Defining Business Activity Monitoring
Understanding a Real-Time Event-Driven Infrastructure

Delft, October, 2005

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Acknowledgements

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Gabriel Marcuzzo do Canto Cavalheiro
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Summary

Business Activity Monitoring (BAM) is an acronym coined by Gartner, Inc. to describe systems that serve to provide real-time access to critical business performance indicators to improve speed and effectiveness of business operations. Ideally, BAM systems should contribute to help enterprises improving their operational performance by helping them sensing, understanding, and responding to events that have a significant impact on their business processes. However, despite the fact that most enterprises nowadays have a pressing need to improve their operational performance, as they find themselves in highly competitive and dynamic business environments, BAM systems have been poorly penetrated.

In fact, at present, the market for BAM systems is not mature yet, as the relationship between problem and solution is unclear. On the one hand, enterprises do not know exactly what to do with real-time operational insights. On the other hand, there are large technical variations across BAM systems, because many software vendors introduced BAM systems by adding new functions to existing products. Additionally, since there are no formal standards specifying what specific features BAM systems must include or theoretical models supporting comparative analyses between BAM systems, the task of selecting a suitable BAM system is certainly a challenging one.

The objective of this research project is to provide a contribution to improve understanding of the relationship between real-time decision support needs of enterprises and BAM system design solutions provided by BAM vendors. To accomplish this objective, we have designed a BAM definitional model based on insights obtained though the synthesis of both existing research literature as well as expert inputs on BAM gathered during a research internship at the Center for Process Innovation (CEPRIN) of the J. Mack Robinson College of Business, Georgia State University, Atlanta, U.S.A. To gain confidence in the BAM definitional model, we validated the model by exposing it to an expert panel and by applying the model as the primary analytic tool in an exploratory case study that covers a BAM implementation project in the airline industry.

The research presents evidence that the relationship between real-time decision support needs of enterprises and BAM system design solutions is determined by the need to ensure that the BAM system supplies BAM alerts that empower the BAM recipients, who are often operational managers directly responsible for the execution of business processes, to respond effectively to the event indicated by the BAM alert. In this respect, we could observe that to empower BAM recipients responding effectively to events, BAM systems depend on two fundamental operational issues. First, it is necessary to ensure short response times to enable the BAM recipient initiating response within the short time windows of opportunities associated with events. Yet, it is valuable to emphasize here that different events require different response times. Second, BAM recipients need to be able to understand the nature of the problem associated with the event so as to be able to initiate a proper response to address the problem. Here, the research reveals that to provide sufficient understanding of the nature of the problem, BAM systems, beyond sensing real-time events and generating low latency event-notification through BAM alerts, might also need to develop context for the BAM alerts to provide BAM recipients with sufficient understanding of the nature of the problem associated with the event and the appropriate response. Another fundamental considerations on BAM concerns the way the way the results of the analysis of events are presented. The fact that in BAM, the real-time operational insights resulting from the analysis of events is “pushed” to BAM recipients makes the need to add the proper contextual information to BAM alerts a critical requirement that requires a deep understanding of the real-time decision support needs of the BAM recipient.
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1 Introduction

Over the past decade, global enterprises have experienced a tremendous growth in the volume of data to be processed by their widely distributed message-based information systems (Luckham: 2002, 18). This growth stems mainly from the large-scale introduction of Websites, e-commerce and Portals, which contributed directly to raise the number of transactions carried out over the Internet (Perks & Beveridge: 2003, 27). As a consequence of this growth in data volumes, the task of analyzing data and understanding the performance of enterprises has become increasingly challenging and time-consuming task, especially considering that data is often distributed across multiple and heterogeneous systems. Yet, as most enterprises nowadays are generally exposed to hyper competitive marketplaces and business conditions that are characterized by volatile and unpredictable demand (Lin et al: 2005, 3), they must maximize the performance of their business processes by minimizing operational costs and maximizing revenues. In this context, events occurring in the information systems of enterprises have become extremely important because they represent threats and opportunities that have a significant impact on performance of enterprises business processes. Examples of events include the placement of an order, a change in the price of raw material, or the acknowledgement that an airplane will arrive 30 minutes later than expected (TIBCO: 2005, 4). Delgado et al defines an event as “an instantaneous state change, i.e., a change of state in a condition from one value to another” (Delgado et al: 2004, 867). On the face of this pressing need to maximize performance, enterprises need to be able to detect and respond upon events, irrespective of the problems with data volumes and distribution of data.

The combination of a high level of awareness about this urgent need and the recognition of the difficulties of enterprises in responding effectively to events provides an indication that new functionality is consistently required. This perception of the enterprise need to improve real-time event monitoring capabilities has motivated discussion on possible solutions. Aware of the position of enterprises, software vendors started developing a new set of functions to help enterprises improving their capabilities of sensing and analyzing events in real-time, but did not know what to call it (see Appendix 5: Assessment Interview: David McCoy). By observing this, the Gartner, Inc. coined the BAM acronym in anticipation of an emerging market for systems that deliver such real-time analytic capabilities based on events. To describe this new set of functions, Gartner, Inc has provided an official definition for BAM as “an acronym to define how we can provide real-time access to critical business performance indicators to improve the speed and the effectiveness of business operations” (McCoy: 2002, 1).

The historical precedence for real-time monitoring of large-scale complex systems include financial trading (i.e., real-time analysis and program trading), military and business “war rooms”, and an airport control tower systems (McCoy et al: 2001, 2). Yet, in contrast to the older real-time monitoring systems, BAM benefits from the use of middleware technologies to generate operational insights when there is a need to respond to the occurrence of business events. In practice, the real-time access to business performance indicators is achieved by extracting and aggregating real-time events from multiple source systems, or internal and external sources (McCoy: 2002, 1). Consequently, BAM is expected to be a natural extension of the investments that enterprises are making in application integration (McCoy: 2002, 1). Specifically, it represents a convergence of operational business intelligence (BI) and real-time application integration (Govekar et al: 2002, 1).

The market prospects for BAM systems have motivated several software vendors operating in different segments such as enterprise application integration, business intelligence (BI) and IT operations to launch a BAM system. These software vendors include both the group of software vendors observed by Gartner, Inc. to introduce BAM, but also other software vendors that launched BAM systems later looking at revenue opportunities in this promising market. However, at this point, it is worthwhile to mention that most current BAM systems are early products that have been assembled from the features of existing software products and, as the market grows
and matures, more comprehensive and specialized BAM offerings are likely to appear (DeFee & Harmon: 2004, 10). For this reason, in the current situation, there are evidences of the existence of significant variations across BAM systems, as different BAM systems are made up out of different technological building blocks.

1.1 Delineation of the Problem

Despite the need of enterprises to respond to events, the BAM systems introduced to the market have been poorly penetrated. At present, less than 5 % of enterprises have adopted a BAM system, which corresponds to under 200 million dollars of revenues. The main cause for this slow adoption is the fact that the market for BAM systems is not mature yet (see Appendix 5: Assessment Interview: David McCoy). On the one hand, enterprises do not know exactly what are their real-time decision support needs. At this point, they are certainly aware that they need to speed up reaction to events, but they do not exactly what are the critical real-time operational insights they need to help them improving response to events and, as a consequence, enterprise performance (see Appendix 1: Quantive Survey 1). On the other hand, there are large technical variations across BAM systems partly because software vendors introduced BAM systems by adding new functions to existing products. Chandy & McGoveran (2004) recognize this problem by noting that the variety of features offered makes it difficult to identify the proper use for BAM systems (Chandy & McGoveran; 2004, 19). Essentially, these are indications that, in BAM, the relationship between problem and solution is unclear and needs refinement.

Although Gartner’s original definition of BAM that is presented in the introduction is a generally accepted definition for the functionality that should be provided by BAM systems, there is a gap in the literature about BAM with regard to the differences in real-time decision support needs and the differences across BAM systems. Accordingly, the core of the problem that must be addressed by this research project is the absence of a theoretical foundation that it is required to permit understanding of the relationship between real-time decision support needs and the most adequate variant of BAM system for the specific real-time decision support need.

1.2 Research Objective and Research Questions

By analysing the context of this research project, the following research objective can be stated.

The objective of this research project is to contribute towards the improvement of the existing theoretical foundation on business activity monitoring (BAM) solutions by providing an understanding of the relationship between real-time decision support needs and BAM system design solutions.

Given the combination of the research question and the insights gained from the preceding analysis, a number of sub questions could be derived. Sub questions to be answered by this research include:

1 Which variants of BAM systems can be distinguished?

2 What are the characteristics of problems that can be addressed by the identified variants of BAM systems?

3 How do the different expectations of stakeholders impact the development of effective BAM systems?
To what extent does the environment to which enterprises are exposed affect the adoption of BAM systems?

1.3 Methods and Techniques

Given the need to make a theoretical contribution to scientific literature on BAM, this project can certainly be characterized as a theory-oriented project. The primary contribution of this project will fill the indicated gap in the literature on BAM by constructing and validating an original research construct in the form of a BAM definitional model. This model is intended to provide understanding of the relationship between the real-time decision support needs of enterprises and BAM system design, as required by the objective of this research project.

To construct the BAM definitional model, this research project relies on the synthesis and integration of both existing studies as well as expert inputs to develop a definitional model for BAM. Accordingly, the research material includes scientific literature as well as assessment interviews and surveys with experts in BAM and related areas. Initially, we evaluated prior research to identify different streams of contributions to our understanding of BAM. Since there are few scientific publications specialized on BAM, we examined literature addressing issues closely related to BAM such as Business Intelligence. Additionally, in order to select relevant literature, we concentrated on referred journals that were most likely to publish high-quality research such as the Business Integration Journal, IEEE Transactions on Software Engineering and Web Services Journal. Besides, we prioritised literature from current experts in specialized subject areas. Hence, we will support the discussions with the used of several references to the following authors in their specific area throughout this report:

- BAM: David McCoy and Bill Gassman
- Data Warehouse: Bill Inmon, Claudia Imhoff and Ralph Kimball
- Complex Event Processing: David Luckham

To gather information from experts, we opted to conduct structured assessment interviews, whenever possible, or to use private email correspondence. To validate the BAM definitional model, we have opted to subject different versions of the model to revision by an expert panel and, after various expert validation rounds, to apply the BAM definitional model to an exploratory case study. The expert validation is important, because it is a practical process that adds credibility to the model design as it involves exposing the model to an expert panel consisting of current experts in fields of study closely related to BAM, such as agility systems, business intelligence, process innovation and runtime software monitoring systems. The expert validation is crucial because it can ensure the relevance and consistency of the BAM definitional model. In the validation through an exploratory case study, the BAM definitional model is used to support the analysis of a BAM implementation project in the airline industry. The case study is fundamental to provide insights on the applicability of the BAM definitional model.

1.4 Research Relevance

As BAM systems can potentially extend the capabilities of current business IT technologies by providing real-time operational insights, most enterprises are likely to have some sort of real-time decision support need that is not currently addressed by their current IT infrastructure. Given the fact that enterprises need to be able to sense, understand and respond rapidly to changes with potential impact on enterprise performance, the need to improve real-time monitoring capabilities is high on the agenda of most enterprises.
The potential that the market for BAM systems holds has been acknowledged by various software vendors. This is emphasized by the fact that various large and small software vendors have already introduced their BAM solutions into the market. Examples large software vendors that offer a BAM system include:

- Microsoft
- Oracle
- SAP
- IBM
- TIBCO

Likewise, examples of small software vendors offering BAM systems include:

- Quantive
- Modusnovo
- Obvient

Basically, there are several studies that indicate that BAM systems have a huge market potential in terms of expected volumes of investment in the adoption of BAM systems by enterprises. Yet, until now, this technology has been poorly penetrated as less than 5% of enterprises have adopted some type of BAM system, which represents less than 200 million dollars of revenues. These characteristics indicate that BAM is still early on the market maturity curve (see appendix 5: Assessment Interview- David McCoy). Accordingly, there are still many uncertainties regarding the market for the technology that need to be clarified. The choice of enterprises regarding the adoption of a BAM system will depend on the balance between benefits and costs associated with the BAM system.

1.5 Structure of the Report

The structure of this report is as follows. To clarify the current need for real-time business monitoring systems, we confront the real-time decision support needs of enterprises with the limitations of mature IT technologies in fulfilling these needs. This is done by mapping real-time decision support needs to improve our understanding of the precise real-time operational insights required by enterprises in chapter 2 and, subsequently, by examining the enterprise technological environment that existed prior to BAM in chapter 3. After exploring the need for BAM, we focus on BAM in chapter 4. This chapter gives an outlook of the main aspects of BAM. Next, in chapter 5, we introduce our BAM definitional model. This chapter motivates the design of the BAM definitional model and illustrates the way the model was validated by a panel of experts. After introducing the BAM definitional model, we use test the applicability of the model. In chapter 6, we use the BAM definitional model to identify classes of BAM systems. Here, we explain the method used for defining the BAM classes and describe the characteristics of the proposed BAM classes. Subsequently, in chapter 7, the model is employed as the primary analytic tool to cover the implementation project involving a BAM system developed by a BAM vendor called Quantive. This chapter demonstrates the practical applicability of the BAM definitional model by covering a BAM implementation project in the airline industry. Finally, in chapter 8, we put forward our conclusions by answering the research questions, presenting research findings, proposing directions for further research, and reflecting on the outcome of this research project.
Figure 1-1: Research Structure
2 Mapping Enterprise Real-Time Decision Support Needs

Prior to examining the technical aspects of BAM, it is important to understand why enterprises need BAM. To this end, we will map the real-time decision support needs of enterprises to understand the characteristics of the problems that need to be addressed by BAM systems. This chapter assessments a set of key drivers that are currently influencing real-time decision support needs. These key drivers were selected based on though insights obtained through literature research and expert consultation. The purpose of this chapter is to provide a better understanding of the different types of real-time decision support needs and the actors that have them.

The organization of this chapter: section 2.1 examines the influence of the operational concept of agility on the decision support needs of enterprises, section 2.2 highlights the most important legislations with impact upon enterprise monitoring systems, section 2.3 map decision support needs within enterprises, section 2.4 examines the impact of the characteristics of the modern enterprise to improve understanding of emerging decision support needs, and section 2.5 provides conclusions on the real-time decision support needs of enterprises.

2.1 Pressure Towards Agility

In mapping the real-time decision support needs of enterprises, it is necessary to understand the operational objectives of enterprises that need to deal with the highly competitive and dynamic business conditions that we referred to in the introduction. In this context, it is possible to observe that the concept of agility provides indications of the operational objectives of enterprises operating under such conditions. Essentially, agile systems address new ways of enabling enterprises to react immediately and effectively adapt to changes occurring in their environment. By conducting a survey with BAM developers, we could find evidences that enterprises need to become less plan-oriented and more agile (see appendix 1: Quantive Survey 1). In fact, the focus of agile systems is in providing visibility of real-time operational status (Dove: 2004, 3). This requires sense-and-respond capabilities. The sense capability involves gathering and interpreting sufficient information that allows the detection of state changes that require response, while the capability of responding to unanticipated change is normally referred to as response ability and this is one of the major benefits provided by agile systems (Artea & Giachetti: 2004, 495). Rick Dove stresses that obtaining response ability is crucial because it allows enterprises to change business processes and to customize operational responses in real-time (Dove: 2004, 1). In this way, agility requires that the capability of “pushing” the results of on those responsible for operational response, to enable them initiating response in real-time to significant events. As a consequence, agility is a key condition to enable enterprises making their processes more agile to deal with competitive and dynamic business conditions.

2.2 Prominent Regulations and Legislations

Beyond the need to become agile, enterprises also need to adjust their business operations in order to comply with regulations and legislations. Previous research has demonstrated that the need for compliance with a set of new regulations and regulations is having a profound impact on real-time decision support needs of enterprises (O’Conor, 2005; Sproule, 2002; Imhoff, 2005). In this respect, the most notable piece of legislation is by far the Sarbanes-Oxley. However, there are other important legislations that are worth considering, which include the Patriot Act and

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1 Rick Dove indicated through email communication that agility is a fundamental capability that delivers competitive advantage for enterprises operation in the current market place.
BASEL II. We describe these three legislations and their impact on the real-time decision support needs of enterprises in the following:

### 2.2.1 Sarbanes-Oxley Act

The introduction of the Sarbanes-Oxley Act represents a radical regulatory change to improve accuracy and reliability of corporate disclosure (Burrowes: 2004, 798). The original aim of the Act was to provide a strong response to the crisis of confidence caused by accounting scandals at Enron, WorldCom and other companies (The Economist: 2005, 73). These accounting scandals resulted from false financial reporting practices to deceive shareholders over the financial performance of enterprises. The Act was formulated though a cooperation between the U.S. Security and Exchange Commission (SEC) and the U.S. Financial Standards Board. Fundamentally, the Sarbanes-Oxley Act introduces measures to improve transparency in the relationship between enterprises and their environment by posing requirements to improve the accuracy and reliability of financial reporting, thereby improving the information provided to and held by the SEC (Oxley: 2003, 5). Despite the fact that the Sarbanes-Oxley Act was introduced by U.S. institutions, it also affects enterprises based in other countries. This Act requires all enterprises, including approximately 469 enterprises listed in the New York Stock Exchange (NYSE) and 451 listed on NASDAQ foreign-based enterprises, that have securities publicly traded in the U.S. on national securities exchange or NASDAQ as well as companies that are required to file reports with the SEC (O’Conor: 2005, 17).

The Sarbanes-Oxley Act is having a significant influence on the real-time decision support needs of enterprises by making the requirements for financial reporting stricter. The most important provisions of the Sarbanes-Oxley Act include Section 302, Section 404, and Section 409. Table 2-1 provides a brief overview of the content and implementation of these provisions:

<table>
<thead>
<tr>
<th>Provision</th>
<th>Status</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section 302</td>
<td>Effective</td>
<td>It introduces personal liability for the enterprise top management. In practice, this section requires the Chief Executive Officer (CEO) and Chief Financial Officer (CFO) to personally sign off the appropriateness of the firm’s financial statements. A CEO or a CFO who submits an insufficiently inaccurate financial report is subject to a fine up to $ 1 million and imprisonment for up to 10 years. However, if the inaccurate financial report was submitted wilfully, the fine can be increased to as much as $ 5 million and the maximum prison term can be raised to 20 years.</td>
</tr>
<tr>
<td>Section 404</td>
<td>Effective</td>
<td>This is the most notable provision of the Act. It specifies requirements for the attestation of the adequacy of financial reporting controls. It makes managers responsible for maintaining an adequate internal control structure and procedures for financial reporting, and demands that companies' auditors attest to the management’s assessment of these controls and disclose any material weaknesses. The major problem associated with section 404 is that producing more accurate reports requires massive amounts of quality detailed data for offline retrospective analysis. However, most business intelligence environments were not designed to store the level of detail required by section 404 or to perform these types of analyses. As a result, enterprises must introduce adequate systems and assess the adequacy of those systems on an annual basis through audits.</td>
</tr>
<tr>
<td>Section 409</td>
<td>Effective date not set</td>
<td>This Section introduces the need for real-time disclosure of events with significant material consequence, such as multimillion-dollar orders. This section also specifies the material events that must be</td>
</tr>
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reported by enterprises. The loss or damage caused by an event can be of sufficient magnitude to put the enterprise at risk.


In summary, the sanctions for violations of Section 302, corporate governance and accountability are high on the agenda of enterprise managers, government and investors throughout the world, while, Section 404 and Section 409 indicates the use of adequate IT technology will be required to ensure compliance with the Sarbanes-Oxley legislation, while Section 302 ensures that the top management will have a high sense of urgency in taking the measures to achieve compliance. The adoption of BAM systems can thus play a role in helping companies complying with Section 404, Section 409 and eventual further regulation on business performance reporting practices.

2.2.2 BASEL II

BASEL II can be observed as another piece of legislation that is likely to influence real-time decision support needs in the coming years. However, the primary distinction of BASEL II is that concentrates on financial institutions. In essence, the BASEL II introduces an international capital adequacy framework to establish accounting standards. The main purpose of the BASEL II is to ensure that financial institutions manage their risks so that they always have sufficient capital to cover their exposure to debt (Porter: 2003, 9). The need for this regulation is justified by the increasing complexity of banking activities and the impossibility for banking supervisors to monitor in detail these activities (Decamps et al: 2004, 132). Banks throughout the world will have to have their systems and process in place by the start of 20072.

As with the Sarbanes Oxley Act, investment in technology is expected to be a fundamental condition to ensure compliance with the requirements posed by the BASEL II. In order to be able to quantify risks, banks will have to be able to gather sufficiently detailed data on their operational activities in real-time to enable the diagnosis of risk levels associated with transactions. For this reason, monitoring systems will need to be able to detect and handle exception events that significantly affect the risks of the operations of banks (Porter: 2003, 9).

2.2.3 USA Patriot Act

The USA Patriot Act will influence the real-time decision support needs of the U.S. government. This Act came about as a response to the terrorist attacks of September 11th. The terrorist attacks have raised the concern for public authorities about the likelihood of the use of the existing IT infrastructures by terrorists to support terrorist activities. To prevent terrorist activities and money laundering practices required to fund these activities, the USA Patriot Act was passed in December 2001 (Gellman: 2002, 256).

The USA Patriotic Act gave additional powers to domestic law enforcement and international intelligence agencies (Madsen: 2002, 2). This is shown by the fact that Title II of the Patriot Act, which is called Enhanced Surveillance Procedures, empowers the Federal criminal code to authorize the interception of wire, oral and electronic communications for the production of evidences for the production of specified chemical weapons, and terrorism or computer fraud and

abuse (Stratford: 2002, 287). Additionally, the Patriot Act will enforce enterprises in the financial sector to improve their capabilities of detecting money laundering (see appendix 1: Quantive Survey 1). For this, enterprises in the financial sector will have to develop the capability to drill-down to find the patterns to of money laundering activities.

The introduction of the Patriot Act suggests that there is a higher public willingness to accept diminished privacy protections to permit government surveillance in terrorism investigations and prosecutions (Gellman: 2002, 260). This can be seen as evidence that legal barriers for monitoring initiatives tend to be partially removed, when monitoring initiatives involve terrorism prevention.

2.3 Mapping Decision Support Needs Within Enterprises

The previous sections have indicated that enterprises have to improve their capabilities of understanding the problems in the execution of their business processes. This section contributes to map the real-time decision support needs of enterprises by looking internally so as to reveal which organizational layer is more likely to benefit from the provision of real-time operational insights. For this, we make a distinction between three basic organizational layers that can be observed in most enterprises. The organizational layers include the top management, the business process owners, who are the operational managers responsible for the execution of business processes, and the operating personnel. For each organizational layer, the decision support need is mapped by describing the objectives and the decision support needs for each layer.

<table>
<thead>
<tr>
<th>Organizational Layer</th>
<th>Objectives</th>
<th>Decision Support Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Management</td>
<td>Ensure the continuity of the enterprise</td>
<td>Summarized operational insights on a regular basis</td>
</tr>
<tr>
<td>Business Process Owners/Operational Managers</td>
<td>Maximise performance of the business process they are responsible for</td>
<td>Real-time operational insights on the execution of business processes</td>
</tr>
<tr>
<td>Operating Personnel</td>
<td>Carry out structured tasks rapidly and correctly</td>
<td>Detailed task description</td>
</tr>
</tbody>
</table>

*Table 2-2: Assessing Decision Support Needs within Enterprises*

By observing table 2-2, we can conclude that business process owners is most likely to need real-time operational insights to deal with the occurrence of exception conditions, because managers are responsible for the performance of the process. We could confirm that by carrying out a survey with a BAM vendor with experience obtained through the implementation of their BAM system (see appendix 2: Survey Quantive II). We could observe that, in many cases, business process owners are aware of the occurrence of the occurrence of events with significant negative material consequence on the resources of the enterprise. But the problem for business process owners is that, although they normally have a complete understanding of the problems in the business processes they are responsible for, they often lack the capacity to detect the occurrence of such events in time to respond to them. Consequently, business process owners can provide valuable indications of the real-time decision support needs of enterprises by pointing out the exception events that affect the performance of the business processes that they are responsible for.
2.4 Examining the Modern Enterprise

The characteristics of the "Modern Enterprise" are also affecting their real-time decision support needs. Essentially, the Modern Enterprise is characterized mainly by its open character, increased decentralization, mergers and acquisitions, as well as the demand for rapid delivery of IT solutions.

- Over the past years, enterprises have become increasingly open as more and more data moves across the boundary of enterprises. Nowadays, it is normal for enterprises their own data in combination of data from customers, suppliers and partners. This is explained primarily by the fact that the Internet has promoted the growth of growth of the distributed information processing beyond the single enterprise (Luckham: 2002, 19). In this context, the need to obtain a single view on the enterprise resources has become very important as enterprise data is distributed (Serain: 2002, 181).

- It is also possible to observe that the Modern Enterprise is clearly becoming less centralized. This results from the fact the distributed character of the operations of most enterprises, especially large-scale enterprises with global operations. The immediate consequence of this trend towards decentralization is that the need to synchronize resources located in different locations is becoming increasingly important as different business processes depend on each other.

- Another trend that has a major influence on the real-time decision support needs of enterprises is the trend towards mergers and acquisitions. In fact, major and acquisitions have become popular due to the potential cost benefits that can be obtained through an increase in the scale of operations, but also because of synergies that can be obtained. However, this trend also creates additional difficulties for understanding the performance of business process. Connecting merged organizations from a technical perspective is a huge challenge that the integration of functions and information across multiple systems. Commonly, mergers and acquisitions cause information inaccuracy, lack of information timeliness, data inconsistencies and possible data corruptions (Perks & Beveridge: 2003, 25). The problem here is thus that mergers and acquisitions create additional difficulties for monitoring the execution of business processes, especially during the period after the mergers and acquisitions.

- The Modern Enterprise is also setting new expectations when it comes to the development and deployment of new IT functionality. The Modern Enterprises relies heavily on the Internet-based applications, which are characterized by simplicity and rapid change (Perks & Beveridge: 2003, 37). In practice, enterprises are requiring the deployment of IT solutions in terms of hours or days (see appendix 1: Quantive Survey 1).
2.5 Considerations on Real-Time Decision Support Needs

The growing importance of focusing on events has been stressed by various developments. By mapping the real-time decision support needs of enterprises, we obtained an initial picture of their real-time decision support needs. We have seen that operational managers are most likely to need real-time operational insights because they are directly responsible for the execution of business processes and that enterprises expect very short development and deployment cycles for IT solutions designed to fulfill their real-time decision support needs. Furthermore, we could identify the following specific decision support needs.

- Sense-and-respond
- Adjust to changing conditions
- Exception handling
- Push-based delivery of event notification
- Provision of diagnosis
- Synchronization of resources
- Drill-down to understand root causes
3 Assessing Limitations of the Enterprise IT Environment

After gaining more familiarity with the real-time decision support needs of enterprises, it is necessary to assess limitations of the enterprise IT environment in providing real-time operational insights required by the real-time decision support needs of enterprises. In this chapter, we assess the characteristics of widely adopted IT technologies in order to understand the limitations of these technologies in providing the real-time operational insights. The objective of this chapter is to improve understanding of the limitations of critical technologies that constitute the enterprise IT environment in providing real-time operational insights. To provide a complete picture of these technologies, we present a chronological description of the adoption of IT technologies.

The organization of this chapter: section 3.1 examines transactional systems, section 3.2 provides a comprehensive assessment of the data warehouse, section 3.3 highlights middleware technologies that have been used by enterprises to integrate transactional systems, and section 3.4 puts forward conclusions with regard to the technical bottlenecks associated with the most common business technologies.

3.1 Transactional Systems

We start assessing BAM’s technological environment by focusing on the transactional systems of enterprises. These systems are extremely important, because enterprises rely on them to carry out their business processes. In fact, over the last 30 years, such enterprises have invested more than a trillion dollars in the gradual implementation of more transaction processing systems (Kimball & Caserta: 2004, 463). At present, these systems form the legacy data management environment of enterprises. In the discussion about the improvement of real-time visibility of operations, the transactional systems occupy a central position, as these systems are the primary source of events.

3.1.1 Characterizing Transactional Systems

Transactional systems are the systems that were implemented by enterprises over the years to support enterprises processing transactions. These systems include the databases supporting ERP, such as those from SAP, BAAN, and PeopleSoft, order entry, point-of-sale, or other business applications (Meltzer: 1999, 50). The general objective of transactional systems is to get transactions processed and completed as soon as possible, because, for the enterprise, processing usually means cost, while completion means revenues (McElreath: 1998, 527). So, when it comes to transactional systems, enterprises expect very good transaction response times. Besides the need for good transaction response times, it is also relevant to mention that, since enterprises have become highly dependent on the availability of their transactional systems to support their business operations, the availability of these systems have become key to them (Information Builders: 2004, 7).

In general, transactional systems usually support multiple applications that are often characterized by overlapping and sometimes contrary definitions (Anahory & Murray: 1997: 3). The interfaces within these systems tend to be synchronous, tightly coupled (Hollar: 2004, 2). The underlying technology of these systems tends to be non-standard and proprietary (Serain: 2002, 4). Therefore, they are traditionally not interoperable and difficult to modify, and integrate. Despite the fact that transactional systems were not designed share information with other systems, applications implemented on transactional systems may require information from other systems (Deeb & North: 2005, 8). This has led to the proliferation of adapters that compensates for different definitions used in different systems by providing inter-application connections.
3.1.2 Limitations of Transactional Systems

The limitations of transactional systems in providing real-time operational insights stem from the fact that they were designed for automating day-to-day operations and are very good at putting data into databases quickly, safely, and efficiently, but provide restricted capabilities for monitoring the performance of enterprises (Meltzer: 1999, 50).

In order to obtain real-time operational insights directly from transactional systems, software designers have built triggers and alerts into software applications for many years to highlight exceptions relating to transactions in the transactional systems (DeFee & Harmon: 2004, 3). But given the non-standard and proprietary characteristics of the transactional systems, alerts and triggers could only detect events occurring in just one application or transactional system (Humphries et al: 1999, 207). In this way, the interoperability of applications used to be a major barrier for a widespread use of traditional real-time alerting technologies, because it aggregating events directly from different transactional systems in real-time was a major challenge.

3.2 Data Warehousing

After examining the transactional systems and traditional alerting technologies, we could understand the limitations in obtaining comprehensive operational insights directly from those systems. To tackle these limitations, many companies have invested in the implementation of large data warehouses that consolidate data from multiple transactional systems in the past decade (DeFee & Harmon: 2004, 3). Essentially, data warehousing is a field that grew out of the integration of technologies and experiences over the last two decades (Orr: 2000, 1). In this section, we present a discussion about the main aspects of the data warehouse. This should provide us insights in the applicability and limitations of the data warehouse.

3.2.1 Characterizing the Data Warehouse

Data warehouses are adequate to fulfill decision support needs when there is a clear need for long-term trend reports. The data warehouse is suitable to fulfill this type of decision support need because it stores huge amounts of detailed data that represents historical data in the sense of events now passed (Inmon et al: 2001, 19). The data warehouse creates a historical perspective on performance of enterprises because it stores fact for each time period (Tanler: 1997, 4). Besides creating a historical view on performance, the data warehouse is also important because it creates a single view on the transactional systems of an enterprise. This single view is accomplished by assembling the data from heterogeneous databases so that users query only a single point consisting of a repository from multiple sources (Thuraisingham: 1999, 60). A distinguishing characteristic of the data warehouse that is worth considering is that it supplies business analysts, such as managers and decision-makers, with information they need, but does not disturb transactional systems doing their jobs (Abramowicz et al: 2002, 4). Hence, it provides an interesting alternative that solves the noted problem of analyzing the performance directly from the transactional systems.

A great number of examples of the exploratory analyzes based on data warehouse is presented by literature. Table 3-1 shows a set of representative examples of exploratory analyzes supported by data warehouse.
Exploratory Analyzes Based on a Data Warehouse

**Source**

"Managers need to view sales by product and region and make correlations with advertising campaigns and marketing promotion."

(Brown & Hill: 1999, 60)

Answering questions such as:

- "What type of customer is the most profitable for our business?"
- "Over the years, how has transaction activity changed?"
- "Where has sales activity been highest in the springtime for the past three years?"
- "When we change prices, how much elasticity is there in the market place?"

(Inmon et al: 2001, 30)

"The most frequent use of a data warehouse is to analyze historical data, discover trends and correlation."

(Meltzer: 1999, 48)

"Use data warehouse to analyze business data historically by focusing on planning such as trends in daily sales levels as compared with previous months."

(Hackett: 2004, 2)

| Table 3-1: Examples of exploratory analyzes based on data warehouses |

In practice, the data warehouse can be deemed as a workflow that involves periodically gathering disparate data from transactional systems (Inmon et al: 2001, 93). The data warehouse integrates, cleanses, organizes, and aggregates it through a series of transformations (Chong: 2005, 17). As data warehouse environments mature, they begin to bring in data from an ever-expanding set of sources (Inmon et al: 1999, 190). To provide a better representation of the challenge involved in integrating data from different transactional systems, we illustrate in figure 3-1 the most common types of data transformation that need to be realized before loading the data warehouse.

**Figure 3-1: Data Transformation Types. Source: adapted from (Humpries et al: 1999, 200)**
3.2.2 Data Warehouse Components

The data warehouse relies on a number of components in order to extract data from the operational systems, integrate, cleanse and store the transformed contextualized operational data into persistent data structures. To understand the limitations of the data warehouse in providing real-time operational insights, it is necessary to examine the main components of a conventional data warehouse. Figure 3-2 provides a simplified illustration of the architecture of a data warehouse by representing the main components and their relationships.

![Figure 3-2: Simplified Data Warehouse Architecture. Source: adapted from (Kimball & Caserta: 2004, 445).](image)

**Extract, Transform and Load (ETL)**

The conventional batched ETL procedure is extremely effective in addressing daily, weekly and monthly batch reporting requirements. ETL creates a new snapshot whenever a change needs to be reflected in the data warehouse (Inmon et al: 2001, 8). For example, as new events occur in the transactional system, such as the entry of an order by a user or a request for information, the application server generates an XML document. Within predefined refreshing cycles, this data can be extracted in batch mode from the administrative system and sent to the Data Warehouse, in the form of a XML document (Giovinazzo: 2003, 238). A fundamental consideration about the ETL process is that it depends on the availability of windows of acceptable downtime for the transactional systems, because it places an additional load on the transactional systems during the loading process (Kimball & Caserta: 2004, 437). Consequently, possibilities of reducing the refresh cycles are limited because there is a risk of overloading the transactional systems, which puts the availability of transactional systems at risk.

**Operational Data Store**

The operational data store (ODS) was originally defined as a place where data was integrated and fed to a downstream data warehouse (Kimball & Caserta: 2004, 425). The ODS environment has a time period identical to that of the transactional system. For this reason, the ODS provides management with relatively low latency reports that update throughout the day (Giovinazzo: 2003, 143). The difference between the ODS and the transactional system, however, is that the ODS contains integrated corporate data, while the transactional system does not (Inmon: 2001, 19).
**Meta Data Repository**

Meta data repository contains the information defining data in an information system (Alter: 1999, 124). In the case of a data warehouse, the metadata repository serves to store information about how to extract information from transactional systems, transform extracted data in accordance with the predefined business rules, and load new information into the enterprise data-warehouse (Abramowicz et al: 2002, 9). Specifically, a meta data repository contains definitions such as the source mappings, data transformations, calculations, date/time, last updates, length of refresh cycles, etc (3COM: 1999, 42).

**Data Mart**

A data mart is a repository of data for a department that has an architectural foundation of a data warehouse (Sousa: 1999, 75). It is a subset of a data warehouse that that is generally customized to fit the needs of a department (Inmon: 2001, 110). It contains different combinations and selections of the same detailed data found at the data warehouse (Sousa: 1999, 76). Data marts can provide focused on a single area, such as marketing, sales, production, or finance (Brown & Hill: 1999, 60).

**3.2.3 Data Analysis Tools**

As the volume of data stored in a data warehouse increases continuously over time, it is necessary to use data analysis tools to analyze this data. The most common data analysis tools used for this purpose are Online Analytic Processing (OLAP) and data mining. Here, we provide a brief overview of both data analysis tools.

**OLAP**

OLAP tools use online data analysis tools to explore large databases containing transactional data (Alter: 1999, 175). This is done by using complex queries to explore large data sets (Ozsu & Vaduriez: 1999, 571). Essentially, OLAP tools aggregate data along common business subjects or dimensions and then allow users to navigate through the hierarchies and dimensions. In this way, OLAP provides multidimensional views (Berson & Smith: 1997, 226).

**Data Mining**

In general, data mining can be defined as the process of extracting information, patterns and trends often previously unknown from large quantities of data (Thuraisingham: 1999, 1). This data analysis tool can be used to provide insights into corporate data by discovering hidden insights that might otherwise go unrecognized by the user such as unknown patterns (Tanler: 1997, 98). The employment of data mining applications can be justified as a means of achieving certain objectives. Main objectives driving knowledge discovery process include extracting useful reports, spotting interesting events and trends, testing assumptions, supporting decision-making processes, and exploiting the data to archive scientific, business, or operational goals (Cios et al: 1998, 7). Data mining is supported by a host of models that capture the patterns of data in several different ways (Alter: 1999, 175). Basic models of data mining include clustering, regression models, classification, summarization, link analysis and sequence analysis (Cios et al: 1998, 13).
3.2.4 Limitations of the Data Warehouse

Although the benefits of the data warehouse are clear, we could identify serious limitations attached to this technology when it comes to the provision of real-time operational insights. There are three obvious limitations associated with the data warehouse that makes this technology unsuitable to provide real-time operational insights. Below, we discuss these limitations:

- The first limitation results from the fact that most data warehouses nowadays rely on the ETL procedure and ETL is certainly not a suitable technique to provide low latency reporting, because the long refresh cycles of ETL creates high latency. For this reason, there is always a significant delay between when the time when transaction occurs and the when the data actually arrives at the data warehouse (see appendix 1: Quantive Survey). Although refresh cycles tend to become shorter, there are risks involved when batch loading process is applied close to real-time as the load imposed on the transactional systems is increased (Kimball & Caserta: 2004, 439). However, we have seen that the availability of transactional systems is key for enterprises.

- The limited scope of data warehouses also makes it difficult to obtain comprehensive operational insights. At the present, 80 % of the data used by the various data warehouses across the corporation come from 20 % of the source systems. The choice of data to be populated in the data warehouse was usually based on needs of a specific group with a particular set of information requirements. The needs of other groups are generally not sufficiently considered (Manning: 1999, 29). As a consequence, the data warehouse tends to be suitable to provide a historical view on just part of the enterprise processes.

- As market conditions change, the real-time decision support needs of enterprises also change, especially considering that data warehouses have limited scope. However, the long implementation cycles associated with data warehouses make them difficult to adapt to changing market conditions. Hence, the data warehouses cannot deal properly with changing business needs that generate new decision support need on a regular basis.

3.3 Middleware Technologies: Enterprise Application Integration

To enable the integration of multiple and heterogeneous transactional systems and the applications supported by them, the software industry developed middleware technologies. Essentially, the middleware technologies, which are also referred to as Enterprise Application Integration (EAI), sit on the top of the basic network and lets all the applications and application servers talk to one another (Lukcham: 2002, 13). The integration of transactional is intended to reunite elements, which are distributed over several systems across a network in order to offer a consolidated view of the enterprise's data (Serain: 2002, 12). Since the beginning of the nineties, middleware products have been adopted by enterprises³. To provide a better understanding of the function of middleware, figure 3-3 illustrates the position of the middleware layer in the OSI model. In this section, we assess the mainstream types of middleware and their limitations in providing comprehensive real-time operational insights.

³ Dr. Jos Vrancken who is a member of the graduation committe for this graduation projects emphasized during discussions that investment in middleware infrastructure is not a recent phenomenon. However, the initial real-time middleware infrastructure were developed in the beginning of the nineties and were characterized by proprietary (non-interoperable) standards.
3.3.1 Types of Middleware

In the following, we examine object-oriented middleware and message-oriented middleware.

Object-Oriented Middleware: Synchronous

Object-oriented middleware serves to make requests and receive responses synchronously and in a transparent way. Operation in synchronous mode means that applications are always in run state and, as result, the unavailability of a destination application causes the loss of a message (Serain: 2002, 26). There are two well-known models for object-oriented middleware. The first model is called Common Object Request Broker Architecture (CORBA) and was introduced in 1990 as an international standard by the Object Management Group (OMG). It provides access to distributed object services by acting as a broker between methods of various applications (Luckham: 2002, 13). The second model was proposed by Microsoft and is called Distributed Component Object Model (DCOM) (Ozsu & Valduriez: 1999, 554). DCOM also provide similar distribution component services based on a similar model as CORBA, but with different technological specifications (Perks & Beveridge: 2003, 190). This means that DCOM and CORBA cannot be combined directly.

Message-Oriented Middleware (MOM): Asynchronous

MOM middleware is an asynchronous type of middleware. In MOM, the sending application (the client) puts its message in its output message queue, and continues with its processing while the MOM middleware product transmits the message to the input queue of the receiving application.

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4 The Object Management Group is a consortium of industry participants that is responsible for the standards for object-based middleware: www.omg.org
(the server), that will read this message as soon as it becomes available (Serain: 2002, 27). In this way, as messages are stored prior to delivery, the temporary unavailability of an application does not imply message loss as with object-oriented middleware. Additionally, it is important to observe that the repositories of messages constitute an important source of real-time events.

3.3.2 Limitations of Middleware

Although middleware technologies are effective in integrating transactional systems and providing a consolidated view of an enterprise’s data, those technologies alone fail to provide comprehensive real-time operational insights. This is explained primarily because different middleware technologies were designed to ensure interoperability among transactional systems rather than to analyse the information processed by these systems. For this reason, although middleware technologies are suitable to provide access to events from multiple and heterogeneous sources, these technologies do not provide sufficient support for event-response because events are normally not properly analyzed.

3.4 Conclusion

In conclusion, transactional systems, the data warehouse, and middleware technologies are not capable of providing the real-time operational insights properly. This chapter has demonstrated that these technologies provide business benefits such as processing transactions rapidly, storing large volumes of data for analytical purposes, or enabling interoperability of existing transactional systems, but do not empower operational managers of enterprises to understand and control the execution of business processes in real-time because these technologies were simply not designed to support effective response to events. Accordingly, the gap between the operational insights provided by technologies implemented by enterprises in the last years and the real-time operational insights, which is currently sought by enterprises, is significant.
4 Understanding Business Activity Monitoring

Given the need of enterprises for real-time operational insights and the limitations of the technologies addressed in providing comprehensive low latency operational insights, BAM is likely to contribute to fill the functional gap of traditional IT infrastructure. However, as outlined chapter 1, there are significant variations to be observed across BAM systems, which difficult an accurate understanding of the applicability of BAM. To resolve this problem, it is necessary to improve understanding of basic elements of BAM systems as well as the differences among BAM systems. This chapter is aimed at providing a comprehensive overview of the most important aspects of BAM.

The organization of this chapter: section 4.1 provides a general functional description of BAM, section 4.2 highlights technical aspects of BAM, section 4.3 provides an brief overview of options for adding context to BAM alerts, section 4.4 describes implementation challenges faced by BAM vendors, section 4.5 provides visions on the future of BAM, section 4.6 draws conclusions on BAM.

4.1 Functional Description of BAM

Besides the BAM functionality specified by the original Gartner’s definition of BAM, which was presented in the introduction, it is also possible to distinguish more specific functional characteristics. Fundamentally, in BAM systems, the emphasis is clearly on responding to events within short time-windows of opportunity (Chandy & McGoveran: 2004, 21). This is because events can generally be seen as “perishable” in the sense that they lose value over time, as the effect of response decreases. BAM systems can contribute to reduce latency in the operations of enterprises, where latency is defined by Hollar (2004) as the time gap between when the system receives information from the point of data generation and uses it wherever needed at other point (Hollar: 2004, 1). The concept of the Zero-Latency Enterprises (ZLE) represents the ideal situation where information is delivered to the right point of data consumption at the right time for maximum business value (Kimball & Caserta: 2004, 423). Accordingly, BAM systems can help enterprises executing their business processes as a ZLE.

Despite the emphasis on reducing latency in the operations of enterprises, it is also important to mention that a suitable must not only provide real-time event notification, but also provide process owners with enough operational insights to enable effective response to events (DeFee & Harmon: 2004, 5). Another important consideration about the function of BAM is that it is not just real-time application-level monitoring. McCoy (2002) indicates that a BAM system should be visualized as a system that serves to monitor a set of existing applications and their interactions (McCoy: 2002, 1).

4.2 Technical Description of BAM

Fundamentally, BAM systems translate input events into real-time analysis for immediate reaction (Govekar et al, 2002, 1). However, the investment committed by enterprises on the adoption of middleware technologies makes it possible that, in BAM, events come from multiple and heterogeneous data sources (Gassman, 2004, 1). It employs application integration and messaging technology as the basis for tapping into continuous real-time event streams. In practice, the real-time access to business performance data is achieved by drawing real-time events from multiple application systems and other internal and external sources, thereby enabling a broader and richer view of business activities (McCoy et al, 2001). Therefore, it is multiplication, correlating multiple sources of independent data (McCoy, 2004, 1).
BAM systems can be incorporated into the IT infrastructure of enterprises as an event analytics layer at the top of existing middleware infrastructure that serves as a platform upon which real-time monitoring applications can be developed.

To represent BAM systems, Gartner, Inc. has proposed a three-tiered BAM model in 2002 that distinguishes three layers. The “Event Absorption Layer”, “Event Processing and Filtering Layer” and the “Event Delivery and Display Layer”. In this model, the border of a BAM system is the interface with the recipients of BAM alerts (Govekar et al: 2002, 3). Here, we provide a brief description of these three layers. Figure 4-1 illustrates the three-tiered BAM model

![Figure 4-1: Gartner’s Conceptual Model for BAM. Source: adapted from (Govekar et al: 2002, 3).](image)

**Event Absorption Layer**

Events are fed into the event absorption layer. The source of event messages for BAM will most often be business or process-related, however, technical events that occur during the operations of the IT infrastructure may also be collected (Gassman, 2004, 3). BAM systems rely on event gathering mechanisms to gather event information, in real-time, directly from operational systems. A BAM system should have a mechanism in place to gather events occurring in different operational systems by tapping into different information sources. This is enabled by a middleware layer that has been placed over the last decade to support interoperability among disparate transactional systems. The messages in the middleware can be observed and aggregated into events. As stated in the previous chapter, the middleware layer includes both object-oriented middleware technologies as well as message-oriented middleware (MOM).
Event Processing and Filtering

Basically, BAM systems must be able to correlate multiple sources of independent data (McCoy, 2004, 1). To this end, a filtering system must be designed that draws data from a wide range of sources and then against rules that when met generate alerts (DeFee & Harmon, 2001, 5). Here, a business rule builder that can handle the exceptions and extract meaning from event information.

Event Delivery and Display

The alerts issued by a BAM system can be sent to diverse parties that have real-time decision support need. In fact, events of significance are analyzed and communicated to recipient by the BAM system in the form of an alert (Govekar et al, 2002, 3). The alerts that are delivered can populate a display or trigger an action (Gassman, 2004, 2). In this way, alerts are used to populate a display, they are often delivered via graphical displays ("Dashboards") that are customized for use in different parts of the enterprise and for different audience (McCoy et al, 2001, 2). Another option is to forward the alerts to BAM recipients through other existing mechanisms such as batch office staff, emails, pagers, PDAs, and other systems to ensure that someone or something can react (McCoy, 2003, 2).

The alert can also be used to trigger an action executed by a Business Process Management (BPM) system. In this respect, controlling the reaction cycle will probably be a role of Business Process Management (BPM) tools (McCoy, 2003, 2). Here, BAM can be part of a BPM, where it generates an input for the BPM system that triggers a workflow corresponding to a predefined sequence of events (Gassman, 2004, 1). The BPM tool can react to the BAM alert by running a chain of tasks that alter a running business process (McCoy, 2004, 2).

4.3 Event-To-Context Correlation

Besides analyzing real-time operational information, BAM systems can also add contextual information to events. This is an important aspect of BAM systems because the addition of contextual information to an event provides additional information about the nature of the situation that is being monitored. For example, the definition of a certain filtering criteria to detect exceptional events can be seen as a basic form of adding context to BAM alerts, which are defined by Gassman (2004) as events with context (Gassman: 2004, 1). So, by specifying a threshold for a certain performance-indicator, which is represented by an event property, the value of the threshold can be regarded as contextual information. However, more sophisticated ways for adding context to events are usually required. Since the decision support need of the BAM recipient may require diagnosing problems to respond to events with high accuracy or event forecast data to guide anticipated response to future problems, just raising alerts indicating the occurrence of exceptional situations can be, in many monitoring situations, insufficient to ensure a proper response. However, an important consideration about the development of context for BAM alert is that adding more sophisticated context to BAM alerts demands processing time and, as a result, leads to longer latency periods. Researchers indicate that there are several ways of adding context to an alert. Interesting options include:

- Simulation systems can be used to predict outcomes ahead so as to provide forecast of a state that suggest problems and, as a consequence, the need for anticipated action (see appendix 2: Quantive Survey 2). To this end, BAM systems can feed valid simulation

5 Dr. Dwight Jones indicated via an email that there developing sophisticated context for BAM alerts adds meaning to alerts, but, at the same time, also adds latency.
model with real-time information at periodic intervals to get a “look ahead” (DeFee & Harmon: 2004, 20). Hence, a simulation model can be in combination with BAM.

- Ad hoc reporting tools can also be used to provide context to BAM alerts by mapping the current situation directly from transactional systems. This can be done by accessing different applications that execute transactions that contain information related to the event.

- BI technology and associated data warehouses can be employed to add context from a historical store for business activity to a real-time alert. This can be done by building models that correlate patterns of events with previous occurrences of problems and opportunities. For example, an hourly trend of expected order volume may be updated nightly by a BI system and used as a reference against real-time orders to detect exceptional variations in order volumes (Gassman: 2004, 5). Additionally, BAM systems can improve long-term analyses by adding the context of real-time feeds into an Operational Data Store (ODS) (Hackthorn: 2004, 2). This enables a more complete understanding of trends, because it supports an analysis of trends by providing understanding of current states.

4.4 BAM implementation Challenges

By examining literature, we could observe that BAM vendors are facing a number of implementation challenges associated with the fact that BAM is early on the market maturity curve. At present, the most important implementation challenges include:

- The first challenge is that the implementing BAM properly requires deep understanding of the scenarios being monitored (McCoy: 2002, 5). In contrast to the BAM vendor, the business process owner is normally aware about the exceptional problems with significant material consequences. Therefore it is necessary to map the specific decision support needs of the business process owner. Therefore, at present, the identification critical metrics for BAM requires an intensive collaboration between BAM vendor and the business process owner.

- Another significant implementation challenge is that there are no standards that indicate how BAM systems should operate (Gassman: 2004, 5). Therefore there are extra risks involved in the implementation of BAM systems because there no standards for validating events or to ensure that events from all possible source systems are aggregated.

- Apart from the challenges already mentioned, there is also a risk that as BAM systems become more popular, the BAM systems will overload BAM’s recipients with too many alerts so that they can focus on the most-critical ones (McCoy & Govekar: 2002, 3) and may disregard many of them due to lack of time (Klein & Besson: 2003, 28). This risk is often referred to as the cognitive overload of the BAM recipient. Given the limited experience acquired by most BAM vendors with BAM implementation projects, at present, it is difficult to define the precise maximum number of alerts that can be raised by a BAM system, especially considering that alerts can carry variable amounts of contextual information.
4.5 Visions on BAM

Despite the current uncertainties regarding the development of a market for BAM systems and the challenges faced by BAM vendors, we could identify visions on the directions that BAM systems are likely to move.

- The development of BAM applications is likely to follow a similar pattern as compared to e-services. Therefore, initiatives towards the standardization of e-services, such as the Service Oriented Architecture (SOA) are likely to occur with BAM when the technology gains a higher market penetration. In this way, templates of BAM applications to be used by firms operating in the same industry are likely to occur (see appendix 5: Interview David McCoy).

- Use event pattern languages to correlate events by tracking event causality. Luckham (2002) stresses that event pattern languages will be able to support predictive monitoring by extract patterns from prior failures and trying to recognize when these happen again (Luckham: 2002, 46). Complex event processing technologies that can be hosted on middleware to detect complex patterns of events still need to mature. With the improvement of event pattern languages, it will become possible to model complex patterns that characterize the period before a certain failure in a reliable way. Besides modelling the patterns of more complex events, it will also be necessary to model the patterns of events that were expected, but did not happen.

4.6 Conclusion

This chapter demonstrated that BAM systems, beyond sensing real-time time events and raising low-latency BAM alerts to notify operational managers about the occurrence events, might also need to extend their functionality by adding distinct types of contextual information to BAM alerts. In fact, the choice for contextual information seems to be a key way for differentiating BAM systems, because the type of contextual information that is added to the alerts determines the operational insights that are provided to the BAM recipient. Accordingly, as the type of contextual information that is added to BAM alerts is determined by the choice for data analysis tools, this choice can be considered as factor for differentiating BAM systems.
5 Designing and Validating a BAM Definitional Model

After providing a comprehensive overview of BAM and introducing a BAM definitional model, it is necessary to validate the model. The purpose of this chapter is to outline the expert validation process of the BAM definitional model and to present the resulting model.

The organization of this chapter: section 5.1 describes the expert validation method, section 5.2 section highlights the validation rounds, section 5.3 explains the resulting BAM definitional model, section 5.4 proposes a methodology for using the BAM definitional model for classifying and cataloguing BAM systems, and section 5.5 presents some considerations on the model.

5.1 Method Description: Model Proposition, Expert Review, and Suggested Improvements

To validate the BAM definitional model, we asked an expert panel to review different design propositions for the BAM definitional model by carrying out a reality check as well as by evaluating the internal consistency. The expert validation process took place in the course of several validation rounds. In the beginning of a validation round, the design proposition of the latest version of the BAM definitional model was reviewed by one subject matter expert at a time. The changes and additions suggested by the expert were, then, incorporated into the following version of the BAM definitional model.

The panel of experts is comprised of a number of subject matter experts who have advanced knowledge in BAM and related areas such as agility systems, business intelligence, process innovation and runtime software monitoring systems. The experts participating in the panel include:

- David McCoy; Gartner, Inc.
- Dr. Dwight M. Jones, Quantive LLC
- Jack Ring; Paradigm Shift International
- Professor Dr. ir Richard Welke; Georgia State University
- Rick Dove, Paradigm Shift International

5.2 Validation Rounds

In this section, we provide an overview of the expert validation process by briefly describing how successive design proposals were validated by the expert panel. To this end, we highlight the changes and additions suggested by an expert after reviewing a proposed design. Table 5-1 highlights the changes introduced in each design round. The complete set of design propositions can be encountered in appendix 6: Proposed Versions of the BAM Definitional Model.
<table>
<thead>
<tr>
<th>Design Proposal</th>
<th>Date</th>
<th>Expert Advise</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>08/04</td>
<td>• Introduce distinction of decision support needs associated with the presented categories of problems (detection versus discovery)</td>
</tr>
</tbody>
</table>
| V2              | 11/04  | • Place technologies in functional layers to facilitate understanding of the characteristics of the technologies involved  
• Discuss the implications of the choice for different data analysis tools |
| V3              | 14/04  | • Make distinction between event execution and facilities to store events  
• Indicate the order in which events are handled by different components of a BAM system  
• Propose categories of problem characteristics that determine real-time decision support needs of enterprises |
| V4              | 15/04  | • Add a representation possible methods for the acquisition of events  
• Provide more complete description of problem characteristics |
| V5              | 19/04  | • Modify the layout of the model to facilitate model visualization and comprehension  
• Represent possibilities for storing the results of analyses |
| V6              | 22/04  | • Remove the arrows of the model to allow better possibilities for positioning BAM systems in the model  
• Add an additional functional layer to represent methods for the acquisition of events |
| V7              | 27/04  | • Make a distinction between storage facilities for raw event store and for contextualized event store  
• Add simulation as a viable data analysis tool |
| V8              | 29/04  | • Adjust the position of simulation in accordance to the expected level of latency associated with this technology  
• Define problem characteristics for problems involving the prediction of future scenarios |
| V9              | 02/05  | • Emphasize the fact that BAM systems are only able to process digitised events  
• Shift the data warehouse to the functional layer represent contextualized data store. The data transformations added by the ETL procedure can be regarded as a way to add context to event information  
• Adds RFID as a possible source of event information |
| V10             | 05/05  | • Provide new names for the proposed categories of problems  
• Provide more detailed problem characteristics |
| V11             | 08/05  | • Add applications to the event sourcing layer |
Add the following event sourcing possibilities:
- Internet/External Sources
- SCADA (Supervisory Control and Data Acquisition)
- MES (Manufacturing Execution Systems)

Replace the name of the layer event interpreting by analytics

Object-Oriented Middleware
Response Learning

Last refinements
The complete model

Table 5-1: Explanation Design Rounds

5.3 The Resulting BAM Definitional model

After going through various validation rounds, we obtained a definitional model. Essentially, the model combines a technical model with a functional model.

5.3.1 BAM Architectural Model

The BAM definitional model uses a layered structure to represent a set of basic architectural components in BAM systems. This model is made up of six columns that define BAM solutions in terms of basic functional layers. The functional layers, which include event execution, event sourcing, event acquisition, raw event store, contextualized event store and analytics. At the atomic level within the columns, the model represents design choices for each functional layer. In total, the technical model has 29 nodes representing the atomic level of such distinctions representing viable options for BAM systems as nodes of within the functional layers. Figure 5-2 shows the BAM architectural Model.

Event Execution

The first dimension to consider is the event execution dimension. This dimension specifies the type of events that are monitored by a given BAM system. The event execution layer makes an atomic distinction between single and complex events as indicated by the definition of the concept of event provided in chapter 2.

Event Sourcing

Regardless of the type of event a given BAM system addresses, event streams are always generated by one or multiple types of source systems. This functional layer represents the source of event streams. Furthermore, an interesting aspect of this functional layer is that it indicates the type of system that generates the events provides an idea about the environment in which the BAM system is implemented.

Event Acquisition

This functional layer corresponds to the first functional layer that actually belongs to BAM systems. In a BAM system, there is an event acquisition tool to collect events of interest as they
occur by tapping into the sourcing system and move them from the operational systems into an event storage facility.

**Raw Event Store**

The real-time stream of raw events that is captured by an event acquisition mechanism is forwarded to a raw event store. This column lists repositories for event executions that are store events without modifying the original event format.

**Contextualized Event Store**

As with the event store, the event acquisition mechanism sends the captured event stream to a contextualized event store. However, in contrast to the raw event store, raw events are put into context by adding contextual information to it before writing to a contextualized event store. In order to put events into context, it is necessary to apply data transformations to the original event format, to add contextual information to the original event format, or combining both possibilities.

**Analytics**

This functional layer specifies the data analysis tools employed by a given BAM system to analyze and correlate the event information stored in both a raw event store and a contextualized event store. Consequently, the analytic tool determines directly the analytic functions provided by a BAM system.

To map the latency ranges associated with most significant analytic tools, we have placed a column next to the analytic methods to indicate the range of latency that corresponds to the type of analysis.

<table>
<thead>
<tr>
<th>Component</th>
<th>Latency Ranges</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applications supported by ODS</td>
<td>1 minute to 30 days</td>
<td>(Inmon et al: 2001, 20)</td>
</tr>
<tr>
<td>ODS</td>
<td>1 minute to 30 days</td>
<td></td>
</tr>
<tr>
<td>Data Warehouse</td>
<td>1 day to 3 years</td>
<td></td>
</tr>
<tr>
<td>Exploration Warehouse</td>
<td>30 days to 5 years</td>
<td></td>
</tr>
<tr>
<td>Data Mining Warehouse</td>
<td>30 days to 5 years</td>
<td></td>
</tr>
<tr>
<td>Data Marts</td>
<td>30 days to 5 years</td>
<td></td>
</tr>
<tr>
<td>Real-Time Data Warehouse</td>
<td>Hours to 1 day</td>
<td>(Kimball &amp; Caserta: 2004, 424)</td>
</tr>
</tbody>
</table>

**Table 5-2: Components and corresponding latency ranges**

Moreover, to represent the analytic tools in a more complete way, we have drawn a grid to show the relevant elements of an analytic tool. The figure below illustrates the complex event detection mechanism that can be used to filter both single and complex event executions.

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6 Dr. Dwight Jones has confirmed via email correspondence that latency could be a criteria to be included in a request for proposal (RFP) for differentiating BAM offerings.
Figure 5-1: Grid to represent Analytic Methods

BAM Architectural Model

Figure 5-2: BAM Architectural Model
5.3.2 Functional Categories

The contribution a BAM system will depend on the nature of the problems addressed by the implementation project. Hence, we propose five original problem categories that can be addressed by BAM systems and the corresponding characteristics of the problem category. The problem categories were specified based on evidences found on literature, but were also inspired by the latency ranges. However, the link between the latency range and the problem categories is far less strong as compared to the analytic tools represented in the functional layer analytics, as the categories are original. Just like the BAM technical model, the proposed categories were also subject to expert validation. The categories include prepared, sensitive, responsive, transparent and wise. Each category is comprised of a number of characteristics. The categories have the following characteristics:

<table>
<thead>
<tr>
<th>Functional Category</th>
<th>Decision-Support Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prepared</td>
<td>• Predictive Monitoring</td>
</tr>
<tr>
<td></td>
<td>• Simulative Prediction of Future States</td>
</tr>
<tr>
<td></td>
<td>• Scheduling</td>
</tr>
<tr>
<td></td>
<td>• Need for Proactive Action</td>
</tr>
<tr>
<td>Sensitive</td>
<td>• Sense-and-Respond</td>
</tr>
<tr>
<td></td>
<td>• Exception handling (Threshold Levels)</td>
</tr>
<tr>
<td></td>
<td>• Respond within Short Time-Windows of Opportunity</td>
</tr>
<tr>
<td></td>
<td>• Relevant Information is Pushed to the Recipient</td>
</tr>
<tr>
<td></td>
<td>• Detailed State-Change Capture</td>
</tr>
<tr>
<td></td>
<td>• Need for Immediate Reactive Attention</td>
</tr>
<tr>
<td>Responsive</td>
<td>• Adjusting to Changing Conditions</td>
</tr>
<tr>
<td></td>
<td>• Provision of Diagnostic Information</td>
</tr>
<tr>
<td></td>
<td>• Operational Reporting</td>
</tr>
<tr>
<td>Transparent</td>
<td>• Drill Down to Find Root Causes</td>
</tr>
<tr>
<td></td>
<td>• After-The-Fact Forensic Analysis</td>
</tr>
<tr>
<td></td>
<td>• Consistent Auditing</td>
</tr>
<tr>
<td>Wise</td>
<td>• Measuring Impact of Policies</td>
</tr>
<tr>
<td></td>
<td>• Hypothesis Testing</td>
</tr>
<tr>
<td></td>
<td>• Trend Analysis</td>
</tr>
<tr>
<td></td>
<td>• Extrapolative Prediction</td>
</tr>
<tr>
<td></td>
<td>• Strategic Planning</td>
</tr>
</tbody>
</table>

Table 5-3: Problem Categories and Corresponding Characteristics

5.3.3 The Complete Model

The final model is called the BAM definitional model. The model serves to delineate and characterize BAM systems by defining the architecture of BAM systems. It should also be seen as a classification tool that can be employed to improve understanding of the dividing line between variants of BAM systems and the implications of different designs, thereby making the task easier for stakeholders to understand BAM systems. Appendix X includes a glossary for a quick reference on the terminology used in the model.

The model is a combination of a technical model with a proposition for a set of general problem categories to be addressed by BAM systems. The underlying idea here is that a BAM system is comprised of functional layers. For each functional layer, a certain BAM system must use one or more components to deliver the functionality represented by the layer. By observing the
components employed in a given functional layer and the characteristics of problems that this solution addresses, it is possible to improve understanding of the relationship between the design characteristics of BAM systems and the functional implications resulting from different designs.

The final BAM definitional model has the following characteristics:

- The scope of the model is sufficient to cover the most relevant variants of BAM systems that fit with the original Gartner’s definition of BAM
- Support a comparative analysis of BAM systems based on functional variances resulting from different technical designs
- Represents a level of detail sufficient to support design reasoning
- Simple to use
Figure 5-3: BAM definitional model

- Event Execution
- Event Sourcing
- Event Acquisition
- Raw Event Store
- Contextualized Event Store
- Analytics
- Event Spectrum Latency
- Decision-Support Needs

Raw Event:
- Message Information
  - Time
  - Resource
  - People
  - Business Process

BAM Event Model:
- Switched LAN Networks
- Packet Application Systems (CERNET, Epix, PLM, etc)
- Object-Oriented Middleware
- Message-Oriented Middleware (MOM)
- Internet/External Sources
- Supervisory Control and Data Acquisition (SCADA)
- Manufacturing Execution Systems (MES)
- Radio Frequency Identification (RFID)
- Cookies/Clickstreams

Event Sourcing:
- Event Slicer
  - Integration (enter API Feed)
  - Database Trigger

Event Acquisition:
- Event Shifter
  - Event Slicer

Raw Event Store:
- Real-Time Event Store

Contextualized Event Store:
- Adjacent Database
  - Transactional Message Warehouse (BPM)
  - Application Security Log
  - Look-Up Table
  - Spreadsheet

Analytics:
- Simulation
  - Predictive Analysis
  - Simulation Engine
    - Forecast Data

Filtering (rule-based system):
- Complex Event Detection
  - Rule-Based System: Statistically Derived Filter
  - Policy
  - Regulation
  - Process Model

Automated Analytics:
- Manual Analytics
  - Ad Hoc Reporting
    - Ad Hoc Query
    - Analytical SQL
    - OLTP System

Discovery:
- OLAP
  - Drill-Down, Data Drift, Slice and Dice
  - Multidimensional View

Data Mining:
- Pattern Recognition
  - Algorithm/Statistics
  - Assumptions
  - Unknown Patterns

Decision-Support Needs:
- Predictive Monitoring
- Simultaneous Prediction of Future States
- Scheduling
- Need for Proactive Action

- Sense-and-respond
- Exception Handling (Threshold Levels)
- Respond within Short Time-Windows of Opportunity
- Relevant Information Pushed to the Recipient
- Detailed State-Change Capture
- Need for Immediate Abandon

- Adjusting to Changing Conditions
- Provision of Diagnostic Information
- Operational Reporting

- Drill Down to Underlying Root Causes
- After-The-Fact Forensic Analysis
- Consistent Auditing

- Measuring the Impact of Policies
- Hypothesis Testing
- Trend Analysis
- Extrapolative Forecast
- Strategic Planning
5.4 Using the BAM Definitional model

The model can be used by BAM stakeholders to classify BAM systems and understand functional properties BAM systems in order to understand the problem characteristics that the BAM system is suitable to address. The underlying idea is that the model can be applied to describe a given BAM system during the requirements gathering phase of an implementation project. The solution can be positioned in the model in order to discuss the relationship between the BAM system design and the most likely applicability of the solution. In this way, the model provides support for a structured discussion on the relationship between technical design and functional characteristics of BAM systems.

Besides examining the relationship between technical design and functional applicability, it is also possible to use the model to catalogue BAM systems. Classes of BAM systems can be catalogued by using the six functional layers of the BAM definitional model. By examining different combinations, it is possible to discuss the viability of certain combinations and the functional implications.

Given the choice for components in each functional layer, the BAM Definitional model provides the ability catalogue groups of BAM systems based on the components employed by the BAM system across the functional layers. In order to identify classes of BAM systems, it is necessary to define common properties to be met by a class of BAM systems. Yet, it is relevant to acknowledge that the definition of a set of properties to define a BAM class depends upon the objectives of the catalogue initiative.

5.5 Considerations on the Model Design

We have introduced a BAM definitional model based on the insights gained throughout this research. The added value of the BAM definitional model results from the fact that the model provides an objective basis for discussion by addressing the main design issues pertaining to BAM systems. This is accomplished by making the design choices involved in the development of BAM systems more debatable. The BAM definitional model can be used to analyse and classify BAM systems in order to improve understanding of the applicability of different variations of BAM systems.

Another important consideration on the model is that, despite the fact that the current model allows the representation of a large number of combinations, it is likely that this model will have to be subject to constant expansion over time in order to keep the model capable of representing the most relevant variants of BAM solutions. As new insights are gained into new feasible choices for atomic level in the functional, the definitional model will have to be extended in order to incorporate the new insights. Although the functional layers tend to remain the same, new atomic values are expected to be added as additional elements are identified.
6 Identifying Classes of BAM

After conducting an expert validation of the BAM definitional model, we have gained sufficient confidence in the model. In this chapter, we will use the BAM definitional model to categorize existing variations of BAM systems design solutions by identifying classes of BAM. The purpose of this chapter is to identify and motivate relevant classes of BAM systems that are able to represent existing variations of BAM systems. This is done by observing the basic properties of BAM systems through the BAM definitional model.

The organization of this chapter: section 6.1 explains the classification method used to identify classes of BAM systems, section 6.2 describes the characteristics of Pure BAM systems, identifies the characteristics of pure BAM systems, section 6.3 identifies and characterizes significant types of hybrid BAM systems, and section 6.4 presents conclusions on the identified classes of BAM systems.

6.1 Classification Method

We classify BAM systems according to the data analyzes tools. Hence, we use the atomic values of the functional layer “Analytics”, which are analytic methods, to determine the dividing line between classes of BAM systems. As this functional layer determines the type of analysis that is performed based on event information, the analytic tool can be deemed an interesting criteria for differentiating BAM systems. This functional layer allows the identification of functional characteristics generated by the type of analysis. So, it is reasonable to assume that different BAM systems relying on different analytic methods are likely to be suitable to serve different purposes. For this reason, we have focused primarily on the analytic method as a means of distinguishing classes of BAM systems. Accordingly, we made a distinction between two main types of BAM. First, categories of BAM system can be both a Pure BAM or a Hybrid of BAM and other analytic technologies.

Nevertheless, despite the importance of the functional layer Analytics, we recognize that it is also feasible to classify BAM systems based on other set of properties. As such, it is important to mention that other classes of BAM can be identified. This is just an initial attempt to identify significant variations in BAM systems based on a set of design properties of BAM systems.

6.2 Pure BAM systems

Pure BAM systems can be defined as those BAM systems that use state machine filters to analyze real-time event streams. In practice, this category builds directly upon the traditional real-time monitoring technologies as it generates very low-latency alerts to indicate the occurrence of an exceptional event. However, the major difference is explained primarily by the fact that a Pure BAM system, in contrast to traditional real-time monitoring systems, is able to gather and integrate events from multiple sources. Figure 6-1 illustrates the analytic method required by this category.
6.3 Hybrid BAM systems

Hybrid BAM systems consist of a combination of a Pure BAM system and other data analysis tools. In practice, they combine real-time events with the results of analysis of a certain analytic method to develop context. The analysis presented in chapter 4 indicates the existence of three important classes of Hybrid BAM systems. These BAM classes include Pure BAM systems in combination with discovery methods (OLAP and Data Mining), simulation, and ad hoc reporting directly from operational systems.

6.3.1 Discovery-Oriented BAM

The Discovery-Oriented BAM is a class of BAM system that combines Pure-BAM with business intelligence. In practice, Discovery-Oriented BAM systems provide context to alerts by comparing real-time events with historical data stored in a data warehouse. To this end, it is necessary to link the BAM system into an existing Data Warehouse and to analyze this historical data with analytic methods such as OLAP or Data Mining. These characteristics of the Discovery-Oriented BAM are illustrated by figure 6-2.
6.3.2 Simulation-Oriented BAM

Simulation-Oriented BAM systems combine a Pure BAM system with an event-based simulation system. Essentially, this class of BAM system emphasizes the possibility for reusing existing valid simulation models. It uses the real-time events collected by the Pure BAM system as input to feed a valid simulation model representing actual business processes to enable predictive monitoring. In this way, by running the simulation, it is possible to obtain forecast data corresponding to the impact of current event data on the business resources. The outcome of the simulation based on real-time events provides insight into exceptional future scenarios that require anticipated response. Such simulation outcome provides the ability to schedule resources for future business processes that depend on current input.

Although this class of BAM system has not been widely deployed yet, there are studies that stress the benefits of this approach (DeFee & Harmon: 2004; Luckham: 2002). For example, DeFee & Harmon (2004) describe an interesting application of a Simulation-Oriented BAM in the health care industry to speed up response to potential health care emergencies. This study demonstrates that the data feeds can be done at periodic intervals to get a "look ahead" on the
impacts to patient treatment cycle based on current resources, patients received, expected future patient arrivals, and the validated standard processes documented in the simulation modeling tool (DeFee & Harmon: 2004, 20). The prediction of the future metrics provides anywhere from 36-48 hours advanced notice to management to address the developing performance problems (DeFee: 2004, 7).

The benefits of this approach are quite straightforward. By obtaining relatively reliable performance prediction data indicating the occurrence of an exceptional event, it is possible to anticipate to problems. For instance, managers can allocate additional resources by making adjustments to the schedule in order to respond to the predicted performance problems. Besides the health care, the Simulation-Oriented BAM is also applicable to other industries, in which valid simulation models of business processes are available. Yet, more studies are needed to confirm the benefits that this class of BAM system can provide to other industries.

![Figure 6-3: Simulation-Oriented BAM](image)

6.3.3 Reporting-Oriented BAM

The Reporting-Oriented BAM is a class of BAM system that links a Pure BAM system with existing ad hoc reporting mechanism so as to execute ad hoc queries on operational systems. Although we could not find a research work covering implementation projects that rely on this particular combination, the Reporting-Oriented BAM is a technically feasible option according to experts (see appendix 2: survey Quantive II).
This class of BAM system can be employed in monitoring situations in which there is a need to collect additional contextual information about the occurrence of an exceptional event. Possible scenarios for the application of Reporting-Oriented BAM include:

- Real-time detection of threats to network security and immediate ad hoc analysis of contextual data related to the alerts such as personal information of people with access rights, or log analysis
- Exceptional situations in a supply chain

![Image of Figure 6-4: Reporting-Oriented BAM](image)

**Figure 6-4: Reporting-Oriented BAM**

### 6.4 Conclusion

This chapter has illustrated that each variation of BAM is reflected in the architectural building blocks employed by BAM systems. In this respect, we have proposed classes of BAM systems based on the choice for components in the functional layer Analytics, but also based on Raw Event Store and Contextualized Event Store in the case of hybrid BAM systems. In general, we could observe that additional context provides increased possibilities for diagnosing problems as more specific information about the monitoring situation can be provided in the BAM alert. This indicates that more context is required when operational managers need to understand the problem associated with an event in thorough ways, prior to initiate response.
7 Exploratory Case Study: BAM Implementation Project in the Airline Industry

Quantive LLC\(^7\) is a software vendor based in Alpharetta, Georgia, U.S.A, which specializes in the development of BAM systems. The company has recently introduced its BAM system to the market. The first implementation project involving the Quantive BAM solution was commissioned by a major U.S. airline. We will refer to the airline by the pseudonym "AirLine" throughout this case study. The information used to write this case study was provided by Quantive.

The purpose of this case study is to examine the implementation of the Quantive BAM solution at the airline industry in order to test the applicability of the BAM definitional model and to improve understanding of the relationship between the design characteristics of the Quantive BAM solution and the nature of the problems tackled by the implementation project. This will be accomplished by employing the BAM definitional model as the primary analytic tool.

The organization of this chapter: section 7.1 highlights the original reasons that motivated the implementation project, section 7.2 present the solution that was implemented to tackle the original problem, section 7.3 provides an overview other application concepts that were developed in the course of the implementation project to monitor other business scenarios, section 7.4 describe the real-time decision support needs addressed in the implementation project, section 7.5 employs the BAM definitional model to examine the components corresponding to the functional layers involved in a BAM implementation project, section 7.6 describes the application development process within the Quantive BAM environment, and section 7.7 puts forward the lessons learned from this case study.

7.1 Assessing the Problem Situation

Prior to focusing on the Quantive BAM solution, it is important to understand the original reasons that motivated the AirLine to adopt a BAM system. These reasons should represent the requirement analysis derived from the initial expectations of the project owner with respect to the implementation project. To this end, we assess the regulatory requirements that the AirLine must comply with. Then, we highlight the difficulties encountered by the AirLine in complying with the requirements before the implementation project, as well as the technical constraints to be taken into account by the implementation project.

7.1.1 Regulatory Environment

All airlines operating flights within the U.S. territory are subject to the regulations issued by the U.S. Federal Aviation Administration (FAA). An important regulation issued by the FAA is AC 43.13-1B Acceptable Methods, Techniques, and Practices- Aircraft Inspection and Repair, which came into force on September 8\(^8\), 1998\(^8\). Chapter 10 of this regulation specifies requirements for the calculation of take-off parameters for commercial aircrafts and the disclosure of information compliance figures. Specifically, it determines that, during the loading procedure of a commercial aircraft, regardless of aircraft size, factors influencing the weight and balance condition of an aircraft, such as total weight and position of load as well as the amount fuel, must be monitored in order to detect significant variations in the position of the center of gravity (c.g.) of the aircraft.

\(^7\) Quantive, LLC [http://www.quantive.com](http://www.quantive.com)

Typically, significant weight variations can result from the load of heavy freight, or an exceptionally high fuel use during ground operation due, for instance, to airport congestion. Under such circumstances, the take-off configuration of the aircraft must be recalculated taking into account the current weight and balance condition.

The reason for issuing this regulation is to improve flight safety. It is simple to understand that if a significant weight variation takes place and no action is taken to recalculate take-off parameters, the aircraft could take-off with inadequate stabilizer settings. In this scenario, depending on the significance of the shift in the c.g. resulting from the non-computed weight variations, these changes could cause the aircraft to gain dangerous flight characteristics. To prevent this scenario from happening, airlines must have a proper weight and balance control system to ensure that the cockpit crew can always set the stabilizer trim properly.

The FAA regulation in question also emphasizes the need to improve accuracy on the disclosure of information about the occurrence of under-performance. Under-performance can be understood as those situations where the regulation is violated and, in the context of this particular regulation, aircrafts end up taking-off with inappropriate settings of the stabilizer trim. Nevertheless, to gather data about the under-performance to obtain crucial statistics, the FAA relies on data submitted by the airlines as failures are reported to FAA on a self-disclosure basis. On the face of it, the FAA is only able to enforce compliance by auditing the airline systems to assess the capabilities of airlines in complying with the regulation and reporting requirements.

Beyond risks for flight safety, non-compliance with the noted FAA regulation implicates that the airlines caught violating the AC 43.13-1B regulation can be fined. Consequently, the airlines must be able to demonstrate to the FAA through audits that their weight and balance control systems are capable of:

- Detecting significant weight changes as they occur and warning those responsible for the calculation of the take-off configurations
- Recording the weight and balance under-performance cases for audit purposes

7.1.2 Assessing the Original Situation

Despite the fact that the AC 43.13-1B regulation of the FAA has been in place for a long time, the AirLine has traditionally had difficulties in complying with the requirements imposed by chapter 10 of this particular regulation. Although the information about the weight and balance condition of the AirLine’s aircrafts could be encountered in several transactions executed by the AirLine for all flights, detecting significant weight variations in real-time was a major issue.

Typically, the full content of those transactions executed by the operational systems of the AirLine in relation to its flights are written to a “flight log”. Hence, the information on different factors affecting weight and balance of aircrafts can be found in the flight log. Nevertheless, the problem here is that the AirLine operates a total of about 2,500 flights per day, which means that huge volumes of data are written to the flight log. As a consequence, the task of searching for a particular transaction in order to identify exceptional weight variations was certainly a quite challenging one.

In essence, the primary problem encountered by the AirLine that difficulted compliance was that, although the information on different aspects of aircraft weight was available in the flight log, the AirLine did not have the capability to detect significant weight variations in real-time. To gather

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weight and balance data about a certain flight, the personnel of the AirLine had to search for the whole sequence of transactions associated with a certain flight and print out various sections of the flight log. This was a labor-intensive and time-consuming process that could only be justified by the most serious issues. Beyond this, as this process could take from hours to days, it could only be used for offline retrospective analyzes where situations had to be reconstructed. Consequently, the AirLine could not detect significant weight changes as required by the FAA.

7.1.3 Technical Constraints

Besides the need to ensure compliance with the noted FAA regulation, there were also important technical constraints to be taken into account when implementing a solution for the noted problem of compliance. The technical constraints stem mainly from the need keep the operational systems of the AirLine running.

Most of load and balance procedures are carried out by a transactional system, which is generically referred to as a 'flight operations system'. This is fundamentally a legacy system that has been used by the AirLine since the sixties. This old system, although stable and reliable, is not capable of providing real-time visibility into take-off parameters. Since the system was originally designed to carry out transactions rapidly and reliably, no mechanisms were included to monitor specific transaction information (we provide more detailed information on the architecture of the flight operations system further in this case study). As a result, despite the fact that the transactions processed by this system contain all information involving the weight and balance condition of aircrafts, it was not technically feasible to access this information during execution of these transactions. Additionally, the flight operations system alone does not detect the occurrence of significant weight changes. Just like other operational systems, the flight operations system writes all its executed transactions to the flight log. Nonetheless, as explained previously, the flight log does not provide real-time access to executed transactions.

The modification of the transactional system to satisfy the regulatory requirements would involve a long project and a certain degree of implementation risk. Yet, since the AirLine relies completely on the flight operations system to support the business processes associated with the flights, the risk of damaging the system is certainly not acceptable. Moreover, there were plans to replace the old system with a new one. These plans indicate that the new system will be fully operational a few years after the start of the implementation project and it will replace the flight operations system gradually as the new system is fully tested.

In summary, the main challenge for the AirLine was to improve compliance with the FAA regulation within a short period and, more importantly, without putting the reliability of the present flight operations system at risk.

7.2 Solution to the Weight and Balance Problem

To tackle the Weight and Balance problem, an event-driven application was designed to improve the AirLine's compliance with the AC 43.13-1B FAA regulation. This section describes this event-driven application by describing the event filtering conditions and by illustrating them with an activity diagram that can be encountered in appendix 6. This technique was selected because it allows for the description of the sequencing of activities, with support for both conditional and parallel behavior (Fowler: 2001, 129). In order to characterize the real-time decision support needs addressed by this event-driven application, we indicate the BAM recipient, the performance-indicator monitored by the event-driven application and the tolerance for latency.
The solution for the Weight and Balance problem was accomplished by raising alerts when significant weight changes occur and send the BAM alert, it is possible for the operational manager in the weight and balance department to take corrective actions to make sure that c.g. is positioned within acceptable limits according to the aircraft flight manual when aircrafts takeoff.

The essential idea is that the IWBT transaction, which is deemed the event of interest for this application, contains event properties indicating the weight of an aircraft. In this way, the application is able to notify BAM recipients the AirLine’s managers of the occurrence of significant weight changes.

Figure below provides a screenshot of all events properties contained by the IWBT. In table 7-1, some the most important event properties are listed and described.

<table>
<thead>
<tr>
<th>Line</th>
<th>Event Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Flight</td>
<td>The flight number, as seen by the traveling public</td>
</tr>
<tr>
<td>5</td>
<td>Date</td>
<td>The numeric day of the month</td>
</tr>
<tr>
<td>6</td>
<td>City_org</td>
<td>The origination city</td>
</tr>
<tr>
<td>7</td>
<td>City_dest</td>
<td>The destination city</td>
</tr>
<tr>
<td>9</td>
<td>ZFW_FWD_Limit</td>
<td>The “forward limit” of the center of gravity</td>
</tr>
<tr>
<td>10</td>
<td>ZFW_AFT_Limit</td>
<td>The “aft limit” of the center of gravity</td>
</tr>
<tr>
<td>11</td>
<td>ZFW_CG</td>
<td>The center of gravity value at the time of transaction</td>
</tr>
<tr>
<td>19</td>
<td>RMP</td>
<td>Aircraft weight before it leaves the gate (Ramp weight)</td>
</tr>
</tbody>
</table>
Table 7-1: IWBT transaction contains the following properties of interest for real-time monitoring purposes

Since the event properties associated with the IWBT transaction include information about the weight of the aircrafts, significant weight variations can be detected by evaluating some of the properties of the IWBT. In practice, this is accomplished by feeding the Weight and Balance application with IWBT transactions.

The Weight and Balance application monitors the ZFW_CG, RWMP_WT, and TOW_WT values concurrently. Whenever one of those values get within 2% of the forward and aft limit, an alert is raised\textsuperscript{10}. This application is illustrated in the appendix: 6 Weight and Balance application.

All alerts raised by the Weight and Balance applications are stored in the adjunct database. This makes it possible for the AirLine to report the occurrence of significant weight variations and the corrective actions taken by the AirLine.

Application Characteristics:
- Performance-Indicators: position c.g., total weight,
- BAM recipient: Operational Managers in the Weight and Balance Department
- Tolerance for Latency: -seconds-minutes

7.3 Other Implemented Event-Driven Applications

The preceding presented an overview of the application that was implemented to tackle the original problem. In this implementation project, the application designed and deployed to tackle the noted weight and balance problem was the starting point for the development of other event-driven applications. We now take up the some interesting applications that were developed upon the Quantive BAM solution. Although the airline’s decision to adopt the Quantive BAM solution was originally based on the need to improve compliance with the previously explained FAA regulation, several other applications were developed. To describe the other implemented event-driven applications, we use a similar descriptive structure.

By mapping the functional activities of the AirLine and the metrics associated with them, the need for other applications could be identified. At the present time, 10 applications and 60 filters have already been implemented by the AirLine. Among these 60 filters, 40 are kept active in order to generate alerts. These filters are configured to feed 10 applications (see appendix 4: Assessment Interview- Major AirLine & Quantive). According to Quantive, these 10 applications raise on average 30 to 40 alerts a day indicating exceptional conditions out of a total of about 2500 flights.

7.3.1 Freight Refusal

An interesting problem that was pointed out by business managers concerns the difference between freight that is booked for a flight and the freight that is actually shipped. This situation is referred to as freight refusal. For the sake of optimization of the AirLine’s resources, it is obviously

\textsuperscript{10} Information presented in the documentation of the filters implemented by Quantive at the airline.
necessary to make sure that a maximum amount of freight booked for a flight is loaded into the aircraft.

There are both legitimate and non-legitimate reasons for the freight refusal phenomenon. The list of legitimate reasons includes lack of space in the aircraft, insufficient time to load all booked freight before departure due to late arrival of the aircraft, no show if the freight was not delivered at the airport in time for the flight, loading equipment damage, etc. Non-legitimate reasons, in turn, consist of reasons that are not listed as a legitimate reason. In general, non-legitimate reasons result from employee failure.

For every flight of the AirLine, there is a ramp controller who is in charge of registering the status of booked freights in a manifest document. In case of freight refusal, the shipment controller is supposed to register the reason for not loading the booked freight. The need for developing an application to monitor the reasons declared for freight refusal can be attributed to the concern of management with respect to the reasons declared for not shipping products. According to Quantive, experience of AirLine managers indicated that situations in which ramp managers do not declare a legitimate reason for freight refusal tend to repeat on a regular basis.

The non-legitimate denial of service has negative consequences for the performance of the AirLine. The AirLine may have to pay to compensate shipment delays, or for deteriorated perishable products. As a result, the AirLine needed to identify the occurrence of non-legitimate freight refusal. However, as mentioned previously, the initiatives to investigate the reason for the occurrence of a freight refusal would require a time-consuming search, given the large volumes of data stored in the flight-log.

After the first IWBT is executed, a transaction containing event properties relative to cargo is also executed. We name this transaction the Cargo Transaction. Appendix 11 illustrates this transaction. The availability of transactional information on the status of freight was considered as an opportunity for the development of an application to provide real-time access into the occurrence of non-legitimate freight refusals.

Here, we make an assumption in order to simplify the representation of this application. First, we assume that the Cargo transaction contains an event property that identifies each product to be shipped, which we call PIC (Product Identification Code). Second, we assume the existence of an event property to indicate the status of all products that are booked for shipment in a certain flight, which is called SPBS (Status of Products Booked for Shipment). SPRS can assume the values:

- Confirmed, meaning that product is ready for shipment
- Cancelled, meaning that a legitimate reason exist for not shipping the product according to shipment book
- Shipped, meaning that product was loaded into the aircraft

By comparing the change of SPBS values during the loading process, it is possible to generate alerts indicating that products that were not shipped without a legitimate reason. This is done by searching for Confirmed products that do not change their status to Shipped in the course of loading process. In this case, it is possible to identify a failure of the ramp controller assigned to this flight. This application is represented in appendix 7: Shipment Control.

Application Characteristics:
- Performance-indicator:
- BAM recipient: Load Supervisors:
- Tolerance for Latency: Hours-Days
7.3.2 Monitoring Flight Planners

The AirLine also implemented an application to monitor the individual performance of flight planners. This category of employee is responsible for allocating resources for the flights operated by the AirLine. Flight planners work in a non-unionized department. After the IWBT is executed, the flight operations system executes a transaction that contains event properties indicating passenger destinations. The “Passenger Destinations” transaction can be found in appendix 11.

The Passenger Destination transaction is executed automatically for the first time between 150 and 92 minutes prior to departure. By comparing the current number of passengers with the previous state corresponding to the number of passengers, it is possible monitor the individual performance of a flight planner responsible for allocating resources to a certain flight. Ideally, the number of passengers shall not vary significantly, especially when it is near departure. Variations beyond a certain level, which was not revealed by Quantive, can signify that the flight planner is not keeping up with the changing status of the flight in a proper way (see appendix: Flight Planners Application). To prevent this, the AirLine can use this application to identify those flight planners who need to attend additional training.

Application Characteristics:
- Performance-Indicator: Variation in number of passengers near flight departure
- BAM recipient: Supervisor Flight Planners
- Tolerance for Latency: Minutes-Hours

7.3.3 Monitoring Dispatchers

It is important to indicate that not all applications that could generate business benefits were implemented. A good example of this is the concept of an event-driven application to monitor the dispatchers that maintain contact with pilots during flights. The idea was to monitor whether dispatchers were paying sufficient attention to all flights. Yet, in contrast to flight planners, this category of staff works in a unionized department. For this reason, the implementation of an application to monitor individual performance of dispatchers was likely to trigger political resistance from the unions. To avoid creating problems with the unions, the decision was taken to cancel the development and implementation of this application.

The experience gained with this application demonstrates that an application that the fact that an application is technically feasible cannot be seen as a guarantee for a successful implementation. This is an indication that the organizational circumstances are also an important aspect to be taken into account when designing an event-driven application.

Application Characteristics:
- Performance-Indicator: Time length of communication between cockpit crew and dispatcher
- BAM recipient: Supervisor Dispatchers
- Tolerance for Latency: Minutes-Hours

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11 Information presented in the documentation of the filters implemented by Quantive at the airline.
7.3.4 Differentiated Passenger Treatment

The applications described in above rely on real-time events to generate alerts. An interesting possibility, however, is to combine the analysis of real-time events with historical data. Although accessing data a Data Warehouse through the Quantive BAM environment is considered to be technically feasible by Quantive, this possibility has not been implemented by the AirLine yet. As a consequence of this, it worthwhile to demonstrate the possibility of adding contextual information to an event by querying a data warehouse. As an illustration of this, we use a simple example proposed by Watson (2003).

Passengers can receive differentiated treatment from the AirLine based on their recorded patterns of service usage. As those passengers that use the services of the AirLine more frequently generate higher revenues for the enterprise, the AirLine could allocate additional resources to make sure that the level of service for this category of customers is kept high. An exceptional situation in which a preferred customer could receive a differentiated treatment is the one in which a passenger has a connecting flight, but the acknowledgement of a delay in the arriving flight creates uncertainty whether the passenger is still able to catch the connecting flight. In this situation, an event-driven application can be employed to detect the need to speed up the handling of certain passengers that are in transit in a busy airport.

The “Passenger Destination” transaction contains information about the final destination of passengers. A passenger in an arriving flight can be a local (“lcl” passenger) or a passenger with a connecting flight (“thru” passenger). The event-driven application can identify the passengers with a connecting flight. After that, the application can check in the reservation system of the AirLine whether the connecting flight is scheduled to departure in less than 30 minutes. In this case, the application checks in a Data Warehouse the flying patterns of the passenger. In case, the passenger is classified as a preferred customer, an alert is generated that includes information about the connecting flight of the passenger to ground staff of the AirLine, who take measures to speed up the handling of the passenger (see the appendix: Passenger Destination Application for the illustration of this application).

Application Characteristics:
- Performance-Indicator: Variation between scheduled and expected arrival of flight and
- BAM recipient: Passenger Handling Personnel
- Tolerance for Latency: Seconds-Minutes

7.4 Mapping the AirLine’s Decision Support Needs

In this section, we list the primary characteristics of the problems addressed by the applications outlined in the preceding to determine the nature of problems addressed by the event-driven applications. In this way it is possible to improve understanding of the type of problems addressed by a BAM system with the system components employed by the Quantive BAM solution.

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12 Information gathered in a second survey on the Quantive’s BAM system. See appendix: Survey II-Quantive’s BAM system
13 Presentation available on the address: http://ra.okstate.edu:8080/ramgen/sharda/spirit/hwatson/trainer.smi
<table>
<thead>
<tr>
<th>Applications</th>
<th>Desirable Latency Range</th>
<th>Problem Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight and Balance</td>
<td>Seconds-Minutes (Alert)</td>
<td>• Sense-and-respond</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Exception Handling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Need for Immediate attention</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Consistent auditing</td>
</tr>
<tr>
<td>Freight Refusal</td>
<td>Minutes-Hours (Alert)</td>
<td>• Sense-and-respond</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Exception Handling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Operational Reporting</td>
</tr>
<tr>
<td>Monitoring Flight Planners</td>
<td>Hours-Days (Alert)</td>
<td>• Exception Handling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Provision of Diagnostic Information</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Operational Reporting</td>
</tr>
<tr>
<td>Monitoring Dispatchers</td>
<td>Hours-Days (Alert)</td>
<td>• Exception Handling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Provision of Diagnostic Information</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Operational Reporting</td>
</tr>
<tr>
<td>Differentiated Passenger Treatment</td>
<td>Seconds-Minutes (Alert) Months-Years (Context)</td>
<td>• Exception Handling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Diagnostic Information</td>
</tr>
</tbody>
</table>

**Table 7-2: Assessing the nature of problems tackled by the applications**

By observing the table above, we conclude that all application focus on the identification of exceptional circumstances. However, the need to become aware of the occurrence of such exceptional circumstance varies. Another relevant difference is that the Weight and Balance and Differentiated Passenger Treatment have low tolerance for latency, as there is a need to react rapidly to the occurrence of an exceptional event. In these cases, although these applications differ in the amount of context required to support an adequate reaction, it is clear that there is a short window of opportunity for reaction after the occurrence of the exceptional event.

### 7.5 Quantive BAM Solution

In this section, we apply the BAM definitional model to describe the functional layers of the Quantive BAM solution and to delineate the system. This allows us to gain familiarity with both the system components used by the Quantive BAM solution as well as the implementation environment. The choice for a component in each of the functional layers can be visualized as the main design variables involved in the development of a BAM system. Figure 7-2 illustrates the elements associated with each functional layer.
7.5.1 Event Execution

In this implementation project, the primary event of interest is a complex event, which consists of several transactions that are executed in a predefined sequence. The complex event can be defined as the set of all transactions containing flight information, such as parameters that influence weight and balance conditions of aircrafts.

As represented by figure 7-3, the initial weight and balance transaction (IWBT) is the initial transaction indicating the existence of a flight and, consequently, the start of the complex event. The IWBT contains the basic flight information and the first execution of this transaction confirms that a flight is scheduled for departure within about four hours\(^{14}\) (We present a complete overview of the event properties contained by the IWBT in the section covering the applications developed upon the Quantive BAM solution). There is a timing relationship between the IWBT and the other transactions carrying information about a certain flight. The IWBT can be deemed as the triggering event. After its execution, an event sequence consisting of transactions containing basic flight information about passengers, freight, fuel, and other elements of the flight is also initiated.

Figure 7-4 illustrates the events of interest that are monitored by event-driven applications that were deployed by the AirLine.

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\(^{14}\) Information presented in the documentation of the filters implemented by Quantive at the airline.
Figure 7-3: Causal history of a complex event initialized by the IWBT

Figure 7-4: Set of events of interest monitored by the AirLine
7.5.2 Event Sourcing

The Event Sourcing in this implementation project can be characterized as a Switched LAN. This results from the fact that the event streams monitored by Quantive BAM solution are mainly output by distributed operational systems based on switches located in places where the AirLine operates flights.

The primary source of event streams for this implementation project is the flight operations system. This is a transactional system that is primarily responsible for managing resources of all flights of the AirLine throughout the world. The flight operations system supports transaction-based applications used by the AirLine’s personnel to carry out business processes related to flights. Alongside the flight operations system, Quantive BAM solution also monitors event streams output by other systems that interact with the flight operations system, such as the Loading Planning System (LPS) and the AirLine’s reservation system. The LPS is a subsystem of the flight operations system, which was designed to automate the load planning processes. The LPS sits on the top of the flight operations system, but executes underlying transactions that require data from both the flight operations system and the reservation system (see appendix 4: Interview Quantive & AirLine). Figure 7-5 illustrates the interface topology of the target systems that serve as event source for the Quantive BAM solution by representing different existing views on these systems. It is valuable to mention that the system views provide for potential BAM recipients and their respective decision support needs.

System views

- Engineers of the AirLine use the LPS to configure Weight and Balance settings of aircraft based on the aircraft flight manual provided by aircraft manufacturer’s weight & balance manuals from manufacturers such as Boeing and McDonald- Douglas (see appendix 4: Interview Quantive & AirLine)

- Cockpit Crew relies on information processed by the flight operations system to adjust the flap settings of aircrafts before departure

- Dispatchers use information from the flight operations system to provide information to the cockpit crew during flight

- Flight Planners rely on the information from the reservation system to schedule resources

- Weight and Balance Managers use the flight operations systems to calculate total weight and c.g. of aircrafts
7.5.3 Event Acquisition

The Quantive BAM solution employs an event sniffer for the acquisition of events. This corresponds to the first functional layer that actually belongs to the Quantive BAM solution. Events of interest are collected as they occur by tapping into the switched network that supports the flight operations. In practice, the event sniffer was implemented by attaching the Windows Server running the event sniffer to a mirror port on the LAN switch that outputs flight operations system’s transactions. Since the data traffic behind the AirLine’s firewall is not encrypted, the properties of the events acquired by the event sniffer from the LAN switch can be directly interpreted.

The event sniffer gives access to a stream of real-time events moving over the Switched Networks as follows:
1. Listen to all packets that pass the event source, which is a LAN switch in the context of this implementation project
2. Filter raw events on a message base by means of continuous evaluation of event property
3. Forward captured events to appropriate application or storage device

Although the flight operations system is a distributed information system, it was not necessary to attach an event sniffer to all LAN switches around the world that handle flight operations system information. Since all flight information is sent to the worldwide control center of the AirLine, it was possible to implement just one “touch-point” in which all event information from all flights throughout the world can be captured.
There is a fundamental reason for the low implementation risks associated with this event acquisition mechanism is that the event sniffer does not affect the operational system supported by the target Switched Network. Because event sniffers cannot place data into the switched network, there is no risk of performance degradation in the operational system as no additional load is placed upon the servers and network resources (see appendix 4: Interview Quantive & AirLine). In this way, the risks associated with the implementation of the Quantive BAM solution are very low as it does not affect the performance and stability of the target operational system, thereby ensuring network’s security, performance and stability after the implementation of the Quantive BAM solution.

7.5.4 Raw Event Store

The real-time stream of raw events that is captured by the event sniffer is written to the raw event store. In the Quantive BAM solution, the raw event store is a real-time event store in the form of a flat file\(^{15}\). As a consequence, the raw events collected from the Switched Network by the event sniffer are stored in the real-time event store without changes. The real-time event store comprises a self-maintaining circular file, in which event data is rolled out as new event information arrives\(^{16}\). In the case of the implementation at the AirLine, information is stored online for the current and the previous month.

7.5.5 Contextualized Event Store

The contextualized event store in this implementation project is an adjunct SQL database. As with the event store, the events of interest are forwarded to the contextualized event store. However, the major difference here is that raw events are put into context by adding contextual information to it before writing to the adjunct database.

In general, the adjunct database is populated with the alerts generated by different applications developed upon the Quantive BAM solution. The alerts can be visualized as contextual interpretation of events. In order to detect the occurrence of complex higher-level events, it is also possible to search for combinations of alerts stored in the adjunct database. Additionally, the adjunct database serves as a repository of relevant information for auditing purposes, as it indicates the occurrence of exceptional events of interest. In this respect, it stores knowledge for additional analysis later.

Due to restrictions related to storage capacity, transactional data is kept in the adjunct database for a period of two months. After that period, contextual event information older than two months is archived.

7.5.6 Analytics

To identify the occurrence of an exceptional situation in real-time, the Quantive BAM solution employs state-machine filters. This type of filter serves to monitor event properties continually by querying events that are stored in the real-time event store. A state-machine filter works by evaluating the value of selected event properties corresponding to significant business performance-indicators. It does event matching by executing rules that represent pre-defined criteria that the events of interest should meet.

\(^{15}\) First Review of the Case Study. July13\(^{5}\), 2005.
\(^{16}\) Email interaction with Dr. Dwight Jones
In addition to the state-machine filter, the Quantive BAM solution also includes a query builder function that gives access to any database that has an ODBC interface. This function serves chiefly to gather contextual information from application databases, rather than supporting ongoing monitoring performance indicators. Yet, in the context of this implementation project, the query builder function is not used in combination with event-driven applications, but rather as a tool for obtaining information for Ad Hoc analyses.

The Quantive BAM solution does not use an event pattern language to interpret the events. The primary reason for not using an event pattern language, at this point, is due to the lack of a mature pattern language. Therefore the state-machine filters tend to remain the primary method of event analysis for the Quantive BAM solution.

### 7.5.7 How Functional Layers Interact

The applications built upon the Quantive BAM solution work in a similar way. In the context of this implementation project, issuing an alert requires the execution of the following steps illustrated by figure 7-6.

1. The switched networks execute transactions continually to support the business processes carried out by the airline.

2. The event sniffer captures the packet transactions, which can be seen as raw events of interest. Beyond acknowledging the existence of the raw events, the event sniffer also forwards all raw events to the real-time event store.

3. Once real-time events are received and the real-time event store is populated, a specific component of the Quantive BAM solution called “inquisitor” aggregates the raw events continuously into complete transactions, which can be visualized as events of interest. After completed, the transactions are sent to a state-machine filter that evaluates event properties based predefined constraints. When a constraint is matched, the corresponding event information is sent in the form of a broadcast message. Any application that needs this information will recognize the “package” and accept it.

4. The application we referred to is a standard Windows.exe application that is created using the Quantive’s application environment. Typically, an application accepts the “package” from one or more filters, performs edits on the data, adds the necessary context, issues alert, and stores results into the adjunct databases. Applications are event driven as they generate alerts to managers about the occurrence of exceptional events so that managers can make the appropriate process adjustment to deal with the situation.
7.5.8 BAM Class

Given the components of the Quantive BAM solution and the characteristics of the problems that are addressed by the applications developed upon it, it is possible to observe that the Quantive BAM solution fits into the “Pure BAM” class.

Figure 7-7: Representation of components in a “Pure BAM” BAM system

Provided the evidences presented in this analysis, Quantive BAM solution seems to fit in the Pure BAM class of BAM system. However, the solution also provides access to SQL databases through industry standard ODBC interfaces. This is an indication that the Quantive BAM solution can also be employed in an implementation project that requires a Report-Oriented class of BAM.

7.6 Understanding Quantive Event-driven applications

After analyzing the functional layers of the Quantive BAM solution, it is necessary to focus on the process involved in developing event-driven applications within the Quantive BAM environment. This should improve understanding of the relationship between the Quantive BAM solution and the applications developed upon it. To this end, we describe the process of developing and validating applications.
7.6.1 Developing an Event-driven application with Quantive Tool Set

Quantive BAM solution includes an application development environment, which is called the Quantive Factory. This environment provides business event modeling tools to specify event selectors used by applications to detect both single and complex events of interest. The application development environment, which is illustrated by figure 7-8, includes modeling functions that can be used to specify the performance indicators to monitor, mathematical formulas representing a pattern corresponding to an exceptional situation and the characteristics of the alert to be issued when the specified event is detected, which is normally delivered by graphic displays “dashboards” that are customized for different BAM recipients.

Since the interface of the Quantive Factory was designed for use by business managers, rather than IT engineers who demand months to deliver a solution, complete applications can be developed without the need for coding. For this reason, the development cycle of event-driven applications becomes much shorter as compared to conventional IT applications. This allows the development and deployment of many applications in less than a day.

![Figure 7-8: Graphical User Interface of Quantive event-driven application development environment. Source: Quantive.](image)

7.6.2 Validating Event-Driven Applications

After developing an event-driven application, it is necessary to validate the application by testing whether the filters that feed the applications are actually detecting the events of interest as intended, or whether the application is issuing false alerts. This is required to make sure that alerts are reliable. Basically, the validation process of applications can be accomplished by
carrying out two types of tests. Tests to validate applications include a manual comparison with a 
database and the test of constraints on executions.

In a manual comparison with a database, the new filters are fed with historical data from the 
airline. To be considered valid, a filter should detect those events that correspond to exceptional 
situations. Following this, a manual comparison of results delivered by event-driven application is 
done with a database.

In testing constraints on executions, filters are fed with simulated event streams to test whether a 
proposed constraint would warn of the occurrence of an exceptional situation. This is done to 
assess the accuracy of the filter.

Besides the validation process, it is also possible to fine-tune the applications over time as more 
experience is accumulated with the alerts raised by the application. This can be done by adding 
approximation filters that contribute to improve the accuracy of the alerts (see appendix 2: Survey 
2).

### 7.7 Lessons Learned

The case study covers the implementation of the Quantive BAM solution at an AirLine revealed 
some patterns that are likely to be present in other implementation projects involving BAM 
systems:

- Technology can be employed to improve compliance with regulatory requirements by 
  providing real-time access to operational events. In the context of this implementation 
  project, compliance was improved partly by creating capabilities for reducing the 
  likelihood of violations of the FAA regulation. Additionally, the Quantive BAM solution also 
  contributed to improve the reporting capabilities in terms of accuracy and timeliness as 
  required by the FAA. This results from the fact that the Quantive BAM solution supports 
  the creation of summaries of alerts from the adjunct database. Thus, the alerts can be 
  used to prepare traceable documents for auditing purposes.

- The implementation of applications upon the Quantive BAM solution was clearly 
  incremental and required Quantive developers and the AirLine managers to work very 
  closely. On the one hand, Quantive developers improved their understanding about the 
  source systems at the AirLine and business processes supported by those systems 
  through the gradual identification of the real-time decision support needs of AirLine’s 
  managers. On the other hand, the business users gained more familiarity with the 
  Quantive BAM solutions. This opened up new possibilities for broadening the scope of 
  the implementation project. The AirLine discovered that applications could contribute not 
  only to the improvement of compliance, but also to improve operational activities. Over 
  time, new applications were developed to allow the AirLine reacting to other exceptional 
  situations with significant business implications. There are evidences that there is an 
  ongoing demand to generate more alerts, which leads to the development of new 
  applications. Hence, the implementation project tends to become even more 
  comprehensive. The only limitation for the development of applications seems to be the 
  cognitive capacity of the BAM recipients, but, in this implementation project, the number of alerts per day has been relatively small.

- A valuable lesson was learned with respect to the influence of the BAM implementation 
  project on the operational systems of the BAM adopting enterprise. In fact, the BAM 
  system has been appropriately integrated with the legacy environment of the AirLine as 
  the implementation project did not affect the operational systems. In short, the 
  operational systems are absolutely not affected by the implementation of a BAM system.
• Additional insight was also gained regarding the characteristics of business processes and problems that the Quantive BAM solution is more suitable to monitor. This solution present characteristics of Pure-BAM BAM as it appears that the solution is highly applicable to schedule and control processes in which immediate response is required and a limited availability of contextual information is tolerated. However, there are also evidences that the Quantive BAM solution can be extended to become Discover-Oriented BAM by combining real-time events with historical data as demonstrated by the differentiated passenger treatment application.

• Another interesting lesson was that the technical feasibility is not the only condition for implementing a successful application upon a BAM system. Past experience with unions has demonstrated to the AirLine that unionized departments are likely to oppose the implementation of applications designed to judge individual performance of employees. Consequently, organizational issues should be taken into account when designing an event-driven application.
8 Conclusion

The organization of this chapter: section 8.1 provides answers to the research questions, section 8.2 presents the main research findings, and section 8.3 proposes directions for further research.

8.1 Research Questions

Here, we provide answers to the research questions presented in the introduction.

1 *Which variants of BAM systems can be distinguished?*

The research has indicated that a huge number of variants of BAM systems can exist, because a BAM system is comprised of out of four functional layers and there are different possibilities for components or combinations of them in each layer. However, we have found evidences that the choice for the data analysis tools, which is represented by the functional layer Analytics, is the choice that has the strongest influence in determining the type of business problems that a BAM system is suitable to address, as this choice determines the characteristics of the contextual information that can be added to BAM alerts. Accordingly, based on the choice for data analysis tools, we have identified four mainstream types of BAM systems based on the data analysis tools used by BAM systems. These four variations of BAM include a Pure BAM class that relies on a state-machine filters to analyse events, but add limited context to events, as well as combinations of this Pure BAM system with data analysis tools such as the “Discovery-Oriented BAM”, “Simulation-Oriented BAM”, and “Reporting-Oriented BAM”. The “Discovery-Oriented BAM” combines a Pure BAM with discovery technologies such as data mining, and OLAP. The “Simulation-Oriented BAM” combines a “Pure BAM” with event-based simulation engine. The “Reporting-Oriented BAM” combines a “Pure BAM” with ad hoc reporting tools.

2 *What are the characteristics of problems that can be addressed by the identified variants of BAM systems?*

The characteristics of problems that can be addressed by the identified variants of BAM systems are determined to a high extent by the need for contextual information to enable an adequate response to a significant event. In fact, we could observe that different variants of BAM are able to fulfill different decision support needs. The pure BAM system is suited to notify the occurrence of exceptional events that require immediate response, but does not require extensive contextual information. The other variants of BAM play an important role in extending the capabilities of the data analysis tools with real-time events, thereby reducing the latency that traditionally characterizes the output provided by most data analysis tools. We can observe that the combination of the “Pure BAM” class with simulation is appropriate for situations that require predictive monitoring. The combination of a “Pure BAM” system with operational reporting mechanisms and discovery tools, were characterized by the capacity to augment the event properties by adding historical information to it so as to provide better understanding of the monitoring situation. However, while the “Reporting-Oriented BAM” class adds context about running processes, the “Discovery-Oriented BAM” adds historical context to events.

3 *How do the different expectations of stakeholders impact the development of effective BAM systems?*

The research revealed that the competing values of stakeholders can have a significant impact in the implementation of a BAM system. Most stakeholders seem to benefit from the widespread introduction of BAM as there is major support for the technology. This results from the fact that the implementation of BAM is aimed at improving the performance of an enterprise. The only
potential obstacle is formed by the use of a BAM system for individual control. The categories of employees that can be monitored by BAM systems on an individual basis can oppose the implementation efforts. In organizational settings where these categories of employees are powerful, such as unionised departments, there is a major risk that BAM initiatives may be blocked by operating employees who are the target of the monitoring initiatives if their interests are not taken into account when developing an event-driven application.

4 To what extent does the regulatory environment to which enterprises are exposed affect the adoption of BAM systems?

The regulatory environment to which enterprises are exposed can be an important driver for the adoption of BAM systems. New regulations such as the Sarbanes-Oxley Act, BASEL II and the Patriot Act indicate that the regulatory environment will demand enterprises to develop capabilities to monitor events occurring in the IT infrastructure in real-time. Additionally, the case study has demonstrated that new regulations can be an important driver for enterprises to adopt BAM system as a means for improving compliance with industry specific regulation. By examining current regulatory developments, we could observe that regulators are demanding enterprises to disclose information on the enterprise performance in a more detailed manner and more frequently. Given these circumstances, BAM is likely to play an important role in supporting compliance as it provides real-time event notification and the possibility for storing recent business process execution for disclosure purposes.

After responding the research sub-questions, it is possible to provide an answer to the main research question.

The objective of this research project is to contribute towards the improvement of the existing theoretical foundation on business activity monitoring (BAM) solutions by providing an understanding of the relationship between real-time decision support needs and BAM system design solutions

The research presents evidence that the relationship between real-time decision support needs of enterprises and BAM system design solutions is determined by the need to ensure that the BAM system supplies BAM alerts that empower the BAM recipients, who are often operational managers directly responsible for the execution of business processes, to respond effectively to the event indicated by the BAM alert. In this respect, we could observe that to empower BAM recipients responding effectively to events, BAM systems depend on two fundamental operational issues. First, it is necessary to ensure short response times to enable the BAM recipient initiating response within the short time windows of opportunities associated with events. Yet, it is valuable to emphasize here that different events require different response times. Second, BAM recipients need to be able to understand the nature of the problem associated with the event so as to be able to initiate a proper response to address the problem. Here, the research reveals that to provide sufficient understanding of the nature of the problem, BAM systems, beyond sensing real-time events and generating low latency event-notification through BAM alerts, might also need to develop context for the BAM alerts to provide BAM recipients with sufficient understanding of the nature of the problem associated with the event and the appropriate response. Another fundamental considerations on BAM concerns the way the way the results of the analysis of events are presented. The fact that in BAM, the real-time operational insights resulting from the analysis of events is "pushed" to BAM recipients makes the need to add the proper contextual information to BAM alerts a critical requirement that requires a deep understanding of the real-time decision support needs of the BAM recipient.

To enable a better understanding of the need for real-time operational insights and, thereby, the need for contextual information to be added to BAM alerts, we have mapped the real-time decision support needs of enterprises in the process of designing the BAM definitional model. This allowed us proposing five problem categories to represent the real-time decision support...
needs of enterprises in terms of the characteristics of business monitoring scenarios faced by enterprises and the latency associated with contextual information that needs to be added to BAM alerts. Accordingly, we propose five categories of real-time decision support needs represented by the labels “Prepared”, “Sensitive”, “Responsive”, “Transparent”, and “Wise” to represent the need for operational insights. In short, the category Prepared represents those monitoring situations that require an anticipated response from the BAM recipient, Sensitive describes monitoring situations in which immediate response and limited information about the nature of the monitoring situation is required, Responsive covers monitoring situations where an adequate response must be guided by additional provision of additional context, Transparent describes monitoring situations that require a deeper understanding of the context of the monitoring situation, and Wise characterizes monitoring situation in which real-time events must be correlated with historical data.

Finally, we could observe that different variants of BAM systems are suitable to address different categories of real-time decision support needs. The most important factor affecting the functional characteristics of BAM systems is the choice for data analysis tools to provide context to BAM alerts. In this respect, we can distinguish between Pure BAM and Hybrid classes of BAM systems. While Pure BAM can be seen as rule-based systems focus on the analysis of real-time events, the Hybrid classes of BAM combine the Pure BAM with a data analysis tool to develop context for BAM alerts that is required by different real-time decision support needs. Hybrid BAM systems employ the outcomes of analysis delivered by data analysis tools. In this way, we have “Discovery-Oriented BAM” that relies on discovery technologies such as OLAP and Data Mining that rely on a data warehouse foundation, “Reporting-Oriented BAM” that employs Ad Hoc reporting systems, and “Simulation-Oriented BAM” that uses simulation engines. In terms of the applicability of the classes of BAM systems, we found evidences of the following relationships in terms of the relationships between classes of BAM systems and categories of enterprise decision support needs:

- The Pure BAM class is adequate to monitor the Sensitive category of decision-support needs
- Simulation-Oriented BAM is suitable to monitor Prepared and Sensitive
- Reporting-Oriented is appropriate to monitor Sensitive, Responsive, and Transparent
- Discovery-Oriented BAM is suitable to monitor Sensitive and Transparent

8.2 Research Findings

Besides answering the research question and sub-questions, this research has also generated a number of meaningful research findings that contribute to an improved understanding of BAM. The most valuable research findings include:

- The case study has revealed that the implementation of BAM systems tend to be characterized by the incremental implementation of event-driven applications. By providing business process owners with valuable real-time BAM alerts, they are likely to indicate other situations within the enterprise, where there is a need to reduce response times to significant events with negative impact upon the enterprise’s performance. Accordingly, over time, the scope and value of a BAM system is likely to increase as new event-driven applications tend to be continually developed and deployed.

- The research also found that BAM implementation projects are multi-disciplinary. The case study has demonstrated that the development of event-driven applications may often require familiarity with the technical elements such as the transactional systems of the AirLine that produce the event streams and the BAM system that monitors this event stream in real-time. However, besides IT technologies, knowledge from other disciplines is required to develop event-driven applications. We could observe that knowledge about
regulations and legislation can be required for the development of event-driven applications for the airline. Similarly, it is reasonable to assume that disciplines such as law, economics, finance, social sciences, and psychology could provide interesting support for the discussion about the development of event-driven applications.

- The decision support needs of BAM recipients can be characterized by a high degree of dynamics. In practice, the need to monitor events is often subject to changing business conditions. Therefore the development of event-driven applications to monitor certain event of interest have a short duration, otherwise event-driven applications can be delivered after the need for the application has passed.

8.3 Directions for Further Research

The research has also enabled us to identify a number of directions for further research. Here we highlight areas where further research is recommended:

- Enterprises operating in the same industry normally carry out similar business process. For this reason, they tend to have similar problems and, thereby, similar decision support needs. So, by looking at different BAM implementation projects in the same industry, it should be possible to possible to map the real-time decision support needs of enterprises in the same industry. Such an initiative should open up possibilities for the reusability of event-driven applications. Hence, we see industry specific analysis of real-time decision support needs as an interesting direction for further research.

- Since BAM systems are capable of crossing the enterprise boundaries by gathering events from different sourcing systems outside the boundaries of the enterprise, one non-technical obstacle that may emerge is a legal restriction to monitoring initiatives resulting from ownership of event data. In fact, we have seen that the transactional system of one enterprise usually processes transactions that include information from customers, suppliers, and partners. At the present, there is limited understanding of the impact of data ownership issues on BAM implementation projects. But provided the fact that many are not likely to wish to share their operational data for valid reasons, such as privacy, security and data integrity, data ownership issues may form a potential bottleneck in BAM implementation projects. Consequently, it is necessary to conduct research that clarifies the effect of data ownership on BAM.

- The BAM definitional model can be employed to assess more BAM systems available in the market. By examining several BAM systems, it will be possible to check whether BAM systems that occupy a similar position in the model indeed address similar categories of problems. This can provide an indication of whether the current model is able to capture all relevant elements that affect the functional characteristics of BAM systems.

- There are many evidences to be observed that BAM alerts can be ignored in case the BAM recipient is overwhelmed by too many alerts. It is known that the ability of BAM recipients to interpret the information contained in BAM alerts is limited. However, at this point, the maximum number of alerts that can be received by a BAM recipient is not known, especially because alerts can contain different types and amounts of contextual information. For this reason, further research is required to assess the interaction between a BAM alert and the BAM recipient to avoid the cognitive overload of BAM recipients.
Literature


Appendix 1: Quantive Survey 1

Meeting Notes: March 28th, 2005.

Participants:
- Professor Dr. Richard J. Welke; Georgia State University
- Gabriel Cavalheiro; Delft University of Technology
- Dr. Dwight M. Jones; Managing Partner of Quantive LLC
- Bernd Harzorg; CEO of APM Experts

<table>
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<tr>
<th>Points of Discussion</th>
<th>Insights</th>
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| BAM’s Origin                         | • Gartner’s Middleware Group  
• Zero-latency enterprise  
• Roy Shulte introduced the concept of the zero-latency organization some time back  
• Premised on projections of a transition to a message-based architecture  
• Along came the Internet (and e-Business) and this didn’t happen  
• BAM became somewhat orphaned; the “next step” based upon an architecture that didn’t play out  
• Now into a new architectural stack that has both messaging and events, but is taking time to take hold, and thus so also BAM  
• However, major players (SAP, Oracle, MS, etc.) having difficulty transitioning to the new architecture, and organizations unwilling to ‘drink this cool-aid.’  
• Above serves to ex-post explain why BAM hasn’t taken off as Gartner (and others) predicted. |

| Current Problems faced by BAM developers | Figuring out target market  
- Which industries?  
- Which companies in a certain industry?  
- Specific or generic solutions?  
- Which problem owners (with which identifiable or known problems)  
- Having access to upper layers of management and a sufficient degree of management attention.  
- Indicating more precisely all possible benefits that can be enjoyed by the end user, when the developer does not know the business of the end user in a complete way. |

| BAM Drivers                           | Decision support systems are not capable of generating instant views on enterprise performance, given delays associated with the process of capturing data from transactional systems, transforming and loading it.  
- Enterprises need to become less plan-oriented and more agile to respond to competitive and changing environment  
- Certain business events are “perishable” as they lose value over time. BAM-style solutions are intended to capture those events in real-time in order to enable enterprises to benefit |
from this information

| Capability | • Filter all messages that pass through a message bus  
|            | • Enable two-levels of agility:  
|            | • Access to business transactions in real-time;  
|            | • Communicate meaningful information to interested user |

| Characteristics of Implementation Projects | • Incremental development. By discussing patterns/filters with customer, additional insights were gained in new problems  
|                                             | • Validation problems with filters missing some events, but solved by incorporating additional filters  
|                                             | • End user driven rather than technology driven |

| Quantive “architecture” and Service Product | • Capture criteria  
|                                            | • Extract criteria  
|                                            | • Addition of proximity filters |

| BAM filtering “patterns” | • Identifying filtering “patterns” is the biggest challenge  
|                          | • Implementing BAM filtering “patterns” is a task that does not demand highly specialized skills  
|                          | • Examples include:  
|                          |   ○ Monitor dispatcher  
|                          |   ○ Identify causes of delays  
|                          |   ○ Trigger activities such as redistributing the load in an airplane, when additional load is confirmed  
|                          |   ○ Identify money laundry |

| Significant Social Impact | • The introduction of monitoring practices may cause unions to oppose the project. |

| Regulatory Drivers | • Section 404 of Sarbanes-Oxley determines the need to monitor enterprise information systems. Consequently, enterprises will be forced to adopt monitoring systems (BAM systems) to comply with regulation.  
|                   | • Patriot Act is likely to force enterprises in the finance sector to improve capabilities of detecting money laundering. These capabilities can eventually be delivered by BAM solutions. |

| Additional insights | • More creative solutions tend to emerge when the IT department is not involved  
|                    | • IT departments deliver solutions after months. However, certain solutions are needed in terms of hours  
|                    | • BAM application can also support process re-design |
Appendix 2: Quantive Survey 2

Date: March 31st, 2005.

Participants:
- Professor Dr. Richard J. Welke; Georgia State University
- Gabriel Cavalheiro; Delft University of Technology
- Dr. Dwight M. Jones; Managing Partner of Quantive LLC
- Dennis E. Cox; Chief Technology Officer of Quantive LLC

<table>
<thead>
<tr>
<th>Points of Discussion</th>
<th>Insights</th>
</tr>
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</table>
| History of Quantive’s BAM solution | - Quantive development process took four years.  
- Project started with the integration of data from different sources, including databases and call center |
| Main design goals             | - Design applications in one day rather than months  
- Possibility of getting IT developers out of the loop because  
  - Business managers are the ones with the higher understanding of business needs.  
- Possibility of getting IT developers out of the loop by  
  - Creating a simple and flexible tool to create applications such that business manager can develop applications/filters |
| Medusa: Quantive’s application | - Is a service that runs on the machine  
- If an application goes down, it detects. |
| Inquisitor                    | - Extract data. Can run on many different machines.  
- The inquisitor shows the use of the package in a general-purpose utility, which permits modification of a remote device.  
- It entirely manages an application  
  - You can see where applications are not updated  
  - Ability to see every application  
  - Ability to see version number  
  - Scenario: Create applications in Dallas and send to Tokio to save training |
| Packet Sniffer                | - Extract transaction from a switch and put it in a flat file.  
- Secure because Enterprises can restrict access to their switches  
- High data load to flat file  
- Tool to upgrade/restart application |
| Filter                        | - Objective: find a message of desire  
- Developer has to have a feeling for the application and the business needs  
- Filters are saved in the registry of the machine  
- In the current Quantive development environment, the filter creates subsets of transactions  
- Copy/paste filter from one machine to the other machines is
| Possible | Creating filter in collaborative way is feasible  
| | Select packet based on one value according extraction criteria  
| | Filters have a number of definitions  
| Context | When a filter captures an event, contextual information such as date, time and sequence can be added  
| | Query results can also be used to add context to event.  
| | Data warehouse can also provide contextual information  
| Theoretical Gaps | What are the patterns of events that justify real-time identification of events?  
| | What is the dividing line between: BAM, Data Warehouse, and Business Intelligence?  
| | Is there a set of criteria defining BAM?  
| | What is the scope and scale of a BAM solution? What can you do?  
| BAM versus data warehouse | BAM. Extrapolation from today’s data  
| | Data Warehouse. Extrapolation from the last month’s data  
| Need to discover critical patterns | There is a managerial problem → there is a pattern associated with the problem → BAM system does something useful with the pattern  
| Predictive BAM | Simulation model tries to predict outcomes ahead  
| | Simulate forward recognition
## Appendix 3: Glossary BAM Definitional Model

<table>
<thead>
<tr>
<th>Layers</th>
<th>Atomic Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Event Execution</strong></td>
<td></td>
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<tr>
<td>Raw Event:</td>
<td>A raw event refers to the messages running across the enterprise information systems that contain information with business meaning and relationships with other messages/raw events.</td>
</tr>
<tr>
<td>Digitized Events:</td>
<td>Digital messages that represent a raw event in the real-world.</td>
</tr>
<tr>
<td>Single Event:</td>
<td>This an event that consists of a single message t</td>
</tr>
<tr>
<td>Complex Event:</td>
<td>A template that specifies multiple events and their order and timing, the data they may contain, as well as other information (Luckham: 2002, 37).</td>
</tr>
<tr>
<td><strong>Event Sourcing</strong></td>
<td></td>
</tr>
<tr>
<td>Switched LAN Networks:</td>
<td>Packet-based networks provide dedicated channel between sender and receiver connected to the same network (Ozsu &amp; Valduriez: 1999, 62).</td>
</tr>
<tr>
<td>Packaged Application Systems:</td>
<td>Commercially available software that addresses a specific type of business process (Alter: 1999, 427). Applications include Customer Relationship Management (CRM), Enterprise Resource Planning (ERP), and Business Process Management (BPM).</td>
</tr>
<tr>
<td>Object-oriented middleware:</td>
<td>serves to make requests and receive responses synchronously and in a transparent way. Operation in synchronous mode means that applications are aways in run state and, as result, the unavailability of a destination application causes the loss of a message (Serain: 2002, 26).</td>
</tr>
<tr>
<td>Message-Oriented Middleware (MOM):</td>
<td>In MOM, the sending application (the client) puts its message in its output message queue, and continues with its processing while the MOM middleware product transmits the message to the input queue of the receiving application (the server), that will read this message as soon as it becomes available (Serain: 2002, 27).</td>
</tr>
<tr>
<td>Supervisory Control and Data Acquisition (SCADA):</td>
<td>A SCADA system allows an operator to make a set point change on remote controllers to open/close, valves/switch, to monitor alarms and to get instrument information from a local process to a widely distributed process such as an oil/gas field, a pipeline system, or hydroelectric generating system (Horng: 2002, 363).</td>
</tr>
<tr>
<td>Manufacturing Execution System (MES):</td>
<td>A MES provides for the integration of a manufacturer production process, including automated systems as well as people and paper intensive. MES integration provides easy real-time access to all elements of a manufacturing operation (Duel: 1994, 115).</td>
</tr>
<tr>
<td>RFID:</td>
<td>This technology allows the transfer of data wirelessly between readers and labels on the goods (Royal Philips Electronics: 2005, 3).</td>
</tr>
<tr>
<td>Cookies:</td>
<td>a solution for storing contextual information in browsers (Serain: 2002, 185)</td>
</tr>
<tr>
<td>Event (Packet) Sniffers:</td>
<td>These utilities monitor some set of interesting traffic on a network. Event Sniffers can filter and record the traffic that they see (Kimbau &amp; Caserta: 2004, 440).</td>
</tr>
</tbody>
</table>
| Event Acquisition | **Integration Broker:** This piece of software is responsible for routing messages between adapters, in accordance with its publication and subscription metadata (Kimball & Caserta: 2004, 447).  
**Database Trigger:** A procedure that is invoked automatically when a predefined event occur in a database (e.g. a data entry or a query).  
**Agent Technology:** An agent is a small program or software object that performs one task with the information it is fed, usually a stream of events, and passes on the results. The agents perform their individual tasks and are constant communication with one another to achieve some overall objective (Luckham: 2002, 21).  

| Raw Event Store | **Real-time event store:** a repository of event executions that is populated by events as they occur.  
**Transactional Message Warehouse (BPM):** log-file of BPM products that contains record of executions.  
**Application Security Log:** It records the transactions between clients and a web servers (Giovinazzo: 2003, 272).  
**OLTP Systems:** These systems track business events (e.g., airline reservation or banking systems) and the entities associated with those events (e.g., customers and products) from creation to completion. However, in general, OLTP systems do not maintain history of an entity’s prior status. Entities are usually retained while there is an open business event or likelihood of an incoming event (McElreath: 1998, 527).  
**Operational Data Store (ODS):** It is a first-generation data warehouse construct intended to support lower-latency reporting through the creation of a distinct architectural construct and application separation from the data warehouse (Kimball & Caserta: 2004, 426).  
**Real-Time Partition:** It is a separate real-time fact table whose grain and dimensionality matches that of the static data warehouse. The real-time fact table contains only the current day’s facts that are not yet loaded into the data warehouse (Kimball & Caserta: 2004, 426).  

| Contextualized Event Store | **Adjunct Database:** database used to store the results of analyses. In BAM, it can be used to store BAM alerts.  
**Look Up Table:** A data structure, usually an array or associative array, used to replace a runtime computation with a simpler lookup operation (en.wikipedia.org/wiki/look_up_table).  
**Spreadsheet:** A file in which data can be stored in an unstructured way.  
**Data Warehouse:** It is a set of subject-oriented, integrated, historical, non-volatile data, comprised of both summarized and detailed data in support of the decision-making process (Inmon et al: 2001, 93).  
**Repository of Discovered Information/Knowledge:** This storage facility can be used to store the information/knowledge about enterprise operations obtained from the analysis of historical data. This repository of discovered information/knowledge can be used to support the development of new event filters, Ad Hoc queries, and Data Mining models.  

| Analytics | **Complex Event Detection:** A complex pattern matcher breaks down its pattern and sends the single event patterns to single-event pattern matchers (Luckham: 2002, 349).  
**Ad Hoc Query:** The use of query statements to monitor huge data sets on a random basis (Inmon et al: 2001, 31).  
**OLAP:** These tools aggregate data along common business subjects or dimensions and then let users navigate through the hierarchies and dimensions (Berson & Smith: 1997, 226).  

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**Data Mining:** These tools that use a variety of statistical and artificial-intelligence (AI) algorithms to analyze the correlation of variables in the data and reveal interesting patterns and relationships with useful business meaning in large data sets (Berson & Smith: 1997, 227).
Appendix 4: Assessment Interview: Major AirLine & Quantive

Date: June 11th, 2005

Participants
- Janice Wiewiora (Infrastructure Support Personnel at the Major AirLine)
- Dr. Dwight M. Jones; Managing Partner of Quantive LLC
- Gabriel Cavalheiro

Interview format: Voice conference via the telephone (non-recorded) with follow up email edits

Questions

1 I would like to gather more background information about the Flight Operating System (FOS) and the Load Planning System. Could you describe the main characteristic of this system?
   - Characteristics of FOS
     - Reliable
     - Old- decades
     - Supports the operations of all flights all over the world
     - Audited by the FAA
     - Includes a Load Planning System (LPS), which is a system designed to automate the load planning processes
       - LPS process data from the FOS and the Reservation System

2 What are the major developments going on around the FOS?
   - Major developments include:
     - New system is being developed to replace FOS
     - In process of rewrite of new system- 2006
       - Replace a lot of hardware and software to allow the progressive replacement of FOS
       - FOS is expected to run for a few years- last to cut over are the dispatchers
     - New system will run in parallel with the FOS until sufficient trust is gained in the new system

3 Could you describe the FAA regulation motivating the filters? - More background information about the regulation will be very helpful.
   - AA engineers configure Weight and Balance settings in the LPS based on specifications provided by the manufacturer of the aircrafts (e.g., Boeing and McDonald-Douglas)
   - FAA regulation indicates the need to audit the operational systems of the airlines
   - Weight and Balance systems/applications need to be approved by FAA

4 How many filters that have already been implemented?
   - 60 filters have already been implemented
   - 40 filters are active
5 Does the AirLine record the information filtered? Or just generates an alert when an exceptional situation is detected?

- 20 filters are actual gathers of information
- Information is generally stored on-line for the current month and the previous month. Older information is then archived.
- Database system used by Quantive is SYBASE

6 What areas do the filters monitor?

- Payload (actual closed to planned)
- Fuel (savings on fuel)
- Freight and Main refusal
- Weight Restricted Flights
- Maintenance (MEL’s) - safety issue

7 Has the AirLine experienced resistance to the implementation of any type of monitoring?

- Non unionized departments tend to be more receptive for the filters (They are powerless to stop it)
- Concept of a filter to monitor dispatchers was not implemented, because dispatchers are a unionized category of employees.
  - Unions can be regarded as a possible source of requirements for filters. If unions are ignored, unions can attempt to block the implementation of a filter
- Implementation of Quantive BAM solution does not affect integrity and performance of operational systems because:
  - Quantive is ‘invisible’ - non-intrusive; no re-engineering required.
  - It does not communicate with operational systems

8 Could you describe briefly the adoption process of Quantive BAM solution? Was the AirLine aware of the problems to be solved by the solution or did the technology generate the ideas for improving the business processes?

- Technology was presented: “Wow: look what we can do!”
- AirLine agents realized the potential contribution of a new technology to solve existing enterprise problems
- Implementation of the solution has been an incremental process. The more familiarity is gained with business processes and the BAM solution, the more concepts for new filters emerge
  - “Viral” - one solution leads to awareness of capability to deal with another
- Quantive BAM solution was designed to be simple to use by the AirLine employees

9 Are there plans to extend the Quantive BAM solution with other analytical tools such as data mining?

- The extension of the system is expected to happen through the creation of new filters, but there are no plans in sight to use data mining tools in this particular implementation
Appendix 5: Assessment Interview- David McCoy

Date: June 14th, 2005

Interviewee: David McCoy (VP and Gartner Fellow)

Interview format: Recorded interview via telephone with follow-up email edits

Questions

About the origin of the acronym BAM:

1. Did Gartner introduce the acronym BAM as a proposition for a new functionality to be developed by software vendors or was the acronym introduced to describe a functionality that already existed, but was not properly named?

David McCoy: The BAM acronym was coined by Gartner (Roy Schulte to be exact) in anticipation of an emerging market. I took over the lead role on the BAM research and led a team that drove the term to market. We had some vendors tell us (paraphrasing) "we knew we did something new and exciting... until we had the BAM term, we did not know what to call it."

I have a question about the demarcation of BAM systems.

2. Do you consider the response-cycle an aspect that should be covered by a BAM solution? Or do you consider the response-cycle to be outside of the environment (e.g., using alerts to trigger a BPM workflow)?

David McCoy: The reaction cycle can be part of the BAM solution. Obviously, we stated in the definition that BAM involves providing real-time access to critical business performance indicators. So, we assumed that someone must be using the alerts provided by the BAM system. Since then, I published research that classifies four different types of response-mechanisms and, in that research, I proposed that BAM systems can make use of dashboards, with or without return loops. Different dashboards can include capabilities for you to automatically or manually react to the event. The manual reaction could be getting an alert and taking action, and the reaction could be part of the BAM system, but it doesn't have to be. As I said, a BAM system could also include an automated response: A BAM alert comes in, and the system automatically responds to the alert, either by changing a value or even initiating a workflow transaction. In some cases, the BAM system incorporates part of the application’s automatic or manual response capabilities. In other cases, the BAM systems provide the alert and someone uses other systems and tools to address the alert. I think in the definition we always make use of alerts. It remains a requirement for the BAM infrastructure to provide the ability to take response to an alert, but the response may or may not be part of the BAM system itself.

3. Is it possible to say that the response support can be considered as the natural function of a workflow?

David McCoy: That is certainly an example that I talked about in the article I wrote about the response classifications. I think that I called that Guiding BAM. The system can take the alert and provide you with the ability to trigger a workflow. You can use BAM or any other system to
respond outside the BAM environment. You’re correct to assume that the definition does not push you to have a complete response-cycle within the BAM tool itself.

Next question is about the current level of adoption.

4 Do you now about the current degree of BAM diffusion? Are there statistics concerning the number of BAM implementations? Can you say that the early-adopter phase has already passed?

David McCoy: I couldn’t say that BAM has reached that level of penetration. It is hard to imagine that BAM is beyond the early adopter phase. It is still very poorly penetrated. Revenues associated with BAM are still not that high. Take the total revenues of pure-play vendors, plus allocated revenues of those who provide products related to BAM, plus vendors of other types of BAM functionality such as that provided by application integration vendors and BI vendors offering BAM, we are talking of under 200 million dollars of revenues. So, it is still very small. I would say that the BAM penetration is certainly less than 5 % of enterprises right now. These are characteristics that you can find in the early adoption phase of technologies. So I don’t think I can say that it is beyond the early adopter stage.

5 Do you think that BAM can be considered as a mature technology?

David McCoy: The technology is already pretty good. It can be considered mature, but the market is certainly not mature.

By talking to Dr. Dwight Jones from Quantive, I realized that the beginning of a BAM implementation process is very difficult because the vendor needs to have knowledge about the business processes that will be monitored by the BAM solution. Therefore it appears to me that there is a need to identify the business processes that require real-time performance monitoring.

6 I would like to know if you are aware of existing initiatives to develop libraries of BAM applications for specific industries?

David McCoy: Vendors are individually attacking the BAM market and trying to build vertical market credibility. One way they do this is by understanding the vertical market (industry) and picking the low-hanging-fruit – those initiatives where vendor and client can both derive benefit from BAM. I have always advised most vendors, especially the smaller ones, to approach BAM with an application-centric mission – to target specific applications for BAM and not to try to sell BAM as a general infrastructure. However, I am aware of no comprehensive initiatives to build libraries of BAM applications for specific industries at the industry level. All of the activity is taking place at the level of the individual vendor. As for knowing which processes to monitor, I think what is happening right now with BAM is that enterprises are becoming more aware of the technology. More projects are considering using BAM. An interesting application is credit card fraud detection. Telecommunications, being able to monitor for long distance fraud, is another area that would benefit from BAM. There are other pretty obvious areas. But I don’t know about any high-level initiatives to develop libraries of BAM applications. It is more likely that certain BAM vendors will explore the market of specific industries. In my view, you can sell BAM as a general tool or you can sell it as a specific application for a specific area, such as call center.
7 So, it seems that the vendors themselves are likely to develop their own BAM libraries. Do you think this is the only possibility for the development of BAM libraries?

David McCoy: There are existing initiatives such as RosettaNet for business processes (BPM) – a similar effort can certainly be repeated in BAM. Rosetta Net transactions were designed to create standards for business processes. As the market for BAM matures, it is possible that the same thing will occur with BAM – standard templates for BAM. But right now I don’t think the market is mature enough to do that. What happens is that vendors are accumulating experience and trying to leverage that experience to build their own libraries.

About the technology incorporated in the current BAM solutions.

8 Have you seen BAM implementations that make use of event pattern languages such as CEP and Complex Event Infrastructure (CEI)?

David McCoy: No, in terms of broad scale use of the IBM initiatives, I don’t think it is very mature at this point. Obviously, IBM will be using CEI, but I haven’t seen vendors that include CEI in their BAM solutions packages.

9 Has Gartner already identified best practices for BAM implementations?

David McCoy: We did some best practice analysis. Bill Gassman (a fellow Gartner analyst) wrote a best practice guide, where he defined two specific categories of best practices for BAM implementations. One is around process and the other involves culture. These are non-technical best practices. Process refers to understanding how to link and collect the events, then how to construct the rules, and how to analyze the results. A key best practice is to avoid overloading the BAM recipient (avoiding cognitive overload of the BAM recipient). Culture refers to how to monitor people in an organization. Embracing the human side is an important aspect of the BAM approach.

You partly answered this question by giving examples of possible BAM implementations. But it seems interesting to know more about the market expectations for BAM solutions.

10 What are the industries that are more likely to adopt BAM solutions?

David McCoy: The Financial sector is always one of the top sectors in adopting new technologies. Financial services are always a great place to start looking. Government seems to be promising. Security and terror contribute to the need for real-time monitoring. A lot of BAM concepts come from the manufacturing sector with its need for real-time monitoring to support process control. In addition, the retail sector can employ BAM to track customer activity.

Finally, the last question.

11 Do you think it is likely that non-US based companies are likely to have already introduced software products to the market that are similar to BAM? Or are all BAM development initiatives concentrated in the U.S.?

David McCoy: There is no restriction to BAM being a U.S. phenomenon. In fact, I’ve assessed BAM solutions developed by non-U.S. companies. Goods historical examples include a company called Modusnovo from Israel. In Israel, with the country’s high tech background, we saw a lot of
very smart concepts emerge there. There is no geographic restriction as long as companies are delivering BAM. Also, there is a French company called Systar. They have a solution similar to BAM. They call it business performance monitoring. This is one of the different acronyms. BAM is a worldwide opportunity.

Thank you very much for your time. I appreciate you taking time from your busy schedule to speak with me.
Appendix 6: Proposed BAM Definition Models

Event Latency-Range

- Miliseconds
- Seconds
- Minutes
- Hours
- Days
- Months
- Years

Decision Support systems

Tactical Decision Making

Strategic Decision Making

Process Redesign

Detect Market Changes

Detect Market Changes

Detect Market Changes

Detect Market Changes

Support Selection of Paths within Preset Scenarios

Anticipate to Future Scenarios

Detect Performance Bottlenecks

Detect Performance Bottlenecks

Detect Performance Bottlenecks

Detect Unusual Patterns of System Use

Ensure Policy Compliance

Detect Fraud

Ensure Accuracy of Reports

Carry out Targeted Advertisement

Obtain Performance Insight from Historical Information

Event-Oriented

Historical Data-Oriented

Version 1: 08/04/05
Version 7: 27/04/05
Version 8: 29/04/05
Appendix 7: Weight and Balance Application
Appendix 8: Freight Refusal Application
Appendix 9: Flight Planner Application
Appendix 10: Service Differentiation Application
Appendix 11: Release_WBP (Used for tracking cargo)

Screenshot provided by Quantive
Appendix 12: Release Passenger Destination

Screenshot provided by Quantive