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FACULTY OF ECONOMICS AND BUSINESS ADMINISTRATION

PhD THESIS

CONTRIBUTIONS TO INFORMATION SYSTEMS USED IN CAPITAL MARKETS

- SUMMARY-

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INTRODUCTION

The present scientific work, entitled “Contributions to Information Systems Used in Capital Markets”, approaches the subject of programming / development of information systems dedicated to the capital markets in its determinant aspects. More precisely, we wish to reach a coherent vision over the context in which the information systems are used in the capital markets and to introduce the main system components necessary for the functioning of the representative institutions activating in the capital markets. In this context, we perform the analysis of the current situation in this field, we present in detail the major system types and evolution trends and we make an overall presentation of personal contributions to the field, most specifically risk and execution systems, with all their components.

Delimitation and motivation of the research subject

The subject for the PhD thesis has been chosen in order to facilitate the PhD candidate’s scientific research activity, which has been and continues to be his main field of activity for more than 10 years. I have considered it to be important and useful to focus on this complex matter of the systems used in the capital markets from an academic point of view, and with challenges of a different nature, compared to those related to an applicative work.

In order for the thesis to be thorough and well fundamented, it is important to rigorously delimitate the area of interest within the subject and to identify a common scientific research and study stream, leading to a unitary vision over the field of activity, a vision identified on scientific bases.

In **chapter I** the subject of the paper is introduced, along with its objectives. The purpose of the research is to present several contributions to the development of system architectures intended for the capital market and to identify the major characteristics at the level of each of them, for supporting all the necessary functions at the level of the participating institutions on the capital market. The functionality of these systems is implemented using a combination of components, both common and dedicated, and we will present the major considerations which must be taken into account as well as the personal contributions.

In order to maintain the realistic purpose of the thesis, only some of the proposed components will be taken into account for implementation, namely the communication levels between systems, the risk and execution system and certain hybrid systems. In order to elaborate such an architecture, it is important to consider, first of all, the major participating agents in the capital markets (i.e. New York, London, Hong Kong, Tokyo etc.), namely, mostly the stock markets, investment banks, brokerage houses and investment / hedge funds.

To approach this subject, we will use a significant amount of information, much of which can be found mainly within the system documentations associated with the participating institutions in the capital markets but also in materials published in the specialized literature, both applicative and research related.

Current status of the knowledge in the field of activity

In order to complete such a subject, we consider as necessary the following elements:

- Thorough studying of the specialized literature in the field,
- Studying of the approach and implementation methods for this type of systems,
- Searching for IT implementation instruments for components in the architectural hierarchy of such systems.

The scientific research performed refers to the systems used in major capital markets, as we have mentioned before, and less to the market structure and participants in adjacent or minor markets. The reason behind this choice is that in the case of major markets there is already a profound experience in the field, which can be used for research and also, it is expected that, in general, the newly emerging markets will be based on solutions already identified within the well established markets.

The subject related literature is abundant, on one hand, but on the other quality materials are relatively scarce because most of the research and applications remain inside their owning institutions, without being accessible to the broad public.

The knowledge of the field is mostly based on applicative solutions, used in general within specialized institutions and probably in a relatively limited amount, on academic or public research. The materials are rather abundant but, overall, the difficulty consists in extracting the valuable aspects emerging in the public domain and applying them within specialized institutions.

Rather often, relevant aspects for scientific research may be sourced from technology providers used within relevant institutions, providers that have an immediate interest in differentiating themselves from the competition.

The academic field and specialized magazines, along with other publications, are very useful for creating a proper image of the information existing within the public and research fields.

In general, it must be stated that, in order to reach a profound knowledge and understanding of the field, it is necessary to gather knowledge from within the institutions activating in this field, especially since, as we have mentioned before, much of the information distributed within these institutions, which are in fact the main research and development centers in this field, do not get to be distributed to the broad public and are generally kept, as much as possible, within the companies.

In the present thesis, we shall take into account the entire research area as well as the public materials. Still, we will have a strong bias on documents which are not public and we shall pay a special attention to the knowledge accumulated by the author during the applicative experience.

For each of the approached subjects in the dedicated chapters, before presenting in detail the scientific contribution brought to the field, we shall make a short overview and presentation of the scientific contributions relevant for the subject.

Defining research objectives

In the formulation of the fundamental hypotheses for the economic phenomena related to the subject of the PhD thesis, we have taken into account the utmost importance of the integration and convergence related aspects.

The IT systems used in the institutions involved in the capital markets tend to consume a large quantity of resources and to be extremely costly. Statistics show that the financial industry is the largest resource consumer in the IT field, considering that the budget of a relevant global institution in the field tends to exceed 1bn USD per year.

The main hypotheses subscribe to the historical, current and future industry related aspects. Namely, in order to propose pertinent and optimal solutions for the issues faced by the participants on the capital market, it is important to understand that performance, integration and convergence are the most vital aspects to be taken into account.

It is important to consider the fact that in the process of defining our objectives, we can focus, at different moments, on different parameters. Let's take the example of extreme performance as a parameter. It can be proven that performance (understood here as a high execution speed or low latency) without integration and convergence in the historic and existing system structure will tend to show significant issues and potentially make the evolving construction process of the systems with an order number of magnitude more difficult than if a well-balanced set of parameters is chosen.

Thus, it is important to understand that the aspects related to IT systems have to be considered in a very thoroughly integrated manner and that it is not possible, at any moment, to miss the fact that each decision taken in adding, modifying or adapting the IT systems has the potential to decisively influence, both functionally and monetarily, the proper functioning and profit of the implementing institutions. Of course, the integration and convergence parameters must support industry specific flexibility and modularity requirements. If the approaches used fail to take into account these fundamental considerations, they shall tend to destabilize the existing platforms, with significant and potentially extreme consequences.

The PhD thesis shall have **three major components**.

In the first part, the thesis shall present a study of the field, status of the research and applicative area. In order to perform this study, I have used both materials from the public domain (books, publications, journals), the personal experience in the field and the research activity. We shall focus on reviewing the main components related to the field (execution systems, risk systems, operational flow etc.) by describing the main functionalities covered, as well as existing solutions and considerations for each relevant component.

In the second part, the thesis shall present possible techniques and methods used in the past, which continue to be of interest and, for certain cases, shall present case studies for examples of improvements of the existing solutions. We will approach various case studies, from a number of areas. Example domains include inter-process communication, functional aspects from various user areas (execution and risk systems), and reviewing the important aspects to be taken into account in order to insure a high level of service for the solutions provided. We will also approach operational aspects, for a research in the field of data flow optimization, along with other field related subjects.

In the third part of the thesis we focus on the scientific research dedicated to providing solutions for an integrated vision over the system architecture, focusing on choosing the right components at each step and taking a particular care for guaranteeing a flexible and modular structure, especially for risk, execution systems and cross-system communication.

PART I: ELEMENTS OF THE CAPITAL MARKET AND ARCHITECTURE OF THE CAPITAL MARKET ASSISTANCE SYSTEMS

In **chapter II** we make a brief introduction of the capital markets, of the main concepts related to capital markets and the way in which these concepts influence the development of the information systems used in the capital markets.

A territory located by excellence under the empire of pragmatism, the field of capital markets has developed during the last four decades a strong theoretical side. Even though the evidence of the direct connection between theory and practice is still doubted, it must not be forgotten that the entire "theory" of the modern financial science is fundamented on the field of financial markets.

This aspect of the domain of finances can be proven any time through its practical nature (and the explosive development of stock markets is proof for that), as well as its theoretical nature, without the possibility of setting precise boundaries of these fields. In fact, agreements regarding marginal issues (which give consistency to classical sciences) appear as useless in the case of financial markets, where divergences occured right from the establishment of the study field.

Thus, we can differentiate distinct schools of thought. The Anglo-Saxon school (especially the American one) defines by financial market all the transactions with monetary instruments (monetary market) and long term titles (capital market), this is the concept adopted by Romania too (Stoica, 2002). On the other hand, the school in the rest of Europe (especially the French one) defines by financial market: the securities market, representing, along with the loan market and the monetary market, a component of capital markets (Teulon, 2001).

Nevertheless, these schools agree that the capital markets represents specialized markets, where the demand and supply of long and medium term financial assets meet and are freely set. In a concrete manner, it is a market where securities are transacted freely (shares, bonds), a market having as main role the mobilizing of the capital of persons (legal/natural) that are saving (share and bond buyers) and following the profitable allocation of these capitals. These funds are attracted by share/bond issuers, in search of capital for the purpose of financing investment projects.

Next, we will review the objectives and characteristics of the stock market (Vinţe, 2006):

- Macroeconomic objective: distribution of capital
- Microeconomic objective: price formation

- Legal objective: protection of participants
- Operational objective: safety of operation and investors' trust
- Social objective: honest and equal treatment of all participants

In the thesis, we review the hypothesis of efficient markets and the way in which these influence investment activities. The efficiency principle of capital markets refers to the fact that today's price is a good approximation of tomorrow's price (Fama, 1965). Such a process is a „martingale" process. According to this, all the information necessary for the prevision of the future prices is already reflected in the current price. A special martingale case is the familiar process of random walks, which require the additional independence hypothesis for the distribution of price variations. These concepts are at the basis of some of the automatic execution algorithms approached by this paper (VWAP, TWAP) (Interactive Brokers, 2011).

Accepting the market efficiency hypothesis renders useless the very application of these practices (Solnik,1997). The informational efficiency of the American market was first highlighted by Cootner (1964), Moore (1964) and Fama (1965). These studies were followed by Solnik (1973) for the main European markets. Hawawini (1985), in his monograph, reviews, in an exhaustive manner, all the efficiency studies performed on European markets. All these studies have highlighted the weak informational efficiency of the stock market.

In these conditions, it was necessary to create new instruments for the management of portfolios, which were materialized through the modern portfolio theory.

The keywords at the base of this theory are: market model; systematic risk; stock index; index agreements; market right or risk premium.

According to this theory, the investor's potential gain will be directly proportional to the assumed market risk. Because of this, the capacity to estimate risk is central for the institutions involved in the capital markets, thus the systems architecture and development / programming is extremely important. This is also the central purpose of the thesis.

In **chapter III** we present preliminary elements regarding the system architecture. The systems used in the companies participating in the capital markets cover a large array of functionalities. In this chapter, we present a vertical classification of the business areas covered (front office, middle office, back office) and a horizontal classification of the systems used in these areas (execution, risk, reporting). The presentation is developed at a high level and in the next chapters we will detail the components and functions of some of these systems.

In order to create a properly defined background for the paper, we present the main participants in the capital markets.

Regulating bodies. Governmental or independent bodies responsible for defining the roles and responsibilities which need to be fulfilled by the capital markets participants (Vinte, 2006), (Anghelache, 2004).

Stock markets (SM). Entities regulating and facilitating the free exchange of shares title deeds of the listed companies (Anghelache, 2001).

Securities intermediates. The securities companies (brokerage companies or investment banks) members of the respective stock market (Anghelache, 2001), (Vinte, 2006).

Hedge funds (HF). The HF have become, during the past 10 years, along with the brokerage companies and investment banks, major players on the capital market (Mishkin, 2008).

Individual investors. Individual or retail investors can be persons with available funds, ranging from thousands to billions of dollars, choosing to invest in the capital markets, directly or indirectly.

The markets outside the stock market or Over The Counter (OTC). Many of the transactions performed on the capital market don't necessarily pass through a stock market, but are transacted between two competent entities (i.e. two investment banks, or one investment bank and any other type of client), based on a legal and mutually approved agreement. The transactions on these markets include any type of instrument, from simple shares, to complex financial instruments, and must be reported by both companies to the competent bodies (Anghelache, 2001).

The systems within the investment banks can be classified vertically (front-to-back) and horizontally (according to the covered functions i.e. trading, sales, pricing, market making). Some of these systems are reused in various areas of IB (i.e. risk, reporting systems), while others are mostly used in a specific function (i.e. execution systems used in trading).

The thesis focuses on the components necessary for building the varied information systems necessary within an IB and in this context presents a classification of the activity areas within IB. The systems used in other IB activity areas are presented: Shared Systems (SS), Middle Office (MO), Risk and Control (RC), Back Office (BO), Corporate (CORP). Mentioning again the fact that the budget of an IB often exceeds 1bn USD per year, the purpose of the potential improvement of the architecture and technical platform becomes obvious.

Front Office. Includes all the functions involved in direct business decision making in an IB. Function types vary greatly from one institution to another and also according to location, yet the vast majority can be grouped as follows:

- investment banking: the activity of facilitating operations for the customers, operations such as stock market floating operations, buy-out management, procurement from other companies etc.
- agency equity trading: sales/purchase related activities, for the bank’s customers, of a great variety of financial products related to shares and their derivatives
- agency fixed income trading: purchase related activities, for the bank’s customers, of a great variety of financial products related to interest rate and products based on loan instruments
- proprietary trading: activities involving direct or indirect investments based on equity or fixed income
- sales: a variety of sales operations for all classes of financial products. The personnel performing the sales position is regularly aligned on the product line with the similar personnel on the trading side
- quants: modeling of financial products and/or trading strategies
- analysis and research: activities targeting the search, aggregation and analysis of company related data, which can represent the object of investments for the bank’s customers or the bank itself (Stowell, 2010)

Middle Office. The function is also called operational function and includes all the aspects involving the activities subsequent to the sales, trading or investment banking functions, involving fund and title transfer activities, management of such entities etc.

The operational activities tend to be very laborious, generally because of the volume and complexity, especially for multinational companies. The activities within this function involve the execution of business specific actions and the affected products.

Risk and control. In this function, the purpose of the activity is that of estimating specific risk measures, at different activity levels, and according to various parameters, and to assist the company in ensuring the maintenance and correct management of risk margins. This functions includes specializations such as:

- portfolio control: verifies the major parameters defining the correct portfolio component
- profit control: verifies the correctness of profit and losses reported by the trading function
- modeling control: verifies the models generated by the front office quant function
- market risk estimation: estimates the risk to which the company is exposed in various market conditions. This is obtained through the numerical simulation of these conditions and the estimation of relevant parameters
- loan risk estimation: estimates the risk to which the company is exposed in various conditions of change in the loan situation. This is obtained through the numerical simulation of these conditions and the estimation of relevant parameters (Fleuriet, 2008)

Back Office. The back office function insures that the IB executes all the operations required by the other functions and by all of the institution’s external partners. These functions generally tend to be specific for a certain market and specific product classes.

Corporate. Includes all the other areas of activity of an IB, such as administration, human resources, payments etc.

The thesis covers both specialized systems (risk systems targeted towards the front-office functions) and systems used in several areas of activity of an IB (risk systems used in almost all activity areas). Also, the thesis presents a classification of the systems used in the areas of activity of the IB.

We present an example of an architecture for a middle sized IB. Using this example we wish to highlight the major components used in IB's in general (Ziman, 2013):

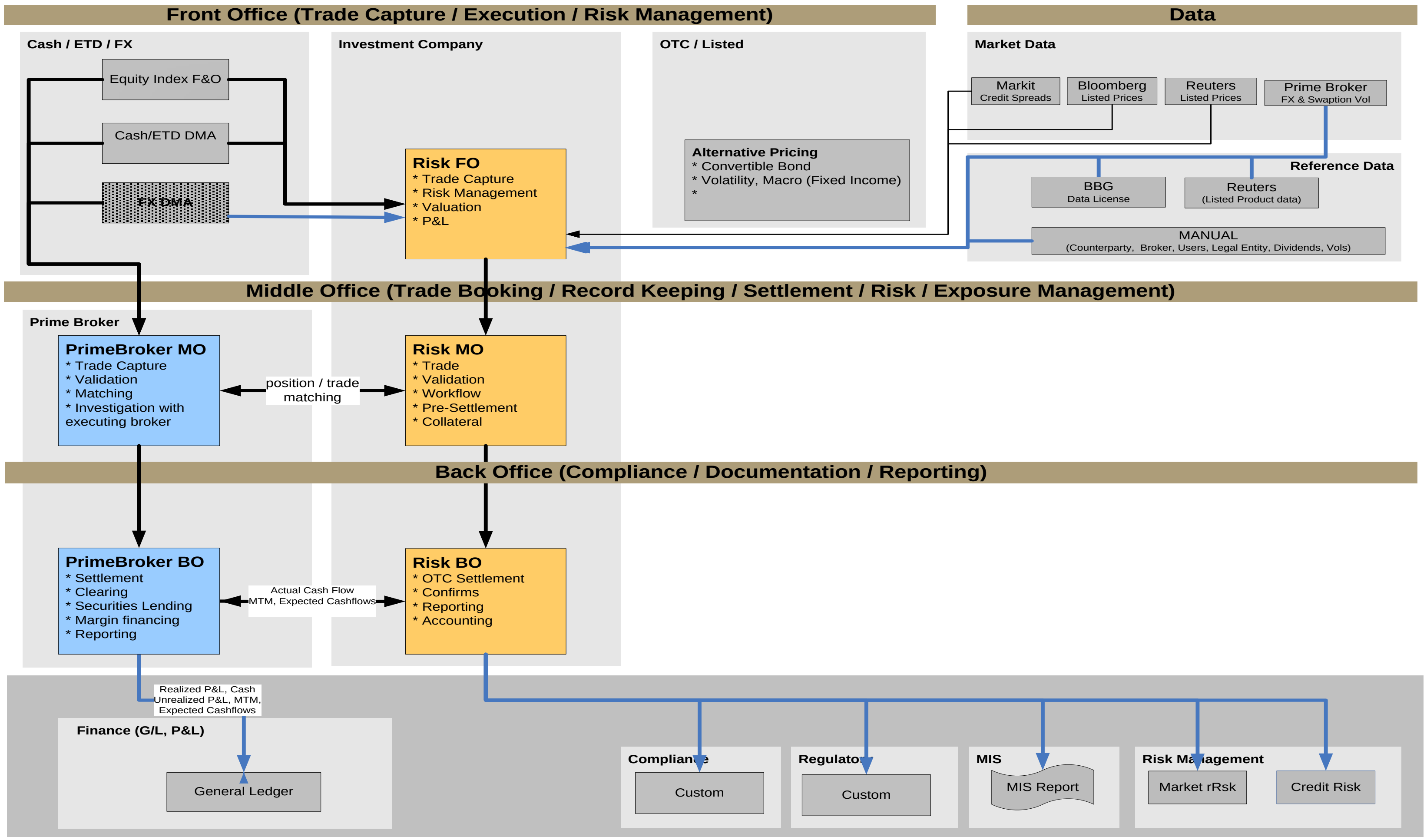


Fig. 1 : High level example of the systems architecture for an IB.

PART II : CONTRIBUTIONS AND OPTIMIZATIONS TO THE EXECUTION AND RISK SYSTEMS

In **chapter IV** the thesis presents the author’s contributions at an architectural and functional level specifically for execution and risk systems. The author has proposed multiple contributions to the architecture of execution systems, contributing to the development of innovating and performant execution platforms, implemented mainly in Asia. The contributions have consisted in the development of the systems architecture, specific components / functionalities as well as the development and programming of these platforms together with the teams built and lead by the author. The author has continued with additional contributions in the area of risk systems, contributing at the same time to the development of the architecture, components / functionalities as well as the development and programming of these platforms together with the teams built and lead by the author within an IB.

Risk systems are the „central nervous system” of the system structure within a banking institution and especially for an Investment Bank.

Risk systems are the nervous center where „terminations” are found for all the data necessary for estimating the accounting status of a financial institution at a given time.

Although these systems require a great quantity of data and tend to present major difficulties in their conception and administration, they must comply with a vast number of requirements, often very different as type and temporality (real time or static processes) and to coordinate the entire activity of a large number of functions within the institution, including transacting, processing, risk control, market and loan risk estimation, regulatory requirements etc. Thus, the conceiving and development of such systems tends to be performed during several years, and tends to be of a mostly proprietary nature for a certain company (because of the difficulty of integration of an existing system developed for a potentially different usage context).

Generally, risk systems tend to be the most complex systems encountered in sophisticated financial institutions and this is the reason why a great deal of attention is required in each phase of their implementation.

The author has taken part in the revolution in the field of electronic markets, through the implementation of one of the first regional platforms of an **execution** system, concentrated on Asia, and being one of the leaders of development in this field of activity, through technical, architectural and business contributions. The products developed by the author and the team led by him were implemented by the majority of participants on the capital markets in Japan around the year 2000, and later on other Asian markets.

The execution systems are central components of the architectural structure of trading houses, offering dedicated interface services with various electronic trading platforms:

- electronic stock markets,
- „dark-pool" electronic markets,
- interbroker markets, for instance, currency trading platforms.

The execution systems tend to be used also by a great variety of users, including traders, persons involved in operations, reconciliations and others.

The purpose of such systems is that of offering the users the software tools which allow them to interact with the electronic markets existing in the geographic area where they transact.

Generally, the execution platforms tend to cover several financial products (stocks, futures, options etc.) and several markets (i.e.: Tokyo, Hong Kong, Korea, Taiwan, etc.) within the same platform.

The electronic platforms were developed especially during the past 15 years, reaching now their the 3rd generation.

The complexity of such systems tends to be that of managing to harmonize characteristics and functionalities specific for the various stock markets and markets with which they interface, into a unitary and consistent whole, so that the user may interact with these markets in a consistent manner, without the need of detailed knowledge regarding each market.

The execution systems are the equivalent of a risk system for the long/short stock trading business, for instance, considering the fact that such a business does not require complex risk parameters nor large number of calculation engines, as is the case of a business transacting complex instruments (such as structured products).

Thus, the execution platforms have represented the central point for the production, transaction and data storage of cash related products. While the electronic platforms began to support more complex instruments, such as futures and options, the execution platforms have become, on one hand, one of the components of the institution's architecture, but they also grew more complex, requiring additional functions, such as real-time option price calculation at each modification of market prices.

As an example, we present the execution platform Pure Execution, whose graphic user interface is presented in Fig. 2.

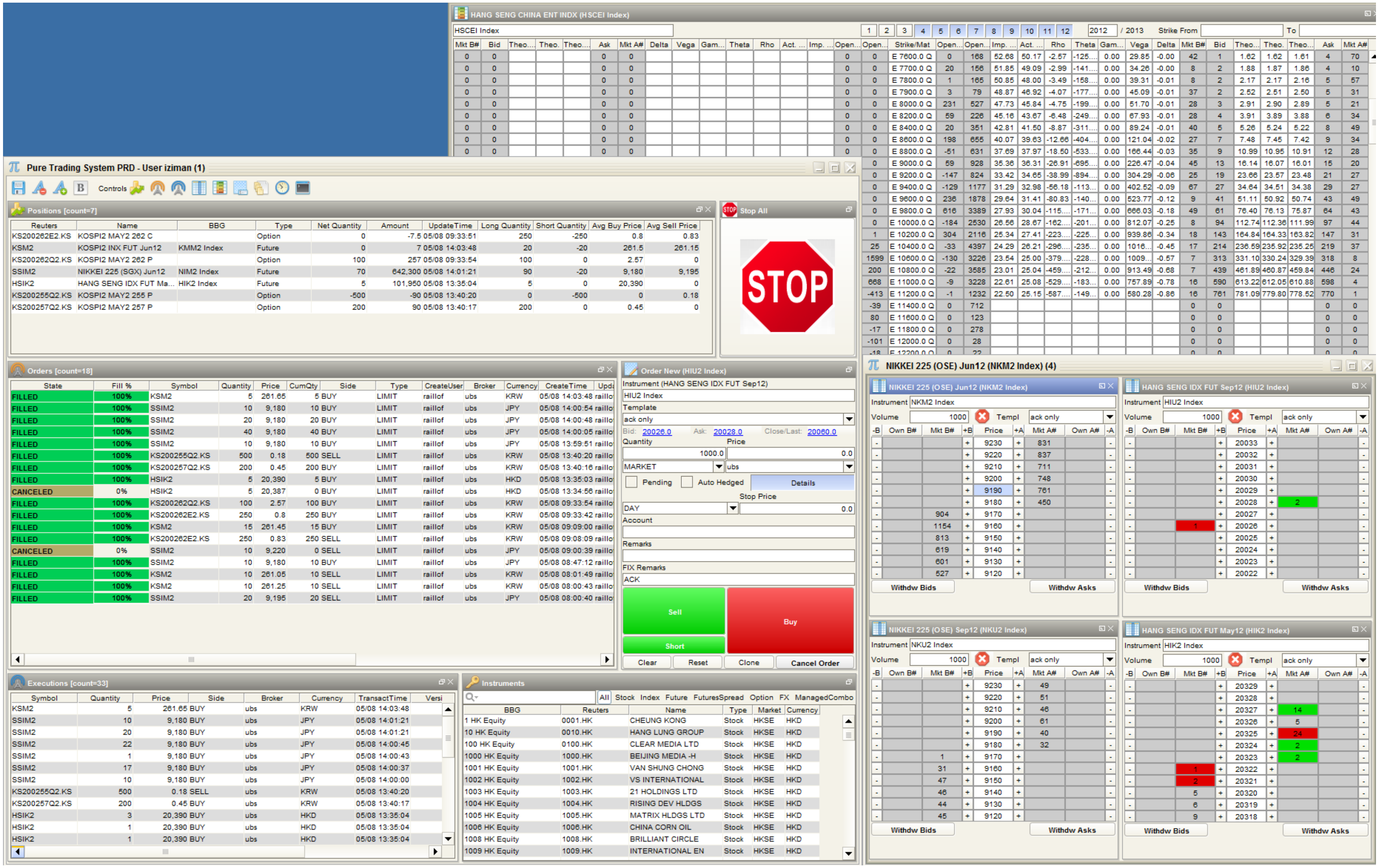


Fig. 2: Pure Execution – graphic user interface.

The automatic execution systems have become an integral part of the current systems architecture for the investment process. Most of these algorithms target the optimization of the execution of a certain trading strategy, by segmenting the impact of large orders, which could move the market prices adversely or by insuring the user's participation throughout the entire transaction day, in an optimal manner.

From a technical and architectural point of view, the complications brought by automatic trading are the large number of transactions (a large transaction can be divided into hundreds or thousands of smaller transactions, executed separately at distinct moments) and of stringent stability and correctness requirements imposed to such systems. The automatic execution has led to latencies lower than microseconds in the field of capital market interfaces, by using technologies such as FPGA (Field Programmable Gate Array) in order to bring the interface to implementations achieved by hardware and not by software.

The author's contribution consisted in the elaboration of the architecture of such systems, establishment of functionalities and algorithm specifications and the facilitation of their development and programming by the team led by the author.

In order to achieve these contributions, the author has performed measurements of the latency parameters existing within the IB respectively before the project execution, has proposed innovating architectures and methods for their optimization and has also led platform development.

The thesis presents the current status in the field of IT assistance systems for the capital market, from the point of view of the systems used. The main focus is on **risk, execution and automatic execution systems**.

The thesis introduces the main parameters and requirements for these systems, shows the implementation specifications for such systems, proposed by the author, and suggests methods for improving and optimizing them.

The next phase is the analysis of special components and characteristics (complexity, coherence and functionality, data volume and performance) on which the author focuses for the purpose of continually proposing increasingly optimal solution.

PART III : PERSONAL CONTRIBUTIONS

In **chapter V** we present **contributions and optimizations to memory based databases – memory based databases as a core element for the architecture of systems used in capital markets** (Ziman, 2012a). An extensible main memory database data model is presented with applications in writing client server components in both the server space as well as in client applications domain. Such a model is required in applications where end user base clients have specific needs and it offers a framework within which various services are implemented based on a common extensible core. The end result of the proposed implementation is a core set of services that offers an XML based API that can be used to define data structures, events and actions in an easily usable package that allows iterative updates and evolution of the environment. Use cases are presented for the implementation of systems used in the capital markets.

The work on EDM came about as the personal struggle of the author while building the Fusion Order eXecution platform (FOX, 1999) to find a way of building complex trading systems that also allow a great degree of customization. After several very successful attempts at building bespoke order-execution trading systems, the complications arise from the need to develop and maintain a platform for many clients who tend to have different, sometimes mutually exclusive requirements. Some vendors, such as Fidessa (RoyalBlue, 1999) have been successful at introducing such platforms. One of the main ingredients in building such a system is an easily configurable in-memory database, using a script based language. There are a limited number of practically usable in-memory-database systems and most are proprietary implementations owned by large corporations, for ex. Oracle owned TimesTen (TimesTen, 2004). As such an enterprise wishing to use a high performance, flexible platform allowing customizable implementations while maintaining costs low may go through the route of using a proprietary developed framework. EDM is such an environment. The subject of main memory database systems is not new and has been analyzed of some time, as early as the ‘80s (Garcia-Molina, 1992), yet due to their still somewhat esoteric nature, when compared with traditional relational database systems, main-memory database systems remain worthy of more intense research. The paper presents the in-detail approach to implementing such a main-memory database system, with application directly in building systems used in the capital markets. Aspects involved require the building of relevant language and parser constructs, database primitives and data hierarchy, and offers an in-depth view of the mechanisms and level of detail required to consider when building the framework. While the original work of the author has been conducted earlier, the several iterations of the implementation have rendered the concepts worthier to present due to their more polished nature.

The Problem The key areas generating problems are:

- Different clients have different service needs.
- Different clients need different data views where the data is computed based on different rules.

The bad news is:

- Writing a server that provides all of the services is impossible.
- Writing Apps that provide all of the services that the server does not support is impossible.
- Writing Apps that support all views needed by the client is impossible.

The good news is:

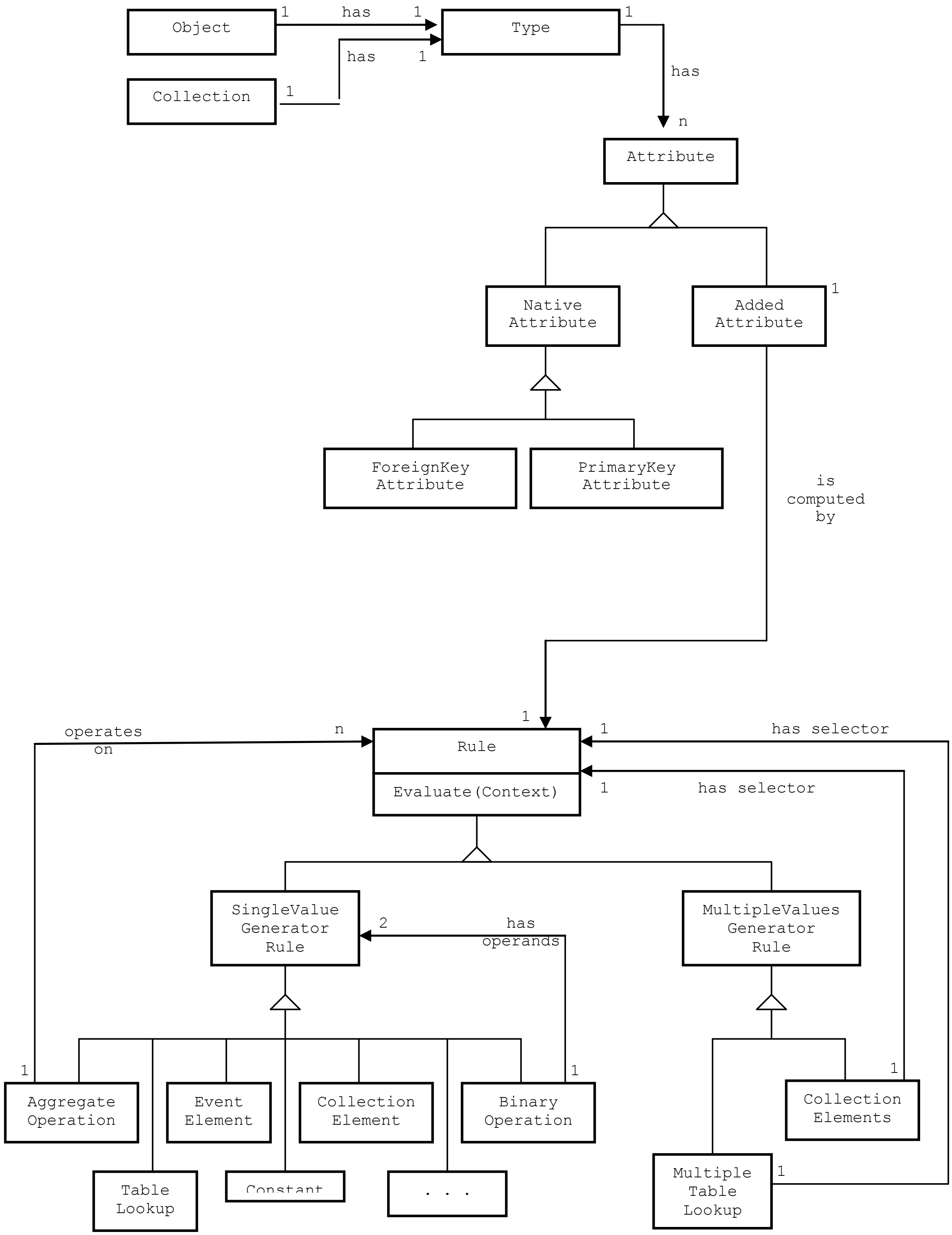
- We can identify a set of core services needed by all the clients (like AddOrder, AddRelease, etc.).
- We can identify a set of core data types used by all the clients (like Order, Release, etc.).

Different client needs regarding their view on data can be considered a customization of the core data types with additional (and different) attributes.

A possible solution to the problem that different clients need different data views can be: "Create a data model that enables the customization of its data types".

This document proposes such a dynamic model. In this model new types can be created and existing types can be changed by adding new fields to them. The values of these additional fields are computed based on rules specified by the clients.

The class diagram for EDM's specification is presented in Fig. 3:



EDM is an original high performance framework that allows a flexible customization of solutions that can be applied in the capital markets electronic exchange interactions domain. In the next steps the extensible data model, the extensible service model and the extensible validation model must be built in a way that enables co-operation between them. These models are frameworks that enable the building of a highly extensible and highly configurable new generation of applications used in commercial products.

In **chapter VI** we present **contributions and optimizations to warrant market making systems** (Ziman, 2011a), more specifically an E-Business platform for the global warrant markets. Global warrant markets are among the most active financial markets in the retail derivatives investment landscape currently. In this context some of the most relevant markets in the last years have been the ones across Asia and in particular Hong Kong, Korea and Japan. This paper introduces the financial instruments used in connection with the warrant markets, presents and offers suggestions for setting up a generic warrant market making system and introduces the main concepts and components that need to be taken into account when developing these systems targeting an E-Business or exchange driven context.

Global warrant markets represent a specific group of markets that have been developed predominantly over the last 15 years. The products traded on these markets are a category of derivative investment instruments. These are option-like products generally issued by a third party and are usually traded on the exchanges or on E-Business online platforms. When traded on exchanges, unlike exchange traded options, only the issuers are allowed to short sell the warrant. The reasons why warrants are attractive investment vehicle include: their leveraging effect and limited loss feature, attractive to aggressive investors, and also they can serve as hedging instruments to reduce the risk exposures arising from other related investments. The paper also addresses concerns related to issuer market manipulation.

While exchange traded warrants are well represented in global markets on exchanges including the ones in Hong Kong, Korea, Frankfurt, London, New York and others, there are also other legislations, such as in Japan but also many other markets including emerging ones, where warrants are traded predominantly outside exchanges on licensed portals implementing E-Business infrastructures. Worth noting is that it has been observed that smooth trading in the warrant market may add to the depth to the market that eventually leads the issuance of more warrants and market growth. Easley, O'Hara and Srinivas (1998) for example suggest option markets with better liquidity attract traders to use such markets more.

Considering the variety of exchanges that support trading warrants we can observe different approaches to the way the markets are regulated and issuers are allowed to participate.

In Hong Kong, one of the markets with the largest degree of freedom, derivative warrants have been particularly well adopted by retail market participants. For a few years, between 2003 and 2007, the turnover in Hong Kong's derivative warrants market averaged HK$3.5 billion a day, representing about 20% of the average daily total stock market turnover. This level of turnover made Hong Kong the most actively traded warrants market in the world. It also suggests a large deal of retail participation. This large degree of retail participation comes with its problems. Concerns and allegations have been raised about certain illicit practices in the derivative warrant market and the suitability of derivative warrants for retail investors; however such claims have been generally refuted (Amihud and Mendelson, 1980; Chow YF et al., 2007; Draper et al. 2001).

In Korea, where the participation is more restricted and the rules imposed on issuers and market participants are stricter, the access to the market has been highly monitored by the regulatory bodies. Due to local expertise participants from within Korea held a significant advantage. To that extent many foreign companies interested to issue warrants on the Korean market chose to use a venture type vehicle in association with Korean entities. Retail investment has been still large in relative terms but still a degree of magnitude smaller than Hong Kong.

In Japan, where warrant market making has not been in the mainstream of the investment vehicles and as such has not been implemented by the major exchanges, the products issues by various market participants such as investment banks have been listed on online E-Business platforms.

The types of products traded as part of the warrant market making business have in the past predominantly been European or American Call/Put Options which tended to be Vanilla, or eventually Vanilla with Averaging Tail (averaging of the last 5 days close prices, also called in Asia as Asian Tail). The underlying set ranges from equities, either outright or indexes, to commodities, such as gold and others, and become increasingly sophisticated.

One of the main attractions to the warrant markets is the relatively small sizes that are traded, which allow private retail investors to participate in trading of products that they otherwise could not trade in. This is possible because institutions which issue warrants and offer them to the public structure them such that each warrant represents rights for ownership of a fraction of the underlying for which they are issued. Important active participants in the market are also the issuers, which need to manage the risk of their inventory positions. The trading patterns have been examined in a number of papers and they tend to show that issuers trade mainly to manage inventory risk and not to manipulate the market, a major concern for market participants (Hasbrouck and Sofianos, 1993; Madhavan and Smidt, 1993; Madhavan and Sofianos, 1998).

This thesis presents a brief description of the warrant markets, explains how warrant market making systems are implemented and what are the main requirements for such a system, presents the impact that the warrants markets have had for retail investors globally and how it has created E-Business models for the financial industry and have presented brief considerations on how such models are implemented in a local, regional or global model.

The paper shows that contrary to concerns raised on occasion, warrant issuers tend to trade fairly and mostly manage their inventory rather than manipulate the markets.

Deploying a warrant market making engine is a relatively complex task and requires careful planning to be considered by new market participants. The parameters and approaches described each have their pros and cons. A warrant market making engine interprets many thousands of events and reacts with low latency based on preset parameters and predefined algorithms and requires in general a significant investment that needs careful consideration.

The warrant market making business is currently very competitive due to the large number of firms already in the market which cover the demand among retail investors. The business has been gaining ground globally but most notably recently in Asia and it is expected that more exchanges will list warrants in new types of products to help increase liquidity and offer a diversity of products for the public. At the same time existing and new E-Business models will become increasingly adopted by participants in emerging markets.

Chapter VII presents contributions to the way that Rapid Application Development (RAD) are used in the context of capital markets systems development (Ziman, 2011b). RAD as a methodology for implementing information systems has been used in a broad range of domains utilizing technology as an informational backbone but perhaps one of the main areas where this approach has been proven to be a natural fit has been in the investment banking (IB) industry, most notably when applied to trading systems. This paper introduces some of the main tenants of

RAD development and focuses on a number of case studies where RAD has proven to be an extremely suitable method for implementing solutions required in the IB industry as well as explaining why RAD may be more successful than other classic development methods when applied to IB related solutions.

RAD has its origins in rapid prototyping approaches and was first formalized by James Martin (1991). He believed that it refers to a development life cycle designed for high quality systems with faster development and lower costs than the traditional lifecycle provided. Martin's work followed up on early concepts such as Barry Boehm's spiral model, Tom Gilb's evolutionary life cycle, and Scott Shultz's rapid iterative productive prototyping (RIPP). The prototyping method used in rapid application development allows the developer to rapidly identify the types of data and process models required to meet the application requirements. However, because of the shorter development time, certain compromises in performance and quality are difficult to avoid. By the mid 1990s the definition of RAD came to be used as a cover term to include a number of methods, techniques and tools by a large number of different vendors applying their own interpretation and approach. This rather unstructured ad hoc evolution of RAD means that the rationale behind its use is not always clear. It is perceived as an IS system methodology, a method for developers to change their development processes or as RAD tools to improve development capabilities (Beynon-Davies 1999). It could be found that on a number of occasions RAD has been considered one of the delivery methods encompassed in Agile development methodologies. According to circulated literature RAD centres on prototyping and user involvement stages where the analysis, design, build and test phases of the development life cycle are compressed into a sequence of short, iterative development cycles. This had been seen as a remedy to perceived flaws of the traditional lifecycle because the iterative approach encourages effectiveness and self-correcting as each increment is refined and improved. To achieve this, a RAD approach necessitates the collaboration of small and diverse teams of developers, end users and other stakeholders (Martin 1991, Tudhope 2001, Beynon-Davies 1996, Elliott 1997). It is sometimes useful to consider that RAD projects may be distinguished in terms of intensive and non-intensive forms. A non-intensive approach to RAD refers to projects where system development is spread over a number of months involving incremental delivery compared to the intensive RAD where project personnel works somewhat secluded to achieve set objectives with a 3 - 6 week timeframe (Beynon-Davies 1999).

For a description on the reasons why RAD is well suited to development of IS in investment banks and more specifically trading systems a brief description of the development process including analysis, planning as well as development, testing and integration is achieved within such organizations. It is important to understand that while the contrary may be desirable in fact an IB trading environment tends to be a hard to capture user functional environment and as such specifications tends to be difficult to pin down and more so have accepted by mail stakeholders, this being often the time one of the main reasons why projects within such organizations may be found to fail repeatedly, despite the need for the functionality that they would offer once delivered. There are multiple reasons why this happens and we can just mention some of them. The trading environment is a highly dynamic one and tends to be populated on the user side by people who have daily responsibilities and for whom system development is not always at the core of their focus at all times. This means that only sporadic attention may be expected from the people best placed to offer requirements, which means that from the very beginning there is a clear case of scope creep. At the same time these same people are in need of new functionality that they demand but yet have a difficult time in focusing on specifying exactly what they require to a level that can then be implemented based on further analysis. At the same time on the analysis and specification definition phase the large number of people that need to be involved for implementing significantly large information systems tends to require a relatively long period of time simply to define requirements, which in fact may have changed before reaching the development phase. As a result often times such institutions are faced with potentially low productivity cycles designed simply to achieve a consensus on requirements. It is important to understand that quite often developments in this area border research and development activities rather than simple problem solving solutions delivery; as a result the time required could be multiplied by orders of magnitude. One general problem is that many users who are involved in the specification phase only really become proficient in providing feedback once they see a first level implementation that is somewhat functional and will then tend to give input on methods of evolving or improving.

This is where RAD comes in and offers developers the chance to promote a controlled, structured but flexible development methodology aimed at providing incremental delivery. This generally involves a series of time-boxed mini iterations and a number of software ‘release’ and test iterations to provide flexibility to meet the recognized volatile needs of the business environment. In general analysts and developers believe this methodology offers all the main benefits of a RAD type approach and is suited to the uncertainty of, and continually changing business requirements. To that extent a structured RAD involves prototyping and iterative delivery while keeping tabs on the problems of lack of rigor, creeping scope and overrun that are perceived as associated with an undisciplined RAD and an iterative development life cycle. The method uses the same main features i.e. workshops, time-boxing, prototyping, intensive user involvement, iterative development and incremental delivery, which they maintain are increasingly used for system functionality development. Analysts and developers believe that a major benefit of an iterative approach to development is that it affords early visibility of the system being developed. As such early validation of the system by the users and the business analysts provides the flexibility to incorporate user feedback and handle any new or changing requirements within the volatile business environment – a key goal of the RAD approach.

A useful example to give at this stage is that of the development process of a proprietary structured equity derivatives system's development cycle. In the case of a given IB it took 4 attempts, of which 3 failed over a period of about 7-8 years, until the 4th attempt has been successfully implemented over a further 7 year period. The reason why the first 3 attempts failed have been varied but it generally had to do with the fact that analysis and development assumed that the needs of end users are already understood and all that is needed is a good quality product that needs to be fully developed and deployed across the firm. The problems in each cases had to do with the fact that the multitude of, sometimes individual, needs could not be estimated in the analysis and specification phase and invariably the systems developed failed to meet the requirements of users and, having already overrun their budgets, lost sponsorship and failed to be successfully terminated. The reason why a 4th attempt has been successful has been exactly because a RAD type approach has been used in which a lower spec version of the system has been developed and deployed to less demanding users and functions and then gradually enhanced over years of development to include further complex functionalities until finally succeeding in eliminating the legacy system. This was a major triumph for a RAD type approach in developing trading systems.

In general as a systems development approach RAD has both critics and supporters whose opinions, in some cases, are fundamental to individual philosophies and perceptions of this method's rationale. Existing literature presents particular themes of discussion within the RAD arena and a prominent area of debate concerns the scalability of RAD across large and complex environments. While a fair observation is that across the software development industry the lack of provenance is reflected by the limited availability of published material, there is substantial reporting of its application and considerable debate about its appropriateness for different types and sizes of systems development. (Osborn 1995, Beynon-Davies 1999, 2000). Also important to note is that RADs origins as a development process is fair to be placed more within a commercial development arena than an academic one. As such literature considers it more appropriate for small to medium simple, highly interactive development projects rather than for environments that are also computationally complex even if the case mentioned before proves that is not necessarily the case. In general it is observed that RADs success is linked to the project management approach, level of management commitment, degree of end-user involvement and the ability of the team to make fast authoritative decisions (Beynon-Davies 1998). Literature also suggests that RAD projects necessitate cultural and managerial changes because people are required to behave in a different way than in the more structured traditional environments. It is therefore important to note that without radical shifts in organizational attitudes and structures and peoples’ mindsets many projects may fail because the change to new methodologies, methods and techniques did not fit within the culture (Hirschberg 1998, McConnell 1996). It can further be observed that the potential of a RAD development and delivery approach to meet information systems requirements in uncertain and volatile business settings of complex system development environments is questioned. Such critics advocate that the need for high levels of user involvement, stakeholder collaboration, lack of project control and rigour are major issues to its success (Martin 1991, Osborn 1995, Beynon-Davies 1996, 2000, Elliott 1997, Cross 1998, Boehm 1999, Highsmith 2000). Our personal experience shows that a RAD process fits well IB trading systems development, if mainly because of the difficulty in finding alternative suitable methods of implementing solutions for such systems.

Due to the time-to-market criticality of such systems RAD methods emerge as a very strong and viable paradigm that IBs tend to adopt. The thesis shows that, where relevant, distributed RAD development should also be considered within IB organizations and it has strong chances to produce consistent results when implemented as a process in a larger context.

We present in **chapter VIII inter-dealer OTC E-markets** (Ziman, 2012c). The global OTC (Over The Counter) markets have been very active in the past decade as many institutions have chosen to rely on growth in the OTC issuance to facilitate deal-making outside of the exchange regulated avenues. Products included in this category are bonds, converts, volatility and variance swaps, CDS contracts. This paper introduces the financial instruments used in connection with the OTC markets, presents and offers suggestions for setting up generic sell and buys side RFQ and market making systems and introduces the main concepts and components that need to be taken into account when developing such systems when targeting the growing E-Business focus of the market.

OTC instruments have become the largest traded securities by volume and notional value globally. The financial products traded OTC include effectively any financial product that is not traded on a regulated venue, such as an exchange, but they are traded between usually two parties who effectively sign a contract, which may be a one off or part of a series of deals. To illustrate the point, current estimates suggest that the size of the global bond market is $82 trillion vs. the size of the global stock market which is $40-$50 trillion. And this is just one of the instruments traded OTC. Clearly the size of this market has become very large and there is recently, even before 2008 but clearly after Sep 2008, an effort to capture the information distribution and deal making flows on channels that are more transparent than the current way of executing them. As part of this analysis in this paper we will concentrate on a few markets, most specifically on bonds, convertible bonds and the various RFQ (Request For Quotes) mechanisms that exist currently as well as the trends manifested recently towards opening up new markets, which we may dear calling E-Markets, for price distribution mostly at this time, but which may evolve later into a more electronically assisted means for deal making.

On a general note, bonds are largely well documented with well identified terms and conditions, with information available to any market participant with access to any of the major information aggregators/distributors, for ex Bloomberg or Thomson/Reuters. However, the price distribution for bonds is still done through broker quotes being sent to a limited number of market participants and not generally publicly available. At the same time, due to the fragmentation of the market, the quotes presented by various brokers may vary significantly from one another, to the extent that some may be considered valid while other may actually be considered invalid (or non-tradable).

Convertible securities (converts) are bonds or preferred stocks that can be exchanged (converted) into a fixed number of common stock shares of the issuing company. Converts combine the capital appreciation potential of equities with the higher income and safety of fixed income instruments. When considering liquidity, this parameter is always an issue in evaluating different investment asset classes, specifically the global convertible securities market is large, diverse, and liquid. With a capitalization of over $400 billion, the global convert market is bigger than the equities markets of Australia or Hong Kong. The Japanese convertible securities market is the largest, with capitalization of approximately $160 billion or 38% of the total global market. U.S. is second with about 31% of the market or $130 billion. Europe is third with about 24%, and the remaining 7% comes from emerging market nations. Among these regions Europe is the fastest growing segment of the market. In general institutions are using converts to monetize assets in the restructuring process in a tax efficient manner. In this context securities being issued by parent companies or large corporate stockholders are convertible into common stock of the companies being sold or spun-off. The reason why these products are attractive is that capital gains taxes are deferred until the convertible privilege is exercisable, generally five years after it is issued. To put things in context it is important to note that markets no longer act in isolation. An event such as a Russian debt default or Taiwanese earthquake will send financial tremors around the world. Increased volatility, or the extent to which prices fluctuate over time, is now a fact of life. From the perspective of risk management and diversification convertible securities reduce portfolio risk. Over the last 25 years, U.S. convertibles have provided about 86% of the return of the S & P 500 with about two-thirds the risk. Convertibles have been even less risky than corporate bonds as measured by the standard deviation of their returns. (Agarval, Fung, 2011). Convertibles demonstrate a low degree of correlation in terms of returns with both equities and bonds. This low degree of correlation, especially with bonds, explains why convertibles can be used to reduce volatility in a portfolio. Studies indicate that the optimal amount of convertibles in a portfolio is about 5% of total assets (Agarval, Fung, 2011)(Brown, 2000).

We present an original price discovery engine dedicated to the convertible bond markets. A convertible bond market making engine is a system with a number of core components that collaborate and react to external events and perform required actions. The system continuously receives data from the markets, processes these prices and, using relevant pricing and risk models, generates corresponding buy/sell orders for the relevant instruments. At the same time the system needs to be able to execute commands coming from users. As an effect the convertible bond market making system carries out the corresponding actions such as estimating hedge points for delta and/or gamma, eventually executing auto-hedging algorithms and changing the quoted prices by continuously generating cancel/replace orders to keep in line with the changing underlying prices and associated volatility market.

Several types of existent events contribute to a convertible market making engine: market information events such as quote data (bid/ask/last/high/low/close), trade events (order placement/order cancellations/order amendments/execution fills), user driven events (clicking the buy/sell order button, changing the parameters for example the trade volatility or the spread value), system events (market status, system health states, network links).

In **chapter IX** we present in detail the architecture of a risc system dedicated to convertible bonds, named Kogaion, system developed and implemented by the author. We present a relatively simple system (when compared to other systems we presented in earlier chapters) which offers functionality required for trading convertible bonds. The main reason for presenting this system is so that we have a chance to delve into many of the details of the system implementation (details that we could not get into in the case of the larger systems presented earlier). The system architecture focuses on the presentation of the way that all the system's components are integrated in order to support the desired functionality.

In **chapter X** we present an original solution developed by the author dedicated to solving the problem of **complete ordering of messages in a heterogeneous system**. The problem that needed to be resolved was that, in very rare occasions, electronic order/execution messages dedicated to be sent to exchanges may have been sent towards the exchanges more than once. The root cause was due to network level problems / failures. Due to this starting situation we needed to add a validation layer which ensured that messages were being sent exactly once to the market. At the time of the implementation an IB has been using this validation layer for all it's market connections within Asia. Prior to implementing this validation layer the ordering function was left to be implemented by intermediary third party communication layers, which had insufficient resiliency capabilities, when used within the performance and latency parameters intended. The project consisted in implementing such an add-on layer for the environment, capable of ensuring that one and only one message of each is sent to the market (while maintaining a low latency on the execution flow).

In **chapter XI** we present **contributions to the development of the next generation risk** (Ziman, 2013). We present an „ideal" architecture for such systems. The architecture proposed is based on the results of a research questionnaire implemented in a multinational investment bank. Some of the results of this study have already been implemented in the risk systems architecture presented earlier in this thesis. Others may be considered as future development targets in the development of such systems. The purpose of the study has been to identify the major guiding requirements and principles on which the main users of risk systems are focusing on in the various areas of their activities. The name of the institution remains confidential but the results are preserved accurate enough such that the study presented offers a pertinent account of the requirements. Certain changes have been affected on the results to maintain privacy and confidentiality.

Based on the criteria obtained the author helped develop the guiding lines for the development of the risk platforms within the institution. In implementing these criteria within the systems a modern platform has been implemented, full of innovations and functionalities that have allowed a global implementation while maintaining an optimal localization level allowing the addressing of specific functions for each role involved.

The execution of such a program requires a sustained multi-year effort. From a technical point of view the implementation of the required functions presented the need to take many difficult decisions both from a technical perspective, as well as a cost perspective as well. For example, while implementing the system, we evolved from using a number of about 10 servers for the entire system to using 1000+ servers after a few years into the project (most of them needed to calculate Monte Carlo based products). At the same time, as part of the same effort, we implemented an workflow which evolved from a flurry of emails into a well-defined state-machine based implementation which allowed the integration of all involved business functions. Such achievements are quite rare in this domain, and it is possible that only a very small number of such implementations have actually succeeded.

In **chapter XII** we present an original way of interpreting and explaining the **role of the technical architect** (Ziman, 2012c). This chapter is an attempt to place the role of technical architecture in its inherently complicated context of the enterprise, with applicability for the technology infrastructure of the investment banking (IB) industry. Investment banks build, buy and reuse technology with the intention to addressing their business and organizational needs, challenges and for competitive advantage. However, depending on the approach not all efforts improve but the platform and instead in some instances lead instead to complications and complexities which tend to result in consuming more resources at all levels. Some IB organizations have adopted various technical architecture approaches to address the challenges posed by technology deployment. As a function and role technical architecture is intended to address all of these aspects, from strategic planning to development and implementation of technology infrastructures. The technical architecture role and approach needs to be understood as a determining factor which, when used correctly, facilitates and enables the prioritization of analysis, development and implementation, which are meant to build and execute the business requirements and vision. The paper presents an approach to the way the role of the Technical Architect should be understood as well as a possible Model which may be used as a consistent approach that IB's could employ to build, maintain, and apply technical architecture.

GENERAL CONCLUSIONS

In the present thesis we have reviewed the various methods and implementation techniques for the information systems used in the capital markets.

In the first chapter, we have performed an analysis of the field and we have introduced the main concepts, relevant for this study. We have continued by introducing the main systems in investment banks, which are major participants to the capital market. We have focused here on the systems used in all the areas of activity of a bank: trading, operations, compliance and back office.

We have then introduced in detail the execution and risk systems, along with all their components, the major and detailed functions necessary for implementing such systems.

We have then continued with the presentation of EDM, in-memory databases, as a central element for the implementation of many systems dedicated to capital markets. EDM is in direct competition with modules such as Fidessa (1999), TimesTen (2004) or StreamBase (2013), but uses a dedicated and easy to implement approach, takes less memory space for implementing its own engine and can be considered comparable to these world renowned systems, and in some aspects, especially the dedicated primitives for execution systems, it offers optimal performances. We have continued by presenting a warrant market-making platform. The platform presented has competed with the leaders in the field on the Asian market, as one of the platforms with a representative penetration in the region, especially in Japan. The functional requirements have required a technological approach which includes a mixture of execution and risk architectures, specialized on the warrant market. The stringent performance and accuracy requirements make the platform an exceptional accomplishment, which has allowed the implementation of a business with an extremely high entry barrier.

Next, we have described the method through which a RAD implementation method is a viable alternative for implementing systems in the context of investment banks, and we have illustrated this through both simple and extremely complex systems. RAD allows implementation success in areas where a classic, ”waterfall” and ”agile” type approach, might cause problems, because of the communication and specification requirement difficulties, thus presenting problems in reaching a continuous dialogue between the business and technology areas. By using the RAD development approach we achieved the implementation of complex systems, succeeding to combine technological sophistication and the ergonomicity necessary for users activating on the capital market, users for which an attention dedicated to a subject for more than a few minutes at a time is often improbable.

We have presented the OTC electronic markets and an original method for their implementation. Although there are commercial approaches in this field, realistically, none of them have managed to achieve an effective market penetration due to both business related and technologyl reasons. From a technical point of view, such systems require ”pattern matching” modules, which can be more or less evolved. Our approach is an effective combination of pragmatism and efficiency and offers the prerequisite for an already used system to be extended with complex algorithms, but potentially less deterministic, such as the neuronal networks.

We have presented the Kogaion system, used for pricing convertible bond products. The system uses a dedicated approach which has allowed us to get into implementation details, at a level much harder to get to in the case of more complex systems. Kogaion is a very useful system which allows the trading of products showing a high profit potential because of the relatively complex nature of the supported financial products.

In the case of the presented transaction validation and complete ordering module, the complexity consisted in the implementation from ”the bottom up” of all the elements necessary for an extremely reliable communication mechanism, of its testing in the context of extremely rigorous functional requirements. The level of functional and stability requirements required for this module is equivalent with the ones used in the telecommunication systems. The complexity was represented by the low level of modifications allowed to the already existing system, the high number of connections, the fact that this validation module had to be the ”last guardian” against errors which could represent very high costs in case of their occurrence. For the implementation of the module we used conventional mechanisms in order to insure the robustness of the approach and to minimize the potential for error.

Finally, we have approached the role of the technical architect in the context of the capital market industry, highlighting the importance of being aware that the success of the technical architect and consequently of the implementation of systems depends on a set of competences not necessary related to the academic education or the on the job training but rather on a complex mixture highly depending on the person and organization. These competencies are supported also by technical, business and other types of knowledge.

It is important to understand that for the execution of the systems presented in this thesis it is necessary to master a wide array of knowledge gathered during the implementation of dedicated systems, be them execution systems, risk systems, MIS (Management Information Systems), reporting systems or others. All of these form a cluster which presents major technical and business difficulties, whose success is often extremely difficult to achieve, and in order to achieve this success in a consistent manner it is necessary to gather knowledge during an extended period of study and work in various fields associated with the capital markets.

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