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INTELLIGENT AGENTS' IMPLEMENTATION FOR STUDY PROCESS QUALITY PERFORMANCE INDICATORS' STATISTICAL ANALYSIS

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The purpose of the paper is to present the methodology and its implementation results in the field of statistical research of study process trends by using intelligent agents at Transport and Telecommunication Institute (TTI).

The article describes how to use mobile agents for data retrieving, computing and monitoring Quality Performance Indicators (KPI), defining the objective, quantitative indicators of the quality of the education process generally and in the selected area.

Key Performance Indicators, also known as KPI or Key Success Indicators (KSI), help the institution to define and to measure the progress toward organizational goals.

The Key Performance Indicators are quantifiable measurements, reflecting the critical success factors of the organization. The higher school may focus its Key Performance Indicators on the graduation rates of its students. Whenever Key Performance Indicators are selected they should reflect the organization goals and the key to its success, and they must be quantifiable (measurable).

The big amount of the Key Performance Indicators can be calculated with using data sets from existing TTI Information System (TTI IS).

This system successfully supports the university study process with all the tools required for the routine study process management: classes scheduling, students' enrolment, session results recording, etc. And on the next step we can use the prototype of the analytical system (TTI AS) for data maintenance and analysis was created at the Transport and Telecommunication Institute by means of the OLAP (On-Line Analytical processing) principle. The paper emphasizes one of the analytical tasks of study processes management at the university, which has been solved with the help of the TTI AS

This investigation is considering only one of the TTI realised programs quality, i.e. the higher professional study program "Transport and Business Logistics".

Keywords: *Analytical System, OLAP-technology and Data Marts, complex indicators, quality indicators.*

Introduction

The investigation in the area of education services quality control was launched at Riga Transport and Telecommunication Institute in 1998 [1]. This work has been conducted within the frames of several projects oriented to the development of the Baltic Region [2].

The emergence of the liberalization of education has forced Universities to strive for international standards in order to be able to compete with their competitors. In addition, the student's demands are getting more and more complex. Universities then must ensure that the students receive high quality service. Universities have responsibility to produce graduates that are able to accommodate challenges emerging in society, such as graduates producing high quality profile and competence.

Education today is subject to the same pressures of the marketplace. Profound changes in competition have made universities and higher education institutions think like business. A number of factors have forced the higher education sector to become much more competitive in its approach to attracting and retaining students.

Meanwhile, there are some strategic challenges, i.e.:

- Offer high quality, challenging academic programs that influence and respond to a changing society.
- Preserve and enhance educational processes through the application of active learning principles.
- Promote excellence in teaching, research, scholarship, and service.
- Recruit and retain a diverse university population.
- Foster a collegial, trusting, and tolerant environment.
- Provide safe, accessible, effective, efficient, and inviting physical facilities.

- Provide responsive, efficient, and cost-effective (educational support) programs and services.

Universities also have to adjust themselves and develop strategies to respond rapidly to the changes in organizational environment and increasing demands of stakeholders.

The higher education (HE) industry worldwide is facing a dynamic and turbulent environment due to trends such as changing demographics in student populations, decline in public funding and greater emphasis on information and communication technologies in learning and teaching. HE is shifting from a public service to a market-driven one and universities now face pressing concerns such as financial constraints and global competition. As a result, HEI are faced with the need to reform many of their existing management practices and mindsets.

All the universities of the world (including TTI) are currently at the centre of intensive environment changes. They are being required to educate more students, with the increasing variety of backgrounds and, unfortunately, with the decreasing government funding. Universities should compete vigorously for students' enrolments and external sources of funding. In this connection universities have had to reassess their fundamental business and the way they go about it.

The Information Technology (IT) is viewed as an important factor in streamlining their operations and all the universities are interested heavily in systems and services. The implementation of the technology covers such aspects as IT infrastructure (networks, standards, hardware, etc.); online learning management systems (such as Moodle) [3]; academic management systems (e.g. ERP - "TTI IS") which may be fully integrated with the learning management systems and financial systems; digital library investments and extensive staff development.

Today the complex system involving such main part as the decision-support system plays a significant role in our University (Figure1) [8].

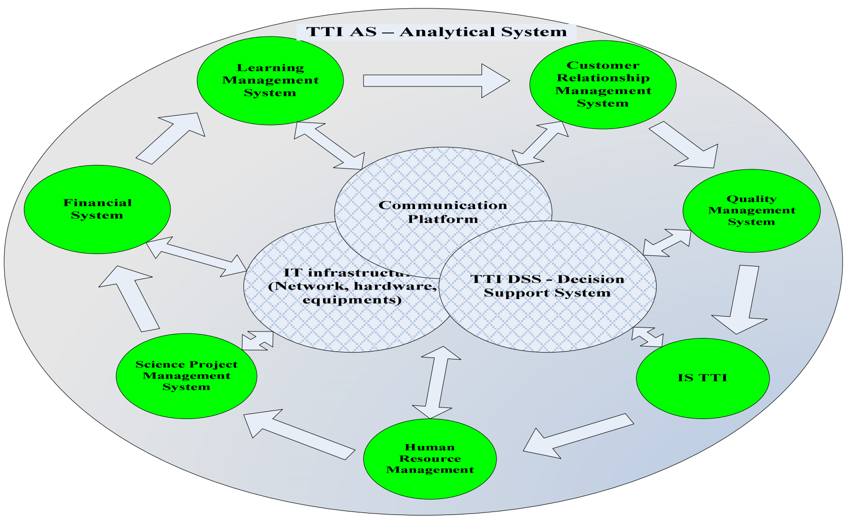

Fig. 1. Scheme of TTI complex system

The target is the efficiency and usability of the TTI managerial decision support system. The algorithms of the decision support system and their application at the Transport and Telecommunication Institute are investigated with the aim of processes management and forecasting. The quantitative and qualitative management of study process, elaboration of managerial decisions and recommendations with the purpose of its improvement are particularly important.

As an example of the suggested methodology a set of KPI was calculated and analysed to characterize study process: the financial efficiency, the study process quality, etc.

Intelligent agents' usage, suggested by authors, gives new opportunities for study process KPI analysis.

1. Intelligent Mobile Agent's Implementation

In computer science, a mobile agent is a composition of computer software and data which is able to migrate (move) from one computer to another autonomously and continue its execution on the destination computer.

A Mobile Agent, namely, is a type of software agent, with the feature of autonomy, social ability, learning, and most importantly, mobility.

More specifically, a mobile agent is a process that can transport its state from one environment to another, with its data intact, and be capable of performing appropriately in the new environment. Mobile agents decide when and where to move. Movement is often evolved from RPC (remote procedure call) methods. Just as a user directs an Internet browser to "visit" a database or website (the browser merely downloads a copy of the site or one version of it in the case of dynamic web sites), similarly, a mobile agent accomplishes a move through data duplication. When a mobile agent decides to move, it saves its own state, transports this saved state to the new host, and resumes execution from the saved state.

A mobile agent is a specific form of mobile code. However, in contrast to the Remote evaluation and Code on demand programming paradigms, mobile agents are active in that they can choose to migrate between computers at any time during their execution. This makes them a powerful tool for implementing distributed applications in a computer network.

An open multi-agent system is a system in which agents that are owned by a variety of stakeholders continuously enter and leave the system.

Commonly applications of mobile agents include:

- Resource availability, discovery, monitoring.
- Information retrieval, system information collection, support operations in client/server paradigm system information.
- Network management, remote collection of network throughput, available bandwidth monitoring, other remote machine network parameters.
- Data replication and collation, server configuration backup, file collecting & sorting, other remote machine data backup.
- Dynamic software deployment, remote install monitoring & gauging making backup.

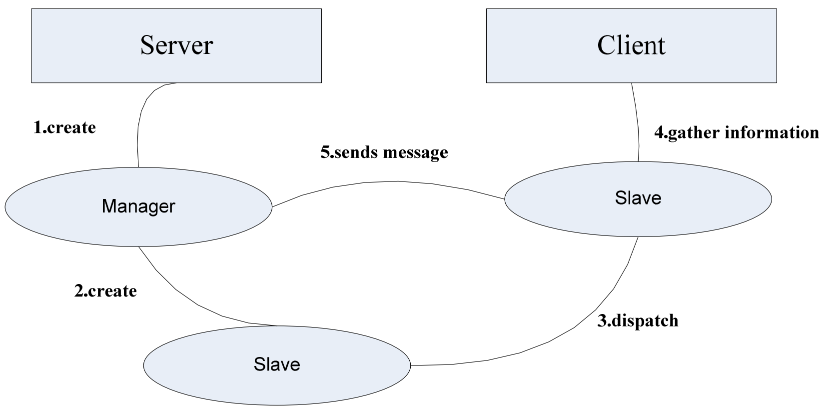

Fig. 2. Scheme of using software agents

A software agent is loosely defined as a program that exercises an individual’s or an organization's authority, and autonomously meets and interacts with other agents and its environment while working toward a goal. Possible interactions among agents include such things as contract and service negotiation, auctioning, and bartering. Software agents may be either stationary or mobile. Stationary agents remain resident at a single platform, while mobile agents travel among platforms by suspending their execution, moving themselves to another platform, and resuming execution upon arrival.

A number of models exist for describing agent systems. For the purpose of discussing mobile agent security issues, however, a simple model consisting of only two components, the agent and the agent platform, is sufficient. An agent consists of the code, data, and state information needed to carry out some computation. The agent platform provides the computational environment in which an agent operates. Multiple agents can cooperate with one another to carry out some task and are able to move or hop among agent platforms. The platform where an agent is instantiated and commences activity is referred to as the home platform, and normally is the most trusted environment for an agent. One or more hosts may make up an agent platform, and an agent platform may support multiple locations or meeting places where agents can interact. Since some of these details do not affect the discussion of security issues, they are omitted from the agent system model illustrated on Figure 3, which depicts the movement of an agent among several platforms.

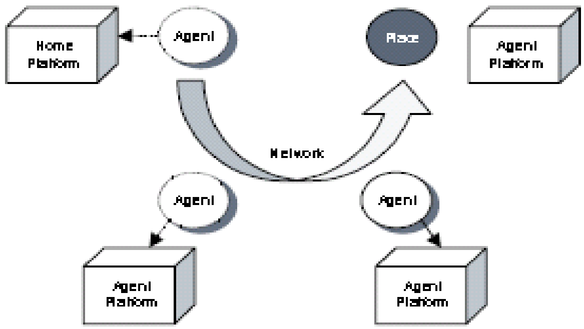

Fig. 3. Agent system model

Mobile agent computing is an extreme form of distributed computing, which poses a severe challenge to the security of an application. One difficult class of threats introduced by mobility is the possibility that the computational environment (i.e., the agent platform) may attempt to subvert the agents comprising the application. Other threats include agents attacking the agent platform itself or other agents at a platform, and outside entities attacking the overall agent framework.

A wide range of techniques, both conventional and newly developed for this paradigm, are available as technical countermeasures to the security threats encountered in deploying agent-based applications. Agent systems typically incorporate such techniques into their design, where internal data structures reflect if, how, and when the mechanism should be applied. Besides control settings on security mechanisms, internal data structures also convey the permissions needed by an agent, such as resource access or consumption. A big amount of publications describe a general-purpose mechanism for managing the privileges (e.g., resource permissions and security mechanism settings) of mobile agents based on the use of attribute certificates. An attribute certificate allows various principles to govern the activities of mobile agents through selective privilege assignment.

The paradigm of the distributed computing and the underlying mobile agent (mobile agents) was considered as a prospective TTI AS direction. The mobile agent is understood as the essence combining the data, code and the ability to move between different runtimes.

The following 3 main tasks of the information management process are planned to be solved by intelligent agents' implementation:

- Information searching, collecting and processing for KPI calculation. A combination of search agents is used.
- Data monitoring. The agents are used for notifying the user of changes in the various data sources in real time.
- Universal access to data. Agents are used as brokers working with different data sources, with mechanisms of the interaction with each other.

2. KPI - Key Performance Indicators

Key Performance Indicators, also known as KPI or Key Success Indicators (KSI), help the University to define and to measure the progress towards organizational goals.

Once the organization has analysed its mission, identified all its stakeholders and defined its goals, it needs the facility of measuring the progress toward those goals. The considered Key Performance Indicators belong to such measuring facilities.

The Key Performance Indicators are quantifiable measurements, reflecting the critical success factors of the organization. The higher school may focus its Key Performance Indicators on the graduation rates of its students. Whenever Key Performance Indicators are selected, they should reflect the University goals and the key to its success, and must be quantifiable (measurable).

Considering the educational process and criteria for its quality, the following indicators can be integrated into the group:

- educational content quality indicators;
- learning technology quality indicators;
- educational results quality ("learning outcome") indicators.

From the other side, some investigators focus on the following five indicators:

- graduates' employment;

- graduates' satisfaction;
- employers' satisfaction;
- students' satisfaction;
- graduation rate.

Each of the complex indicators consists of a large number of indicators, among which there are numerical and qualitative numbers. Obviously, the quantitative assessment of the quality will be possible after selecting the method of transforming the non-quantitative indicators to quantitative ones.

A wide range of Key Performance indicators was mentioned [7]. There are known about 49 most popular ones. Some of them may be very interesting for our investigation:

- Percentage of graduated students relative to all students.
- Percentage of graduated students that graduate 'late' e.g. outside the allotted time.
- Percentage of graduated students that graduate 'early' e.g. within the allotted time.
- Percentage of dropouts relative to number students within measurement period.

One of the current issues of interest is the need for performance management, especially measurement of Key Performance Indicators. Key Performance Indicators (KPI) is a fundamental concept in the area of performance management.

In business context, today many organisations apply Key Performance Indicators (KPI) to measure its growth and competitive position. To ensure institution growth, University must provide current levels and trends of its KPI achievement. And to ensure its competitive position, University should provide its appropriate comparisons for KPI. These facts are related to University main goals, which are becoming growing institution and gaining sustainable competitive advantage.

This paper tried to provide a methodology of measuring research, academic and supporting Key Performance Indicators (KPI) of Universities [9].

Statement of the Problem: Based on above description, there is a need to provide processes that promote KPI selection, its weighting and measurement. In this context, the proposed framework attempted to answer the following questions:

(a) What processes are utilized in selecting appropriate KPI of a University?

(b) What procedures are in place in order to make difference importance of each KPI element (weighting system)?

(c) How do the University measure KPI to ensure its growth and competitive advantage?

Objectives: The proposed methodology has objective to:

- Provide evaluation tools of academic, research and supporting activities in University.
- Provide University positioning system to ensure its growth and competitive advantage
- Reveal the importance of current levels, trends and appropriate comparisons for key measures and indicators of University performance management

Proposed methodology: Research method is based on Analytic Hierarchy Process (AHP), a technique usually used in multi criteria decision. The advantage of using this technique is in conducting the subjective evaluation situation on the important components or variables in the decision making process. The model built is based on three components which are academic (teaching), research and supporting activities. Every component has its related KPIs. The proposed framework consists of:

Criteria Identification: To evaluate University performance, basically there are three main aspects or criteria, i.e.: academic (teaching), research and supporting activities. These three criteria are then weighted using AHP technique.

KPI Identification: Based on, this criterion, the next step is to identify list of KPI related to each criteria. This list is completed by experts who are familiar or involved in University activities. In order to be more realistic, the selected KPI are analysed by some experts group

KPI Selection: If there are too many KPI, it will be difficult to manage and measure. So it needs to select the most important KPI that have significant contribution to University performance. In order to class this list in descending order of relevance, the research conducts a survey involving experts who are directly involved in University activities. In this case, a questionnaire, in which the experts have to give a mark to each criterion, is distributed. The experts use the three-point scale of "not important", "somewhat important" and "very important" using "Cut off Point" approach. Its result is the selected KPI according to its degree of importance.

In this case, we have to find first the most important KPI from list of KPI candidates. The latter will have to relate to academic, research and supporting criteria. This list will be completed by experts who are more aware of the problems that University have to cope with. It will happen to be finally some KPI selected.

In order to class this list in descending order of relevance, it needs to conduct a survey involving respondents selected the ones who are directly involved in University management. The number of members involved in the evaluation process depends on the size of the organization. It has been chosen to give them a questionnaire in which they will have to give a mark to each KPI. They will use the three-point scale of "not important", "somewhat important" and "very important".

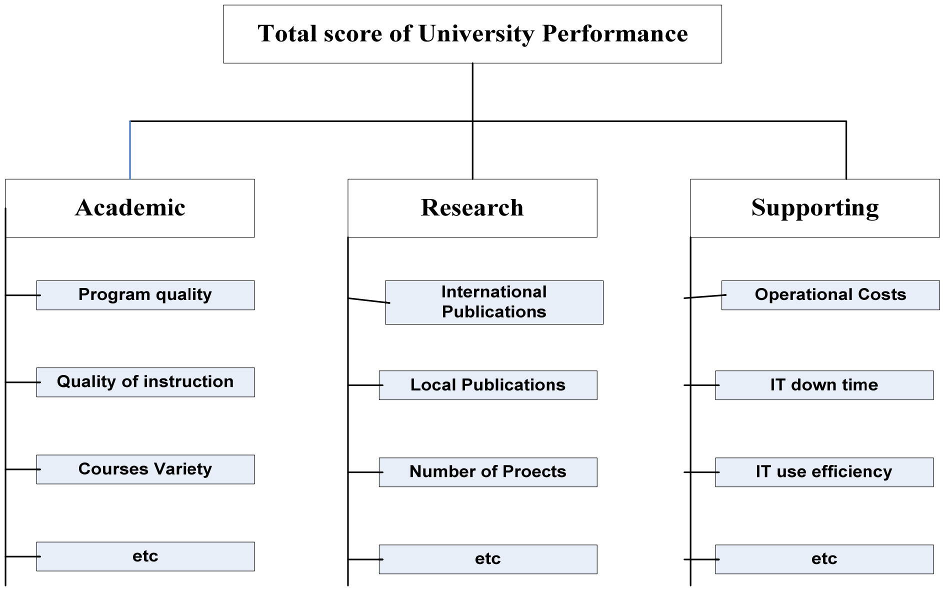

Fig. 4. Hierarchy of KPI

KPI Tree: The next step is to build KPI tree, which is basically composed by three levels: the goals, the criteria and the KPI (figure 4). In the evolution of the AHP system that we are presenting, we build the hierarchy which consists of:

- The goal (1st level): Total score of University performance
- The criteria (2nd level): we can find three criteria; "academic (teaching)", "research" and "supporting".
- The rating scale (3rd level): contains KPI related to each criterion, and its rating scale.

Criteria and KPI Weighting: In the second level (criterion), the three criteria ("academic", "research" and "supporting") are weighted using pair wise comparison proposed by AHP approach. Results of questionnaire survey are translated into pair wise comparison matrix and then it is followed by weighting process.

AHP method provides a fundamental scale to assign pair wise comparison judgment, as shown on Table 1 [9].

Table 1. Example of pair wise comparison judgment matrix criteria

	A	R	S	Priority vector
Academic (A)	1,000	3,000	1,600	0,518
Research (R)	0,330	1,000	0,770	0,195
Supporting (S)	0,625	1,300	1,000	0,287

Table 2. Inconsistency matrix

	A (0,518)	R (0,195)	S (0,287)	Line sum
Academic (A)	0,518	0,585	0,459	1,562
Research (R)	0,172	0,195	0,221	0,588
Supporting (S)	0,324	0,254	0,287	0,865

The meaning of the table is that criterion A is strongly more important than criterion B. For the criteria weighting, the fundamental scale is not sharp enough to assign relevant pair wise judgements. AHP method proposes to create as many refinements as needed for the specific problem, and to estimate verbally the value of each new point of the scale. This work has to be done by the evaluation team, in order to obtain a consensus about the evaluation scale. The evaluation team had created a scale divided 1 to 9. Also evaluators use their own comparison ruler, but using the same principle than the basic one.

KPI Scoring: KPI are measured based on principles of trends and comparison dimensions. Trends consist of current level and last year performances. For example, if current level is performance of year of 2006, so trends consist of performances of years 2005 and 2006. This shows the growth of two latest years. On the other hand, comparison shows position current level performances compared to its competitor performances or benchmarks (Table 3).

Total Score of HEI Performance: Total score of University performance is calculated with the following formula for Total Performance score (T):

$$T = \sum_{i=1}^{k} \sum_{j=1}^{n} SijWij \qquad (1)$$

where,

i is index for performance criteria (academic, research and supporting);
j is index for KPI-j of criterion i,
S_{ij} is weight of criterion i,
W_{ij} is weight of KPI-j related to criterion i,

Wheel Model of University Performance: A simple analogy would be to look at an University performance as a wheel and the individual KPI are the spokes to the wheel (Figure 5). Having just one or two spokes loose can make a wheel out-of balance.

The longer a wheel runs out of balance the more damaging the effect to the organization. When the wheel on a cart becomes so unstable that its primary function fails, you would simply replace the wheel. Obviously, an organization cannot simply replace itself, but your customer can and will replace the wheel (you the Supplier) if you fail to perform to the Customers' needs and expectations.

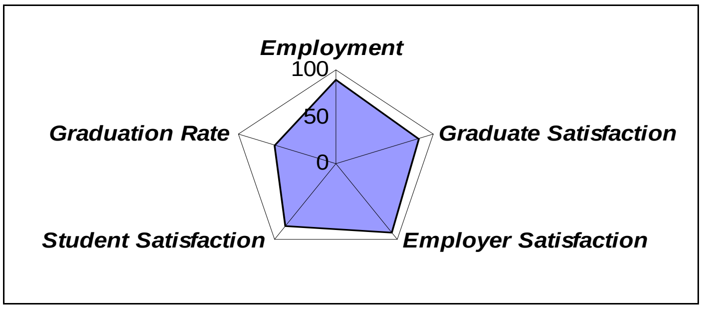

Fig. 5. Wheel model for University Performance and its KPIs

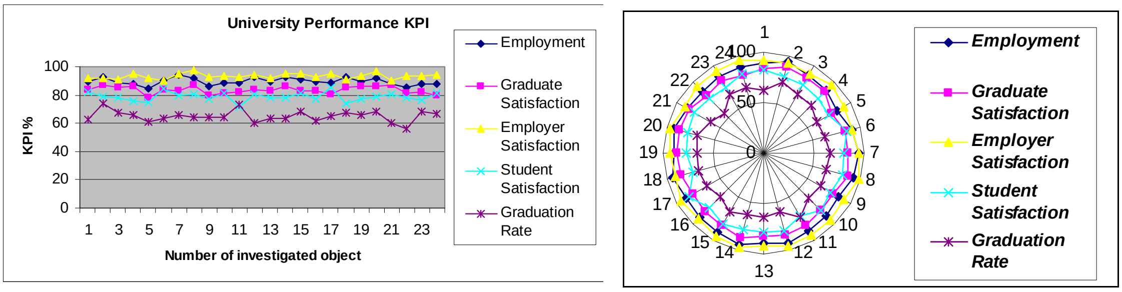

Fig. 6. Key Performance Indicators graphic representation

This approach gives the opportunity to investigate the obtained KPI from all the appropriate views and to provide the study process trends analysis.

The following results presented on Figures 7, 8, **9,** have been obtained by means of the technology based on intellectual mobile agent conception. This technology has been implemented on MS SQL Server 2005 platform. The mobile objects perform the following tasks:

- Information searching, collecting and processing for KPI calculation. A combination of search agents is used.
- Data monitoring. The agents are used for notifying the user of changes in the various data sources in real time.
- Universal access to data. Agents are used as brokers working with different data sources, with mechanisms of the interaction with each other.

The results of the intelligent agents' execution have been stored and processed by means of the MS Office Excel 2007, as MS SQL Server 2005 OLAP client.

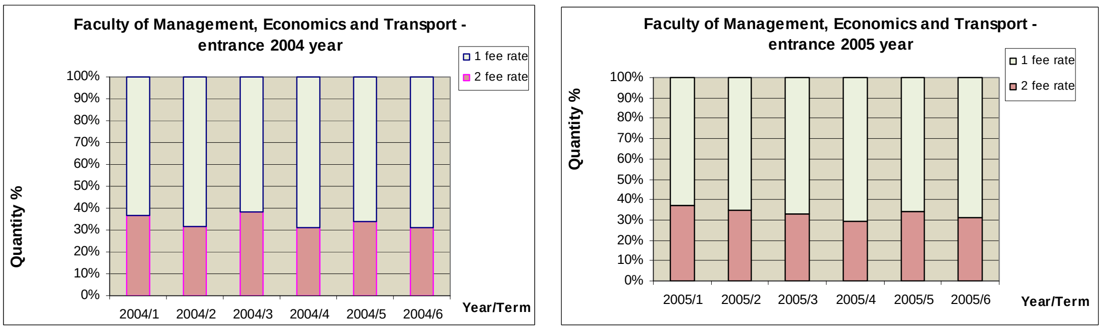

Fig. 7. Dynamics and distribution of students' amount with two tuition fee rates on FMET (2004, 2005 entrance years)

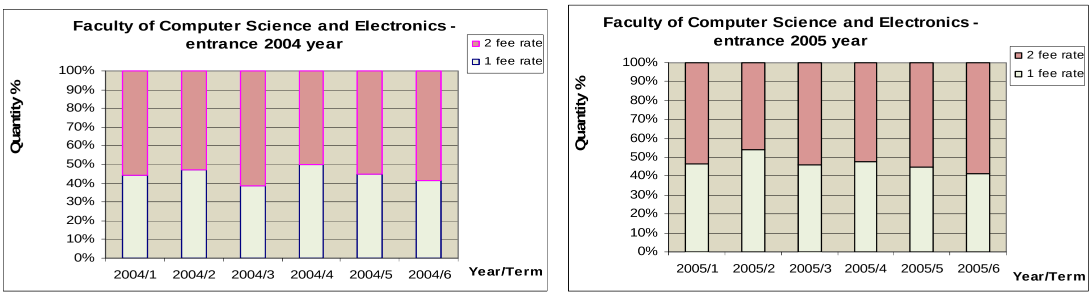

Fig. 8. Dynamics and distribution of students' amount with two tuition fee rates on FCSE (2004, 2005 entrance years)

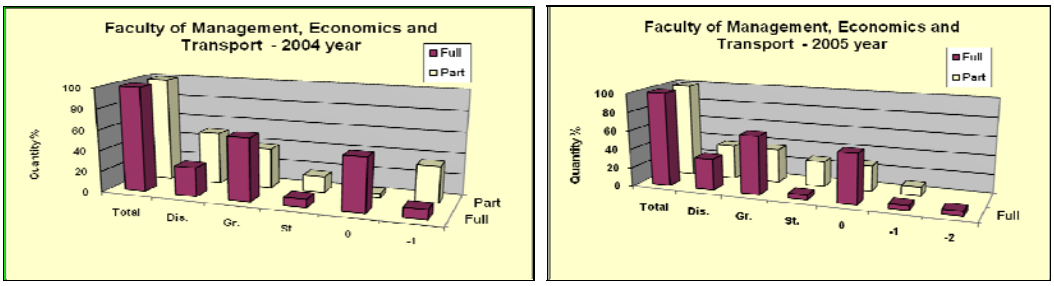

Fig. 9. Comparative analysis of students' study programs completion time (2004, 2005 entrance years)

Figure 7 and Figure 8 presents the results of the comparative analysis, e.g. the distribution of students' amount with two tuition fee rates. That provides the study process trends analysis for different faculty and the entrance year.

The dynamics of different tuition fee rates for two separate faculties and two entrance years (FCSE – the Faculty of Computer Science and Electronics, FMET – the Faculty of Management, Economics and Transport). KPI dynamic also depends on the entrance year.

Figure 9 shows the comparative analysis of students' study programs successful completion in the section of Full time/Part time for 2004/2005 entrance years.

It presents the comparison of study success of the students for 2004 and 2005 entrance years (the Faculty of Management, Economics and Transport) for full-time and part-time. The diagrams show the difference in completion time between full-time and part-time students.

This approach allows making the quantitative comparison of KPI for all the programs implemented at the Faculty of Computer Science and Electronics (FCSE) and the Faculty of Management, Economics and Transport (FMET).

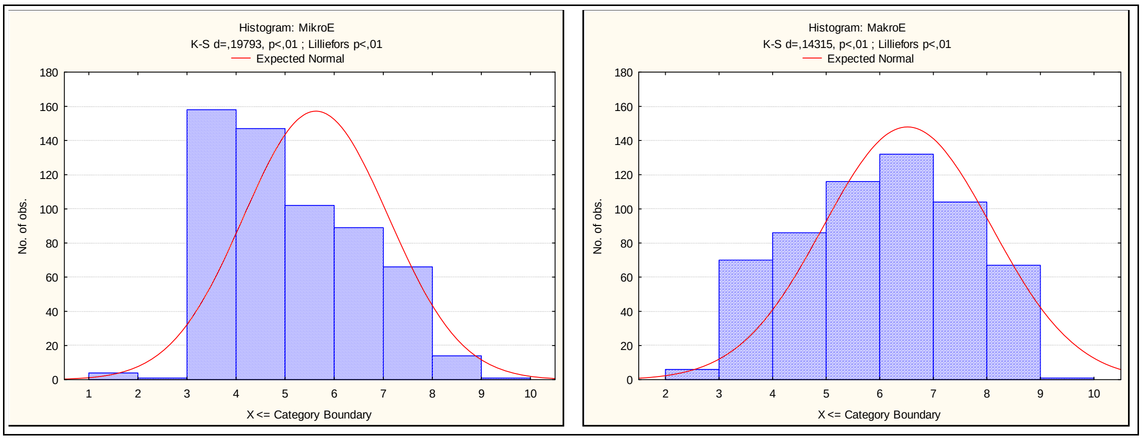

Fig. 10. Comparative analysis of students' marks deviation from normal distribution

Figure 10 presents the comparison of student marks distribution and its deviation from normal distribution for study courses "Macroeconomics" and "Microeconomics".

Taking into consideration the recommendations of ECTS (European Credit Transfer and Accumulation System), students' marks distribution for the sufficiently large students' groups should be close to the normal distribution.

The students' marks distribution for "Macroeconomics" presented on the right part of the Figure 10 is close to the normal distribution.

The students' marks distribution for "Microeconomics" presented on the left part of the Figure10, deviates considerably from the normal distribution. This fact reflects the existence of some unknown external disturbing factors, which must be clarified before KPI calculation.

Conclusions

The results of the investigation make it possible to conclude that:

- Methodology and its implementation results in the field of statistical research of TTI study process trends by using intelligent agents are presented.
- Mobile Agent system model is suggested for KPI calculation.
- Some graphical representations for analyses of calculated KPI are introduced to characterize the study process at the University.
- Several examples of statistical data analysis by selected KPI using mobile agents are presented to provide the TTI study process trends examination.

Obtained results can be successfully used for the study process improvement. The considered results may be applied for the education process analysis provided at the other Universities and other educational establishments for decision-making support and the progress measurement towards organizational goals.

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