Real Time Business Intelligence for the Adaptive Enterprise

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***Abstract*— In today's competitive environment, analysing data to predict market trends and to improve enterprise performance is an essential business activity. However, it is becoming clear that business success requires such data analysis to be carried out in real-time, and that actions in response to analysis results must also be performed in real-time in order to meet the rapid change in demand from customers and regulators alike. This paper discusses issues and problems of current business intelligence systems, and then outlines our vision of future real-time business intelligence. We present a list of emerging technologies that are being developed within the research program of British Telecommunications plc (BT), which could contribute to the realisation of real-time business intelligence, in addition to some examples of applying these technologies to improve BT's systems and services.**

***Index Terms*—real-time business intelligence, data analysis, data integration, business process management**

I. INTRODUCTION

Analysing data to predict market trends of products and services, and to improve the performance of enterprise business systems, has always been part of running a competitive business. Until recently, these have often been done in the form of monthly and yearly reports by marketing and finance departments. However, this tradition is starting to change. With the increasing competition and rapidly changing customer needs, enterprise decision makers are no longer satisfied with scheduled analytics reports, pre-configured key performance indicators or fixed dashboards. They demand ad hoc queries to be answered quickly, actionable information from analytic applications using real-time business performance data, and they demand these insights be accessible to the right people when and where they need them.

There are two main reasons for these. First, the conditions and environments in which businesses operate are in a constant state of flux. Sales patterns change from place to place and from time to time. Currency valuations shift and alter profit margins. Suppliers change delivery schedules and their prices. Customers become more educated and therefore more demanding.

Second, advances in technology, especially the Internet and modern ICT technologies, make real-time business intelligence seemingly achievable. Indeed, the Internet has made information available at your figure tips. Almost all company data sources could be made accessible over an intranet. Nowadays it is very easy to capture all sorts of data and store them cheaply. However, real-time data, analysis and actions still seem a remote reality.

Business intelligence (BI) tries to address these shortfalls by providing software tools that are customised for end business users, and deliver business insights in real time at the point of a decision. Current BI solutions fall short of what is desired. They require specialists to run a statistical analysis, or a data mining process, and set up reports that can then be accessed by business users — they do not enable actions to be propagated back into business processes. BI products rarely support user selectable data sources and real-time data integration. Almost all current BI products depend on pre-built data warehouses. There are almost no sets of real-time business performance data available because business activity monitoring is still outside the BI domain. Due to these breaks in the BI infrastructure and manual interventions by analysts, end business users do not typically have real-time access to information and cannot change processes in real time based on insights obtained from BI reports.

In this paper, we present our vision of what future real-time business intelligence would provide, discuss the technology challenges, and describe some of our projects towards the implementation of our vision. The rest of the paper is structured as follows. Section II presents an overview of business intelligence and real-time business intelligence. Then we outline our vision of real-time business intelligence in section III. Section IV discusses the technology gaps and challenges, while section V gives some concrete examples. Finally, we predict how RTBI will be used, and we conclude with a summary.

II. OVERVIEW OF BUSINESS INTELLIGENCE

This section gives brief definitions of BI and real-time business intelligence (RTBI) in order to introduce our vision and understand the technology challenges.

A. *What is business intelligence?*

As with many generic concepts, business intelligence is not a well-defined term. Some consider BI as data reporting and visualisation. Others include business performance management. Database vendors highlight data extraction, transformation and integration. Analytics vendors

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emphasise statistical analysis and data mining.

These different views make it very clear that BI has many facets. To capture them, we loosely define that BI is all about how to capture, access, understand, analyse and turn one of the most valuable assets of an enterprise — raw data — into actionable information in order to improve business performance (see Figure 1).

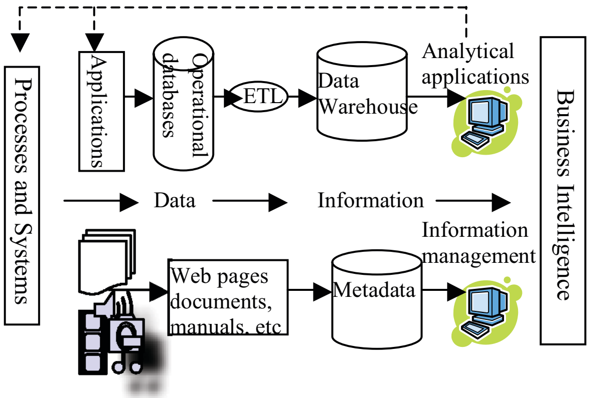

Figure 1: Business intelligence - turning data into information into action.

Typical features of BI software include: reporting and visualization; trend analysis (historical and emerging); customer behaviour analysis; predictive modelling (analyse most likely future scenarios).

BI requires three main categories of technology — data warehouses, analytical tools, and reporting tools.

Data warehouses gather data from disparate sources including databases and unstructured text, and integrate them for further analysis. Analytical tools analyse data and derive insights. Visualisation and reporting tools produce outputs that are designed for the information consumer. These tools generate reports and dashboards with different degrees of detail and sometimes drilldown capabilities.

B. *What is real-time business intelligence*

The meaning of real-time business intelligence mainly depends on understanding what 'real-time' means for a business. Not surprisingly there are no agreed definitions here either.

'Real time' can mean:

- the requirement to obtain zero latency within a process,
- that a process provides information whenever it is required by management or other processes,
- the ability to derive key performance measures that relate to the situation at the current point in time and not just to some historic situation.

Based on these descriptions, RTBI provides the same functionality as the traditional business intelligence, but operates on data that is extracted from operational data sources with zero latency, and provides means to propagate actions back into business processes in real time. Specifically, RTBI could comprise: real-time information delivery; real-time data modeling; real-time data analysis; real-time action based on insights.

III. RTBI VISION

The main idea behind our vision of RTBI is the seamless transition from data into information into action. Current BI systems suffer from two bottle-necks in realizing this vision. The transition from data into information is hindered by the shortage of analysts and experts who are required to configure and run analytical software.

The second bottle-neck is the transition from information into action. Today's BI solutions do not go beyond reporting. If BI software cannot link back into processes automatically and drive process parameters, the transition from information to action can only be manual.

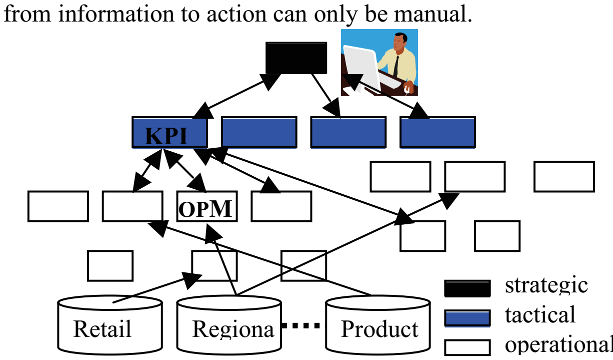

Figure 2: Current business management systems. SO – Strategic Objective; KPI – Key Performance Indicator and OPM – Operational Performance Measure.

Figure 2 illustrates the situation of current business management systems. The information flow between operational, tactical and strategic layers is broken by manual intervention. The challenge is to use intelligent technologies to model the manual intervention present in current systems and automate both the flow of information from operational to tactical to strategic layer, representing data to the information stage of RTBI, and the actions necessary to translate strategic objectives back to operational drivers to effect strategic decisions in real time. Additional challenges exist in areas of on-demand infrastructure configuration, data integration, and on demand data warehousing as shown in Figure 3.

As an example, consider that a company's new strategic objective is to reduce customer dissatisfaction by 10%. That could, for example, translate into the requirement of handling 20% more calls in a contact centre, which means changing the key performance indicator (KPI) 'number of calls answered per day'. On a process level, that could translate into a mix of operational performance measures such as reducing the average call time, increasing the percentage of callers routed to the correct agent, and increasing the number of active contact centre staff which relates to measures like head count and attendance rate.

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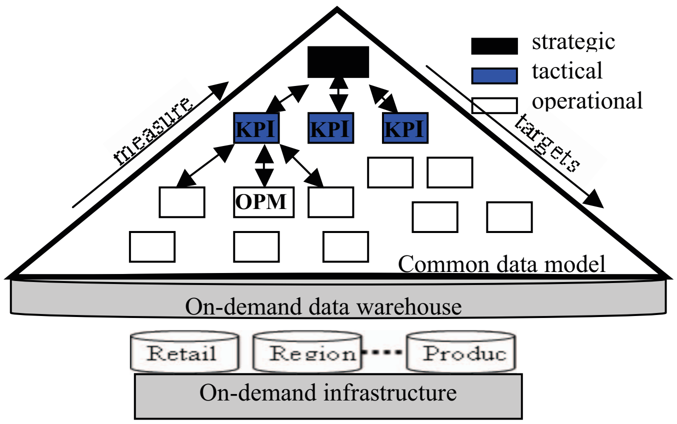

Figure 3: The vision for RTBI.

Current BI tools are mainly passive and their objective is to cater for the information consumer by providing reports or dashboard-like monitoring of various business processes. By moving from BI to RTBI, running a business will become similar to 'flying by wire', and we will see technology similar to that used in IT system management that allows disparate computers and networks to be controlled. Instead of ordinary performance dashboards with drill-down capabilities, we will also see process dashboards that allow the user to drive processes. To expand on the dashboard metaphor, an RTBI system would add a steering wheel, levers and pedals to the control suite, and enable business managers to change parameters of processes in real time. Obviously, it needs to put intelligent checks in place to prevent harmful changes.

IV. TECHNOLOGY CHALLENGES AND GAPS

There are many technical challenges to make our vision work. For the presentation of technology challenges, we have grouped them into three layers. The relationships between them are shown in Figure 4.

A. Analytics layer

Many BI solutions require expert analysts to drive or configure them. The analyst sits between the BI software that operates on the data and the information that is used by management to make decisions. This 'analyst-in-the-middle' approach prevents RTBI because the analyst represents a time lag that must be removed.

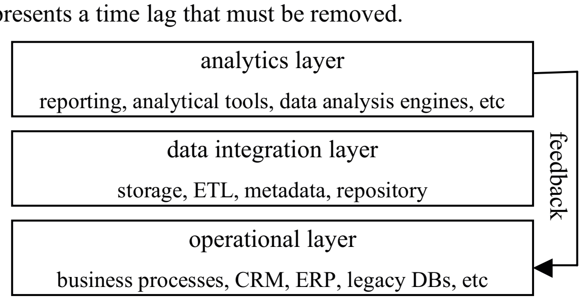

Figure 4: The three layers of the BI stack.

To remove the analytical time lag from the process, RTBI software will require a high degree of automation. It must be able to work based on the specification of the data sources and the requirements of the outcome of an analysis process. The software must be able to select appropriate analysis methods and apply them automatically. The results must then be checked against user requirements. If the requirements are not sufficiently met, the analysis is repeated with different parameters. At the end of the analysis process, the best solution is automatically selected and presented as a high-level report. If the user decides to act on this information, the solution will be wrapped into a software module, for example a decision module that can be immediately deployed into a process, such as the script generation process for a contact centre.

The new role for the analyst will be in the initial setup and configuration of RTBI systems and their constant monitoring and improvement.

B. Data integration layer

In recent reports [1, 2] Gartner finds that most enterprises focus on the elements that are visible to the business users — functionality in query/reporting tools and BI applications, training on these tools, and the impact of BI on critical business processes. Far too little time is spent on 'behind the scenes' or 'hidden' aspects of BI — the critical underpinnings that ensure a robust implementation capable of delivering insight in a reliable, scalable and flexible manner. Gartner considers the data integration layer of critical importance when deploying a BI solution.

The data layer needs to provide quality data to the analytics layer, because business intelligence based on poor quality is harmful. However, the data feed to the analytics layer requires data from different operational systems, and very often fused data from these systems. In order for an RTBI solution to succeed, it is paramount either that there is a continuous real time data feed from operational sources into the data warehouse, or that the RTBI system has access to operational sources via an integration layer.

The widespread use of BI requires a data layer which can plug and play data sources, because enterprises cannot afford to build data warehouses for every BI application. Thus the technologies must be developed to provide the following:

- A common business vocabulary: it provides an integrated view of data and is rich enough to describe any data sources.
- Streamlined development cycle: This is a step-by-step guide to creating machine processable meta-data repositories and a mapping between meta-data and concept-based data access.
- Automated data mismatch reconciliation: This is a way of combining data while removing any mismatches between the different data sets.

There are many technology challenges such as platform, syntax, semantics and data quality metrics. Most available

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technologies and products are doing well in addressing syntax and platform issues. XML seems to have become a de facto syntax standard. The two main platform technologies are J2EE used by Microsoft's rivals and Microsoft's own .NET. In the area of semantics, the W3C Semantic Web initiative proposes to use ontologies to address data semantic problems. Many vendors are now beginning to add Semantic Web technologies to their products.

C. *Operational layer*

For a complete RTBI approach, this layer must provide two functions: business activity monitoring (BAM) and real-time process tuning and change. Some BI vendors have already begun talking about BAM and process refinement based on feedback from operational events, but with limited actual implementation. Current BAM tools provide dashboards and charts that display the process attributes and KPI's, without the ability to make intelligent conclusions about the overall process behaviour. Such high-level conclusions are left to the process manager to discover, usually requiring extensive process knowledge and expertise. Another shortcoming of current BAM provision is in the area of conformance of human actors with the optimum process model. Although some rule-based conformance tools have emerged lately, these are mainly related to regulatory compliance and not with conformance with the optimum execution model.

As far as automated process tuning and re-engineering is concerned, current tools only provide a limited capability that applies in the case of fully automated, service-based processes which do not involve human interaction. An example of this would be selecting the cheapest web service out of the available list. In current practice, real business process change and tuning is carried out through a number of initiatives (e.g. Six Sigma and Total Quality Improvement) that are mainly manual, expensive and time consuming due to the complex subjective nature of process re-design. Furthermore, many of these initiatives fail due to the inability to check whether people are actually conforming to the suggested optimal process.

The challenge for RTBI is to facilitate automated mapping of existing business processes within an organisation, capture the knowledge to automate process tuning, optimisation and re-engineering, and monitor people and systems for process conformance.

V. Towards implementation of RTBI

This section describes some example projects and technologies developed as building blocks for the realisation of our RTBI vision.

A. *Advanced analytics*

1) *Automatic data analysis*

SPIDA [3] is a platform that uses soft computing methods like fuzzy logic and neuro-fuzzy systems [4] for automating intelligent data analysis. The core of SPIDA is a client/server-based tool-box for data analysis that focuses on modern machine-learning techniques, including data preprocessing and visualisation. SPIDA enables non-experts to run an advanced data analysis without the need to understand, select and configure analysis algorithms. In a simple question/answer dialogue, SPIDA gathers high-level information about the problem and user preferences about the solution and data. It then automatically selects and configures analysis models, preprocesses data, executes analysis processes and displays results.

After an analysis model has been created from data, SPIDA re-evaluates its suitability. If necessary, internal model-learning parameters will be changed by SPIDA to improve the suitability of each model. New instances of each model will be learned from data in an iterative process.

Models that have been created in SPIDA can be wrapped into self-contained software modules. These modules can be integrated into other software applications.

SPIDA can be used as the core analytical engine for future RTBI systems. It provides a high degree of automation which is essential for RTBI. SPIDA's capability to be driven by intuitive high-level targets will enable it to interface to the strategic objectives of the enterprise.

2) *Decision optimisation and what-if analysis*

RTBI systems must provide facilities for conducting a what-if analysis at any time. If managers decide to change strategic objectives based on the latest analysis results, they must know in advance how these changes will possibly affect the enterprise.

We have implemented a software platform that can be used as a decision optimisation and what-if analysis module in an RTBI system. DecTOP is a decision table evaluation and optimisation tool. It can monitor the performance of a decision model not only on an overall level, but also on the level of individual decisions. DecTOP enables the user to identify individual decisions of poor performance, and to optimise them manually or automatically. The user can study any number of variants of the decision model in parallel and compare their performance. By changing individual decisions, the user can conduct a what-if analysis. The automatic optimisation of the decision model can be based on different measures concurrently, for example, accuracy or cost. Previously, we have applied DecTOP to analyse BT's fault clearing process [5].

3) *Changing processes*

Changing live business processes based on BI results is one of the most demanding RTBI challenges because it requires process automation and possibly reengineering of legacy processes. We have recently deployed a platform in the area of mobile workforce management that can optimise certain process parameters based on analysis results.

The intelligent travel time estimation and management system (ITEMS) is a platform for automatically updating parts of the scheduling process for the mobile workforce of an enterprise. Successful scheduling requires suitable estimates of inter-job times that are mainly determined by travel time. However, it is not sufficient to simply use routing software, because it cannot estimate the time that is required to find a parking space, to gain access to the site, etc. It is also impossible for technicians to log detailed information about the routes they have taken — they only log their actual travel (inter-job) time. Thus, it is not possible to compare travel data with recommendations from routing software.

Travel times that are estimated from historic travel data are more reliable, because they reflect the actual travel behaviour of the workforce, even if only point-to point information is available. However, point-to-point information is also the only kind of data a scheduler can suitably process, because it would be intractable for a scheduler to analyse different routes while computing a job schedule. Recorded inter-job times automatically reflect features of the areas between which the journey took place. Areas where it is difficult to find a parking space, for example, will automatically result in higher values for the estimated travel time. Because workforce travel displays distinct local patterns, only a fraction of all possible combinations of areas has to be considered by a model for travel estimation. If for some areas there is no travel data available, default estimates are used. For areas where travel occurs regularly, estimates will improve over time. Improved estimates for travel will improve job scheduling, which will finally result in a reduction of unnecessary travel and can thus create huge savings.

ITEMS has a learning component that constantly builds new models for travel-time prediction. It compares the new model with the performance of the model currently used by the scheduler and updates the scheduler if the new model performs significantly better. ITEMS can operate in real time, if the travel data of the mobile workforce is recorded in real time. A customised version of ITEMS has been deployed within BT [6].

The intelligent business process management IBPM platform is being developed to support BAM and automated business process change. As seen in Figure 5, information extracted by the data analysis component will be used to achieve the business goals or, in terms of execution, to optimise the KPI's. Any change in the policies in the enterprise will be reflected in the KPI and consequently will be considered by the optimisation system automatically.

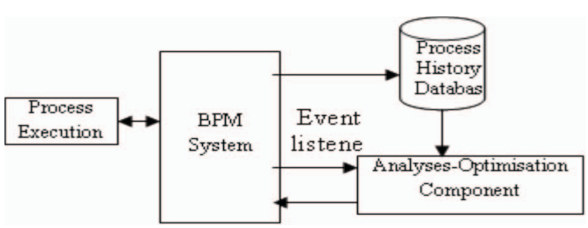

Figure 5: The IBPM platform.

There are three main means to tune a process using IBPM as the base framework:

- Task assignment: the most obvious way to improve the efficiency of a process is to provide a better means to assign resources. Old priority-based scheduling algorithms can be replaced with more intelligent methods.
- Task routing: IBPM processes can define routing nodes where the system can decide which path the instance will take depending on the goals of the systems.
- Process modification: with IBPM the process definition can change at run-time providing great flexibility to the user. Although redesigning the process to improve the performance automatically is theoretically possible, it constitutes a challenge that we are currently far from achieving efficiently.

B. Semantics-based information fusion

The DOME project has developed ontology-based techniques to support the building of a real-time data fusion platform. The system retrieves information from multiple data resources, fuses them and resolves mismatches according to the user's queries or application requirements. This section gives a brief overview of the DOME system. Details of DOME can be found in Cui et al [7, 8].

The DOME prototype consists of a number of key components — an ontology server managing the contents of the entire enterprise data sources, a mapping server which manages the relationships between ontologies and data sources, and a query engine for decomposing queries and fusing sub-query results.

The DOME information model is based on ontology. DOME ontology includes terms used to denote real or abstract entities, and their relationships such as inheritance, formal structures of entities (e.g. attributes), and any constraints. We use the following ontologies to model data sources and applications — a shared ontology, source ontologies and user and application ontologies. The inter-relationships between the various ontologies are shown in Figure 6.

A shared ontology is a common, agreed vocabulary. We treat this ontology as a superset of vocabulary which is rich enough to describe any enterprise data sources.

Source ontologies define the data semantics of their associated data sources. The terms in source ontologies are often taken from a shared ontology, but their definitions could be further constrained. For example, certain attributes may be sub-typed or have fixed values. New terms may be defined, over and above those in the shared ontology.

Shared, source, user and application ontologies are the critical components for DOME to perform context-based mismatch reconciliation at runtime. As an example, products could be priced in different currencies. DOME could automatically convert all product prices into pounds sterling for UK users, and US dollars for US users.

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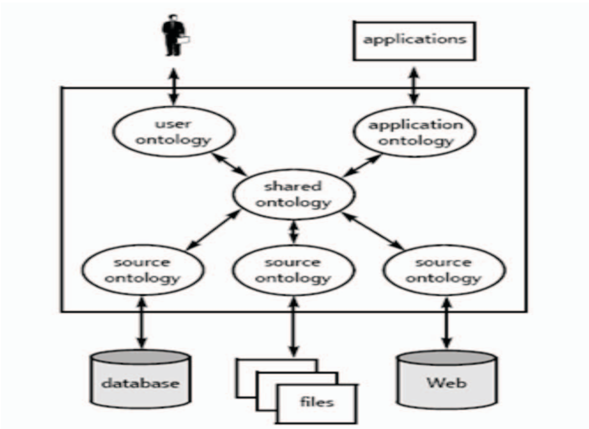

Figure 6: Model of data sources, users and applications, and their relationships.

We have applied the DOME system to database marketing which uses internal and external data sources, and to e-catalogue management for e-markets to fuse different catalogues.

C. Interfaces and customization

To make RTBI a reality, BI tools need to be in the hands of business users at all levels. This requires simple, intuitive and non-technical interfaces. Current BI tools are either still aimed at the analyst/expert, or have gone down the route of specific applications. In the first case the tools are too complex, and in the second case the tools are too specific, to deliver all the required intelligence.

BI interfaces should ideally be delivered via Web based interfaces, or plug into standard office tools. While these interfaces are also suitable for SMEs that use hosted services, interfaces that plug into office software could provide a competitive advantage for the SME market (compare Microsoft's 'BI for the Masses' programme [9]).

To make BI tools more accessible and useful to business users, automatic adaptive user profiling can help to automatically tailor the software to the user's needs. We should also not forget mobile users. BI can help mobile sales forces or work forces out in the field.

Systems like SPIDA, DecTOP, IBPM and ITEMS are examples of systems that try to make intelligent solutions accessible to non-expert users, each by hiding different aspects of an analytical process and by providing intuitive Web-based interfaces for different types of user (see section IV.A).

VI. FUTURE DEVELOPMENT OF RTBI

A. Embedded BI

BI will be increasingly embedded in pre-packaged applications and services. Figure 7 illustrates how RTBI should be embedded into a process to use process data and external drivers to analyse and update an internal decision model that drives the process. Based on the complexity of the process, the RTBI module can either run automatically or wait for feedback from higher instances that interpret the generated report before they approve any changes to the process. The report of the RTBI module can also provide alarms and predictions. Based on business rules, this information can be escalated in real time to the right instances and trigger action immediately.

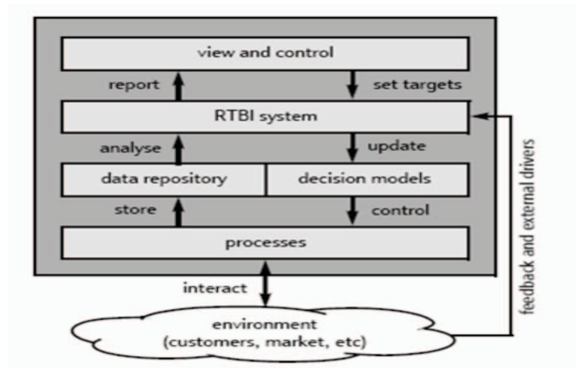

Figure 7: Embedded RTBI.

Figure 8 shows how the embedding of RTBI modules can be recursively repeated within an enterprise. RTBI modules within low-level processes directly access process data. They turn this data into in measures, and report it to higher ranking processes. They can also directly turn measures into action by deriving process internal targets and update the process (see Figure 7). Actions in the form of targets are propagated from higher order processes down the hierarchy. This recursive implementation of RTBI provides the potential for local optimization and global optimisation. Processes on any level have the possibility to tune their performance themselves according to local BI results and prescribed targets. At the same time, the board has access to all key performance measures of the business, can change global targets, analyse the possible impact and cost in what-if scenarios, and finally propagate new targets back into the business, which are then translated into process-specific targets during the propagation down the process hierarchy.

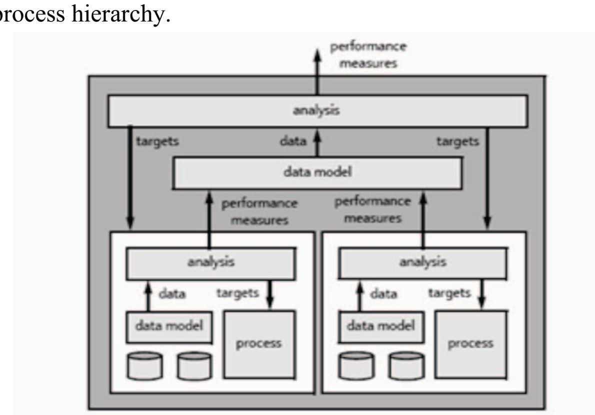

Figure 8: A recursively embeddable RTBI structure.

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B. BI tools development

In order to realise that vision of fully joined up systems, three core prerequisites must be fulfilled (Figure 8).

- Adaptive processes: process parameters must be adaptable, based on insights provided by BI tools.
- Infrastructure — enterprise-wide data model. All relevant data must be represented and made available for analysis. New data is entered into the enterprise wide repository as soon as it is generated (middle layer).
- Modelling — flexible automatic analytics. Several layers of BI solutions with increasing degrees of automation are provided to support different analytic scenarios (top layer).

This structure allows data to flow from processes via an enterprise-wide infrastructure to analysis tools that turn data into information, and into action by propagating targets back to the process layer. Access to the data model and the analysis tools will be distributed throughout the enterprise.

The top layer of the RTBI model contains BI (modelling and analytics) software that access the middle layer to analyse data and provides new parameters for the bottom layer in order to optimize processes.

In our RTBI vision, future BI software will encompass all three categories (see Figure 9), and on top of that requires different degrees of automation for different user groups and different purposes. Future RTBI will run fully automatic discovery processes that sift through data on a continuous basis in order to find anomalies or interesting patterns. Results are flagged up in automatically generated reports that contain recommendations for changes on a process level.

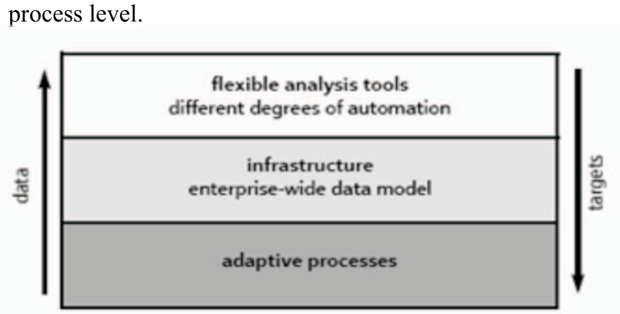

Figure 9: Major building blocks for RTBI.

BI software, that provides this level of automation and user support, can be set up to run in an unsupervised discovery mode as well. It will be able to automatically pick up any significant change in performance indicators, and try to find models that explain this change.

As managers become familiar with BI they will demand access to high-quality data for analysis results. They will want to select data sources and use them according to their requirements.

C. Processes and ICT infrastructure

The ICT (Information and Computing Technologies) infrastructure of the enterprise is a key factor in process performance, and therefore in the overall performance. Businesses try to minimise spend on ICT, and design their infrastructure such that their processes can just operate without problems. However, the question is how ICT infrastructure must change in order to accommodate changes in processes.

When RTBI propagates targets from the strategic level via the tactical level into the operation level, it is eventually the processes that must adapt to achieve new targets. This means that new operational performance indicators are set which result in new KPIs which realise the new strategic objective. For that to work, the dependence of operational performance measures (OPMs) on process parameters must be known. ICT infrastructure can be viewed as contributing parameters to OPMs.

All these measures can have an impact on the ICT infrastructure. Consider the example in Section III. Shortening the call time could mean that the CRM system must provide the customer details faster, i.e. the response time of the data warehouse must shrink. Improving call routing could mean the installation of a new generation of routing software, and increasing the number of staff means buying more terminals and increasing network capacity.

This example illustrates that ICT must become a tuneable parameter of a process, but in an RTBI scenario this must go much further. The level of knowledge, which ICT resources are required to achieve in some OPMs, must be provided and configured. If ICT infrastructure is viewed as a configurable resource, and the dependency between ICT configurations and OPM is known, then a business can automatically and dynamically allocate ICT resources to processes.

D. RTBI for ICT

Gartner has found further that companies are underestimating the hosting opportunity [10, 11]. In the BI/DW (data warehousing) space, hosting services are among the least available offerings from CSI companies. End users that are re-engineering or establishing processes (for example, interactive marketing) are candidates for BI/DW hosting. By creating RTBI products on top of hosting solutions, service providers not only have a powerful product offering, but at the same time are in the unique position to be able to fully analyse, understand and control their own ICT products in that space. The same functionality that is offered as an add-on product to the customers can also be used to monitor the performance of the service provider's own business.

E. Data feed to analytical tools

Data warehousing technologies will continue to be the main technologies for feeding data to analytics tools. However, the batch-based ETL (Extract, Transform and Load) will become a bottle-neck. Real-time ETL will appear that are able to fetch data from operational data sources in real time. These real-time ETL modules will still be built beforehand using pre-packaged ETL tools available on the market. New vendors might still appear, but existing big vendors will dominate this market.

A significant change in this space will be the development of specific data connectors. At the moment, these connectors are not very flexible, and cannot be used by ordinary business users. Although these connectors will not be exposed to end users, they need to provide end users with declarative descriptions of the data sources to which they are connected, so that users will be able to select data sources based on criteria like quality, context and content.

Meta-data and semantic content repositories will appear. These will provide those capabilities that are similar to 'data shopping malls'. They will contain sets of data arranged by use for each business unit that will allow the business-unit managers to analyse data specific to their area of interest. Data shopping malls will be more accurate, more responsive and less susceptible to the statistical anomalies of large data sets in the data warehouse.

Standards and tools will be available for data source owners to publish their semantic contents. This is in stark contrast to the current ETL and data warehouse practice where data sources have to reconcile their mismatches with the DW schemata. When new data warehouses are built, the whole process repeats again. With the published semantic contents of data sources, tools will become available which will reason over the semantics and contexts, and then ETL data from them will be put into data warehouses. All this will happen in real time as end users choose the data sources to use by their chosen analytical tools.

F. *Infrastructure development*

The future RTBI infrastructure will include the following elements:

- static data warehouses and dynamically user configurable data shopping malls where users can select the data sources they require,
- taxonomies and ontologies for describing contents and providing semantic content and context information,
- advanced ETL tools for gathering and feeding data to analytical tools — this new generation of ETL tools will be able to ETL data from unstructured data such as customer feedback and e-mails in addition to databases,
- feedback mechanisms to operational systems.

The infrastructure must be able to change business processes in response to new actions based on business intelligence. This will be realised by controlled feedback mechanisms that allow users to access and modify process parameters in operational systems. Obviously, this feedback mechanism has to be protected by proper checks and bounds (see also section III).

VII. CONCLUSION

Real-time business intelligence will be available to everyone in the enterprise, and will be embedded in many business systems. Although many technologies are available to implement this vision, many challenges remain to make this vision a reality. We have outlined key challenges like automated analytics, semantics based information fusion and process automation, and presented some examples which support the feasibility of our vision. We believe that technologies like intelligent data analysis, soft computing and ontologies will play a major role in the development of RTBI.

There are already signs that BI solutions are beginning to close the loop and start to develop into RTBI solutions. Currently, we can observe analytical tool vendors moving into the business application space and at the same time we see application specialists expanding into the analytical space. Clearly, vendors have understood that they need to support both analytics and applications. That the BI market has significant growth potential is highlighted by Microsoft's recent move into this area. Microsoft has proclaimed the age of 'business intelligence for the masses' and has a clear strategy of driving business intelligence from their SQL server solutions into their Office suite. We also see ICT performance management vendors, such as Syndera, starting to brand their products as BI solutions.

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