, Year)	values specified by the user (for demo propose)
	# TWY incursions (IP_INCTWY) - (Day, Month, QRT, Year)	
	# RWY incursions (IP_INCEWY) - (Day, Month, QRT, Year)	
		See Customer-Stakeholders Sheet
increase vehicle operations airside efficiency (IP_VOE) - (Day, Month, QRT, Year)	# exceeding speed/vehicle Category (IP_VOE) - (Month, QRT, Year)	values specified by the user (for demo propose)
	# vehicle incursions (IP_INCVI) - (Day, Month, QRT, Year)	
Effective relationship with key stakeholders (IP_CRM) - (Day, Month, QRT, Year)	# complains by Stakeholder (IP_SC) - (Month, QRT, Year)	value specified by the user (for demo propose)
	Average Service delay by Flight (IP_SDF) - (Month, QRT, Year)	Data derived from fact table AC Movements (FACMOVES) and Vehicle Services (FVS)
	Average Service completion time (IP_SC~T) - (Month, QRT, Year)	Data derived from fact table Vehicle Services (FVS)
	# claims for damages (IP_CD) - (Month, QRT, Year)	value specified by the user (for demo propose)
	# volume of air traffic: aicraft movements (IP_ACM) - (Month, QRT, Year)	Data derived from fact table AC Movements (FACMOVES)

Table 9.3 – Internal Processes Perspective Guidelines

9.2.4. Aerodrome Environment-Community Perspective

KPI		PI	Business Rules
Condition level of the civil aviation infrastructure and systems (O_LAIS) - (Month, QRT, Year)		# Stand closed (O_SC) - (Month, QRT, Year)	Data derived from Dimension Airport Stand Status (DASS)
		# Road closed (O_RC) - (Month, QRT, Year)	Data derived from Dimension Airport Feature Layers (DAIRPORTLAYERS)
		# incidents ( ) - (Aay, Month, QRT, Year)	Data derived from fact table Airport Incidents & Accidents (FIA)
		# LVO conditions (O_LVO) - (Month, QRT, Year)	value specified by the user (for demo propose)
		# Types of tasks (O_TT) - (Month, QRT, Year)	Data derived from fact table Vehicle Services (FVS)
Alerts & Alarms (O_AA) - (Month, QRT, Year)	Alerts (O_TALERTS) - (Month, QRT, Year)	# Alert Types (O_ALERT) - (Month, QRT, Year)	Data derived from Dimensions Alerts (DALERTS) and Alarms (DALARMS)
		# Alerts of high-risk potential (O_ALERTHRP) - (Year)	
	Alarms (O_TALARMS) - (Month, QRT, Year)	# Alarms Types (O_ALARM) - (Month, QRT, Year)	
		# Alarms of high-risk potential (O_ALARMHRP) - (Month, QRT, Year)	
Supporting infrastructure (O_SI) - (Month, QRT, Year)		# Investigation of accidents and incidents (O_IAI) - (Month, QRT, Year)	value specified by the user (for demo propose)
		# Aerodrome emergency services (O_AES) - (Month, QRT, Year)	value specified by the user (for demo propose)
		# Vehicle Fleet per category (O_VFC) - (Month, QRT, Year)	Data derived from Dimensions Vehicle (DVEHICE)
		# agee Fleet per category (O_AVFC) - (Month, QRT, Year)	

Table 9.4 – Aerodrome Environment-Community Perspective Guidelines