Integration of Building Automation Systems and Facility Information Systems

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Abstract

The need for integrated automation and Computer Aided Facility Management Information (CAFI) systems has been increased recently. Though some industrial standards could support integration, they are usually not implemented both sides of the connection. While Facility Management Information Systems usually support system integration, Automation Systems, e.g. Building Automation Systems (BAS), are usually vendor-specific and rarely support it.

It's possible to integrate Computer-Aided Integrated Facility Management and some Building Automation Systems, but the literature about integrating such systems is still poor, however there's significant need for integrating such systems. This integration has huge advantages, e.g. real-time data processing, integrating vendor-specific building automation systems, CAFM systems, CAD and ERP systems, etc. This paper gives a short overview about the background, limits, possibilities, and collects the special issues of the integration.

Key words: Computer Aided Facility Management, Building Automation Systems, integration.

1 Introduction

Status-monitoring systems collect real-time and non-real- time information. This information may need data processing before displaying. Both the data collector and the connected Computer-Aided Facility Information (CAFI) system can process, store, display the collected information or use third-party software for any of these purposes. There is no accepted industrial standard format to collect, store, process and display this information. However, the monitoring systems, such as Building Automation Systems (BAS), often have vendor- specific monitoring software that can display results on a computer's screen. These are usually closed systems, but there are some open systems, which can have an interface or store the peripheral information in a database to access its data from outer applications.

This paper observes open status (property) monitoring systems trying to gather the critical points (mainly special issues) to implement successful integration with CAFI systems. So data from multiple vendors' monitoring information systems can be integrated with the same CAFI system that is also connected with the company's ERP system. The CAFI system can effectively support management decision-making and use the proper criteria system to determine the current state of the observed system to alert the specialists.

This research is an extension to the ICHEPIS project *(Inventorisation for a Cultural Heritage Periodic Reporting System - Development of standardized database model for integration of the UNESCO World Heritage Periodic Reporting System and the National Heritage Conservation Information System)*, that was performed by the Budapest University of Technology and Economics (BUTE) Information and Knowledge Management Department, the Royal Angkor Foundation and the Hungarian Administration of Cultural Heritage from 1999 to 2003. Its aim was to create suggestions (drafts) for implementing and reengineering the information systems on the UNESCO World Heritage sites to improve and standardize the level of site protection. On the sites the monitoring and automation control systems must be integrated with CAFI systems to achieve the proper level of protection, so the site specialists first determine the range of objects and properties for later observing, than choose the appropriate monitoring system and the peripheries (e.g. a Building Automation System) for remote sensing.

1.1 Background and purpose of the study

The aim of this research was to observe automation systems and how they can be integrated with Computer-Aided Facility Information (CAFI) systems.

Unfortunately literature about the integration of CAFI and Building Automation Systems is rather poor, so a decision was made to create a short overview after collecting the main advatages, critical points, possibilities, limits and a suggested method of the integration CAFI and Building Automation Systems. The integration offers several possibilities to improve the services in the Corporation's Information System (CIS), so the company will be able to reduce operational costs and reach a higher level of protection.

Building Automation Systems (BAS) are vendor specific systems, often are not integrated with the other parts of the CIS. Computer-Aided Integrated Facility Management (CAIFM) systems are usually integrated with the other parts of the CIS, e.g. Enterprise Resource Planning (ERP) system. So with the integration of building automation and CAFI systems the BAS and all other parts of the CIS can also be integrated.

It is recommandable to connect Building Automation Systems via CAFI systems to the CIS, because both system collect and process building-related data.

The main advantages of the integration:

- *Real-time building (facility) information and information processing in CAFI, CIS*:

  Automation systems are real-time systems, so they administer real-time information. In a connected system, if the CAFI system can read data collected by one or more BAS-s, these informations can be used for real-time alerting, data processing.

- *The possibility of integration more different vendor specific BAS-s via CAFI systems*: Modern CAFI systems usually support integration with other systems, even via databases.

- *Decision making, data processing or conditional alerting that needs input information from one or more BAS-s and CAFI (or other CIS) are now available.*

- *BAS extensions without third-party software*:

  Some building data processing services can be executed by the CAFI systems, instead of developing and running third- party data processing services.

- *Read (reach) BAS-collected data from other parts of CIS.*

- *Reduces operational and perhaps development (e.g. no need to develop some third-party data processing or alerting software) costs.*

- *Higher protection level can be reached (by precise alerting).*

ERP systems are rather frequently analyzed integrated systems, but some theses can be well-used in this area, too. Some authors state that the critical challenge in ERP implementation has to do with first identifying gaps between the ERP functionality and the specific organizational requirement, and then deciding how these gaps will be handled [8]-[12]. In this territory the problem is a little bit more complex, since these systems usually don't (or just poorly) support integration with outer systems.

In publication [8] Kyung-Kwon Hong and Young-Gul Kim analyse the implementation of ERP systems from an organizational fit point of view. They found that the followings are needed for a successful implementation (their results can be properly-used in this area, too):

- The organizational fit of ERP is positively related to ERP implementation success.

- There is an interaction effect of the level of *ERP adaptation* on the relationship between organizational fit of ERP and ERP implementation success.
- There is an interaction effect of the level of *process adaptation* on the relationship between organizational fit of ERP and ERP implementation success.
- There is an interaction effect of the *organizational resistance* on the relationship between organizational fit of ERP and ERP implementation success.

They also discussed the issues of the organizational (ERP and process) adaptation the new information system and the organizational resistance, sample and data collection, measurement development, instrument and content validation, reliability. Another publication discusses the issues of the implementation of ERP packages in different organisational and national cultures [13]. These results can be well used also in this area, therefore in this paper mainly the IT-related issues of the integration are accelerated.

Kevin Yu, Thomas Froese and Francois Grobler publicated [2] data models for computer-integrated facilities management (CIFM). The IAI developed Industry Foundation Classes (IFC) and particularly standardized data models for FM usage to improve the facilities management practice and enable information sharing among computer applications. They also introduced an information system architecture for CIFM.

In a later publication Shengwei Wang and Junlong Xie [3] showed a development framework for CIFM. It gives an overview about the architectural solutions to integrate Building Management Systems with each others and Facility Management systems on the Internet, intranet or extranet. They showed more architecture models and described how to link more standalone BMS systems with each others and how to integrate BMS with CIFM systems using such software agents that can make alerts from under CIFM systems. They showed a web-server application based on HTTP, ASP and DCOM technologies that are used for monitoring (control) purposes.

For the interoperability and ease of integration, the devices from different manufactrers have to use the same standard protocols. They stated that BACNet [4] and LONWorks [5] are the standard protocols developed to meet the needs of network protocol standardization in the building-automation industry. The control networks based on these protocols are called "open networks" [3], their architecture can be seen on Figure 1.

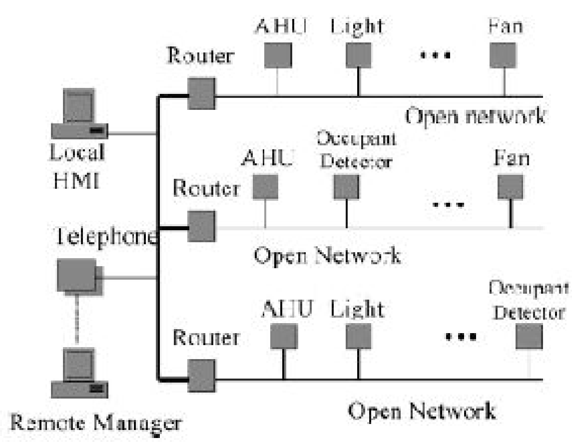

Figure 1: Architecture of open networks [3]

The architecture of internet enabled open networks can be seen on Figure 2. This network architecture includes a web-server and some routers to bind the sub networks and the different network components with each others.
The more phases of the system integration work can be solved without or with less programming, the better can be reduced the costs. This study analyses the possibilities of the integration Building Management and Computer-Integrated Facilities Management Systems with or without programming. Since

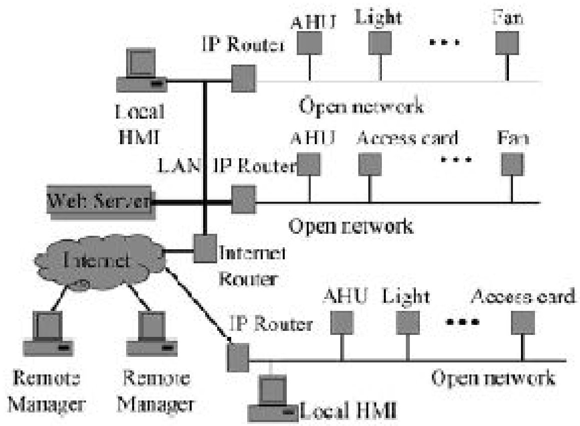

Figure 2: Architecture of Internet-enabled open networks

the CIFM systems support better integration than the former FM solutions did, it is worth to collect the most important current possibilities and key considerations for successful integration.

The possibilities of the integration of BMS and CIFM systems are collected, including those with or without additional programming. It uses a developed system architecture scheme that doesn't care for exactly what protocol is used to build the connection between the subsystems, but it assumes that the BMS systems have own databases that are open for accessing by third-party applications, such as CIFM systems. In an earlier publication [3] more network protocols [4]-[5] are suggested for this purpose, but the scheme uses standalone databases, each dedicated to and collects data for a (or may be more) certain application, but is accessible from other applications, at least for reading purposes. Of course, this scheme even defines such points, where third-party applications can also be included, if there is need for it.

2 Approach

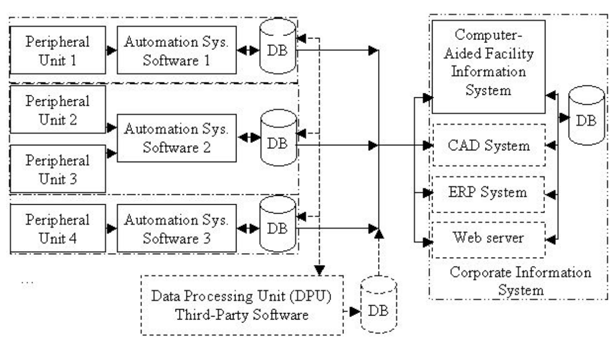

Figure 3: Potential system architecture

The system architecture scheme can be seen on Figure 3, where the arrows show the direction of the possible information transmission, the dashed lines mean optional objects or flows. The system consists of at least one BAS that includes one or more peripheral units and an Automation Software that stores the collected information in its database. They assumed to be open systems, so their collected/stored information can be reached by other applications. The automation systems can be connected to the CAFI system either directly, via interfaces, through shared databases or third-party data processing applications. The CAFI system supports integration, so it can be connected with the BAS-s, third-party data processing units and other subsystems in the CIS, such as Enterprise Resource Planning or CAD systems.

It's not assumed that two BAS systems can be integrated with each others, since they are vendor-specific monitoring (control) systems, any of them can be connected with multiple periphery units (e.g. smoke triggers or different kind of peripheral devices).

The CAFI system can monitor (but rarely control) the peripheral devices. This is the only unit in the system that has all the peripheral information. Advanced Computer-Aided Integrated Facility Information (CAIFI) systems handle peripheral events raised by multiple vendor-specific control/monitoring systems. So the facility information system has all the information from each input devices that can be used to build complex criteria to create well-working alarms. CAIFI system cannot control the output peripheries (e.g. heating or air-conditioning systems), not even by controlling the vendor-specific control units, so this information can be used only to alert the specialists. The device controllers usually don't support controlling from outer systems (like CAIFI system), but for monitoring purposes the system can operate as an integrated system: even the CAIFI system can alert the specialists.

This limit usually means no problem, because in automation control systems the safety has highest priority, therefore third-party software usually is not allowed to influence the operation of the controlled subsystems, but the monitoring may be enabled.

3 Experiment and results

The purpose of the study was to adjust the critical points of facility automation and management information systems, so first the general conditions and limits of the integration and the other critical integration factors are discussed.

3.1 Circumstances and conditions of the integration

3.1.1 General reasons why integration fails

- Interface usually not supported on each side: AS, CAIFI system or DPU (if exists).
- Database or file storage format (if exists) of the automation system:
  - CAIFI system or DPU don't support that database storage/file format.
  - AS or CAIFI system locks its dedicated database/file or can't use it shared.
- If there is a DPU in the system, the same requirements concern to the AS-DPU and DPU-CAIFM connections, like the one that would be between AS and CAIFI system.

3.1.2 CAIFM limitations

- Don't support connections with other databases,
- Tries to lock the shared database,
- Doesn't support data field customisation,
- If the position of the real FM object (e.g. furniture) changes can't be followed under the CAIFI system user interface. The old CAD plans don't change automatically and can't be changed manually.

3.1.3 The ideal case for the integration

Integration is most successful (by our experience) if

- Even object position or shape changes can automatically change position of the appropriate object on the CAD/GIS based map of the CAIFI system user interface,
- Time-coded database records can be found,

- All the sensed information can be accessed by third-party software (e.g. CAIFI systems or DPU-s), not only for the automation software,
- All the changes of the automation system can be sensed automatically in the CAIFI system, and the CAIFI system can be instructed to react.

3.2 Automation system elements

3.2.1 Peripheries

The peripheries can be input (sensors) or output (controlled) devices. Monitoring systems collect information only from input devices, automation control systems use the gathered information to make decisions and control the output devices. Monitoring systems collect data about the observed objects with different sampler frequency. There are real-time and non-realtime peripheries and data processing software.
Frequently used input peripheries:

- CCTV movie-camera [video (and audio) data],
- Microphone [audio],
- Thermometer [temperature],
- Smoke trigger [smell],
- Motion sensor [motion] (*even laser, infrared sensors),
- Door state sensor [state: opened, closed, key-in, etc.],
- Moisture, Air-Pressure [weather],
- GPS [geo-position],
- Piezometer, inclinometer, etc. [geological] [1],
- pH-level meter, [chemical],
- Radar devices [space monitoring],
- Air photos [air monitoring],
- Glassbreak Detector
- Door/Window Magnetic Contact, etc.
- Power failures,
- Low battery [6]

Frequently used output peripheries:

- Switches [e.g. lightning control],
- HVAC [heating, air-conditioning],
- Audio output,
- Video output,
- Computer output [e.g. monitor].

Usually the monitoring software's user interface for control and set the settings, analyze and evaluate inputs.
E.g. Honeywell classifies Automation and Control peripheries as follows:

- Environmental and Combustion Control (ECC),

- Fire Solutions Group,
- Industrial Measurement and Control,
- Security,
- Sensing and Control,
- VCSEL (Vertical Cavity Surface Emitting Laser). [7]

3.2.2 Automation software

Automation systems directly receive sensed information from the peripheries. Usually this vendor-specific software runs on a computer, where administrators can monitor the collected information.

- Automation system software shows the input values of the measurement and usually allows users to monitor the map of the sensors.
- Unfortunately these systems rarely support exporting the collected information, though it's an essential condition to the integration with CAIFI systems.
- Different automation systems can have different database and/or file storage formats.
- Automation systems can be integrated with a chosen CAIFI system, if they are connected with interfaces or if they know each others' database and file storage formats and their locations,
- CAIFM systems usually can open/reach only Geographic Information System (GIS) and Computer-Aided Design (CAD) files, though there are some limitations.
- Generally objects of CAIFM systems are stored in GIS or CAD-based graphical files, while peripheral inputs are in other file formats or in databases, but inputs of sensors that collect spatial information (e.g. GPS) are stored in databases, instead of files.
- Latest stored information of each stored sensor periphery means the current state of the observed objects.
- If only changes are stored or sent, capacity needs in the system can be significantly reduced, however sometimes sensed information have to be sent, else any data errors in the network, processing or storage can result false values in the CAIFI system.
- Extra features:
  - History list (changes with time-codes; not supported if file-storage is used),
  - Several periphery-specific reporting and analysis possibilities.

3.3 Data exchange and data processing

Among the monitoring and CAFI systems can be even used one or more (third-party) data processing units (e.g. services or software agents), but some CAFI systems are currently able to reach the collected and stored data in shared databases or through interfaces.

In remote-sensing automation systems the distance between the sensor and the monitoring/control units can significantly differ either inside the system (e.g. GPS and temperature sensors response times), but a little delay usually will not heart the automation system. The remote-sensing systems collect and store peripheral information in different frequency, so alarm conditions needs to be re-evaluated in the CAFI system every time a data change occurs.

Data processing units (DPU) are usually software agents, daemons or services that execute those works that are not supported in the connected subsystems. There is need for data processing if the connected automation and CAIFI systems or any periphery in the system could not do that. Data Processing Units can access and manipuate each subsystems' database, so they can even be used for mirroring the database of the automation systems and notify the CAIFI system. DPU-s can even have an own-use-database. To achieve an acceptable integration-level, it is essential that all the collecting, processing and transmitting phases should be executed automatically.

Data processing can be executed

- In the peripheral devices,
- Between peripheries and the automation system (as a DPU),
- In the automation system,
- Between automation and CAIFI systems (as a DPU),
- In the CAIFI system,
- More from the options above,
- Nowhere, if no data processing needed.

Data exchange is usually implemented in interfaces, shared databases or common-used files on both the input and output sides. The algorithms are usually periphery-specific (e.g. video or audio compressing). With data processing anyone can

- Create new structures (e.g. new database tables using the received input data),
- Compress the collected data for storing or sending through a low-bandwidth network,
- Transform data between two systems (if they wouldn't understand each others otherwise).

With data loss compression techniques network bandwidth and/or storage needs can be highly reduced, meanwhile multimedia-quality remains enjoyable, but later analysing may require better media quality. They usually require to be decompressed before analysing, so processing may become slower. Additionally, these compression techniques may clear the analysed information from the data sources.

3.4 Alarms and event handling

Alarms are usually supported in CAIFI systems. They are triggers that can alert the specialists (e.g. by showing a message-box or optionally with some sound), if the formally given logical condition becomes to true (false) or is true (false).

These conditions should be re-evaluated by every expression input data change, whether these inputs come from automation systems or not. CAIFI systems should automatically sense these changes, re-evaluate and start alarms.

Note, that even the current CAIFI systems are not able to sense the data changes in outer databases, so software agents needed for the proper integration if the system needs to handle alerts based on such information. Unfortunately, the production of software agents needs programming, but the integration can become very expensive.

This time software agents should sense the data change and notify the CAFI system, so it can react. Since usually there is no event that can be sensed by the software agent if some data change occurs in the observed database(s), the agents often poll these database(s), searching for data changes. It may need full mirror of the observed database data for later comparision. If the database size is large or can become large, it can result significant process time consumption that can be critical for the operation of the whole system.

Usually agents can notify the CAFM system only indirectly, by changing its database, so the CAFM system can sense the changes and raise alerts if some logical conditions' automatically re-evaluated value needs it.

Of course, agents in this model can be even used to process any data.

These conditions may use more separated automation systems' sensed data in the same expression, that's a kind of integration more, separated automation systems. Responsibility could become very high, because these alerts may trigger even catastrophes (e.g. fire in the observed rooms). Because of some errors between the Automation System and the CAIFI system, users won't be alerted by the system at all. If automation systems support alarms, from security reasons it's suggested to alert in the relevant subsystem. If the automation system doesn't support it, or needs to make an alarm with a condition that needs input from separated automation systems, the alarm should be implemented in the connected CAIFI system.

If the CAIFI system receives every sensed information without information loss filtering, changes and events can be displayed in a history-list for the whole system. Automation systems may not support it, and this way all the historical information could be seen from here. This report could be used for later historical analysis of the observed objects and the information system.

Unfortunately neither CAIFI nor automation systems support user interface integration. Vendor-specific automation systems are closed systems with various storage formats. There are such systems that doesn't support that third-party applications (e.g. CAIFI systems) can access their data. There're no standards in any side, so integration on the user interface is rarely supported.

3.5 How and what to display

The CAIFI systems usually show a CAD-layout, where users can choose the appropriate object. Additional supported navigation methods are usually even simple (e.g. tree-box based search). What information to display? If CAIFI systems support displaying different kinds of sensed information that is linked to the object, with some customisation the sensed data and their links can be displayed with previous data fields.

- Display sensed information in custom fields among conventional FM information for a chosen object,
- Show remote sensors on the user interface of the CAIFI system,
- Show reports with this information,
- Displays time-coded historic information.

3.6 Necessary customizing in the CAIFI system

Unlike the vendor-specific automation systems usually doesn't support it, customisation is highly supported in CAIFI systems. In these systems needs to be defined how to get and display information from AS-s or DPU-s. For integrated displaying new data fields, alerts and reports should be generated. To reach the automation information in CAIFI systems, needs to set up data-exchange interfaces, or the shared databases and files should be bind with the newly created data fields on the user interface. Since every system don't support such customisation, we should choose an appropriate CAIFI system. Sometimes we should use or implement third-party applications (DPU-s) to connect the automation and CAIFI systems correctly. In such cases for the CAIFI system DPU- s behave like automation systems.

If position changes occur, usually these changes can't change the graphical CAD- or GIS based map. So, if a wall crashes down, it won't be eliminated from the showed CAD map, but alerts can be generated. In such cases the showed map needs redrawing (e.g. an alarm can support alerting the specialists), but it would be usually hard to follow changes. If we need this, we can implement appropriate DPU-s that can redraw the map automatically.

3.7 Planning and installing the systems

It's suggestable to follow the steps below for a successful integration:

- Collecting the requirements,
- Logical planning,
  - Includes hardware and software plans, the logical specification of each subsystems (AS, CAIFI and optionally DPU- s) and database, network, device sizing (storage and input periphery sizing),

  - Have to decide whether to purchase a customizable solution or develop an own application for CAIFI and AS purposes,
- Phisical planning and planning system integration,
- Installing the separated subsystems (automation systems, the CAIFI system and optionally the DPU-s),
- Build the connection between Automation System(s) and CAIFI system
  - Hardware-level: network connection,
  - Software-level: interfaces, DPU-s, share files and/or databases,
- Customize the CAIFI system
  - Create alerts, reports and custom used data fields, etc.
- Functional, value and integration tests (including catastrophe tests).

4 Conclusions

This paper has presented a research into the integration of Computer-Integrated Facility Management (CIFM) and Building Automation Systems. However it's difficult to integrate Building Automation Systems with third-party applications, there are some Computer-Aided Integrated Facility Information (CAIFI) systems that can be connected with the data collectors or databases of the automation subsystems and used for status (object-property) monitoring purposes. With some systems high- standard integration can be reached. This study overviews the conditions and limits of integration and introduces how to integrate one or more automation systems with a CAIFI system.

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References

[1] C. Cencetti, P. Conversini, F. Radicioni, S. Seli and P. Tacconi: The Evolution of Montebestia Landslide (Umbria, Central Italy). Site Investigations, In-Situ Tests and GPS Monitoring, Phys. Chem. Earth (B), Vol. 25. No. 9. pp. 799-808, 2000

[2] Kevin Yu, Thomas Froese, Francois Grobler: A development for data models for computer-integrated facilities management, Automation in Construction 9 (2000) 145-167

[3] Shengwei Wang, Junlong Xie: Integrating Building Management System and Facilities Management on the Internet, Automation in Construction 11 (2002) 707-715

[4] ANSI/ASHRAE Standard 135-1995, A data communication protocol for building automation and control networks, ASHRAE, 1995. in Kevin Yu, Thomas Froese, Francois Grobler: A development for data models for computer-integrated facilities management, Automation in Construction 9 (2000) 145-167

[5] ANSI/EIA 709.1-A-1999, Control network protocol specification, EIA, 1999. in Kevin Yu, Thomas Froese, Francois Grobler: A development for data models for computer-integrated facilities management, Automation in Construction 9 (2000) 145-167

[6] Safety & Security Systems Terminology, Honeywell Home Page, http://content.honeywell.com/yourhome/security/Security_Term.htm, 2003.

[7] Automation & Control Products, http://content.honeywell.com/acp/, Honeywell Home Page, 2003.

[8] Kyung-Kwon Hong, Young-Gul Kim: The critical success factors for ERP implementation: an organizational fit perspective, Information & Management 40 (2002) 25-40.

[9] N.H. Bancroft, H. Seip, A. Sprengel, Implementing SAP R/3, 2nd Edition, Manning Publications, Greenwich, CT, 1998, in: Kyung-Kwon Hong, Young-Gul Kim: The critical success factors for ERP implementation: an organizational fit perspective, Information & Management 40 (2002) 25-40.

[10] C. Soh, S.S. Kien, J. Tay-Yap, Cultural fits and misfits: is ERP a universal solution? Communications of the ACM 43 (3), 2000, pp. 47-51, in: Kyung-Kwon Hong, Young-Gul Kim: The critical success factors for ERP implementation: an organizational fit perspective, Information & Management 40 (2002) 25-40.

[11] O. Volkoff: Enterprise system implementation: a process of individual metamorphosis, American Conference on Information Systems, 1999, in: Kyung-Kwon Hong, Young-Gul Kim: The critical success factors for ERP implementation: an organizational fit perspective, Information & Management 40 (2002) 25-40.

[12] O. Volkoff: Using the structurational model of technology to analyze an ERP implementation, in: Proceedings of Academy of Management '99 Conference, 1999, in: Kyung-Kwon Hong, Young-Gul Kim: The critical success factors for ERP implementation: an organizational fit perspective, Information & Management 40 (2002) 25-40.

[13] Marina Krumbholz, Neil Maiden: The implementation of enterprise resource planning packages in different organisational and national cultures, Information Systems 26 (2001) 185-204.