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Bartosz CIEŚLA[*]*, Grzegorz GUNIA*[**]

DEVELOPMENT OF INTEGRATED MANAGEMENT INFORMATION SYSTEMS IN THE CONTEXT OF INDUSTRY 4.0

Abstract

In this paper, development trends of information systems, information systems technology and enterprise information management were analyzed in the context of Industry 4.0 tools. In the first part (par. 1–2), fundamental definitions referred to the subject were presented as well as historic background of Integrated Management Information Systems. In the second part (par. 3), evolution and trends in ERP class systems, electronic economy tools and Product Lifecycle Management software were described. In the third part (par. 4–5), observed trends in information systems technology, in relation to Industry 4.0 tools, were discussed including manufacturing resources, production objects and novel management strategies approach. Many conclusions were related with actual manufacturing practices observed by the authors.

1. ENTERPISES INFORMATION SYSTEM TECHNOLOGY

1.1. Enterprises Information System (EIS)

For enabling an effective information flow between source and user as well as its efficient utilization, system for collecting, storing and transferring information internally and externally should be designed. It is called Information System (IS).

[*] Redor Ltd., Grażyńskiego Street 2, 43-300 Bielsko-Biała, Poland, b.ciesla@hotmail.com
[**] University of Bielsko-Biała, Faculty of Mechanical Engineering and Computer Sciences, Production Engineering Department, Willowa Street 2, 43-309 Bielsko-Biała, Poland, ggunia@ath.bielsko.pl

IS can be defined as multilevel structure, which is used for transforming certain input information/data into desired output information, by means of dedicated procedures and models. On the basis of this output information, particular decisions are made (Kisielnicki & Sroka, 2005).

1.2. Enterprises Information System Technology (EIST)

Information System Technology (IST) is a separate part of IS, which is computerized for achieving relevant, particular objectives, so it can be defined as information system based on information technology (Kisielnicki & Sroka, 2005). In the other words, it is a set of interrelated elements, designed for transforming data and implementing communication flow with application of computer technology.

Enterprises Information System Technology is a part of EIS which is responsible for generating and collecting source data, as well as transforming, analyzing and visualizing this data. It is done with application of methods, techniques and tools of Information (Computer) Technology (Januszewski, 2001).

Essential components of EIST are: equipment (workstations, servers, ICT infrastructure, …), software (operating systems OS, application software App, database systems, …), human resources (system administrators and users), organization (procedures, rules, EIST instructions and laws).

Integrated Management Information Systems are modularly organized EISTs, operating all enterprises activities: marketing, resources planning and supplies (logistic), technical preparation of production, manufacturing processes managing, distribution, sales, maintenance, finance and human resources (Adamczewski, 2014).

From the point of view of technical solutions, Integrated Management Information System, is a system in which (Lech, 2003), (Januszewski, 2008):

- user with his own workstation, is able to use any system function,
- all users of the same system, are working on the same system interface,
- input of data into the system is done only once, and this automatically upgrades state of the system as well is visible for all system users.

2. EVOLUTION OF INTEGRATED MANAGEMENT INFORMATION SYSTEMS

Development of ERP (Enterprise Resource Planning) class systems has begun in the 60's. Its first version was MRP I (Material Requirements Planning). This system was designed for calculating precise amount of materials and components needs in time, so effective supplies schedule for fluctuating demands of various products was enabled to create. Working principle of this system is to transform production plan to components and materials requirements with precision amount of it and access to information about requirement date, for every production batch.

Upgrade of MRP I model was involving closing information loop (Closed Loop MRP). With this technique reaction for fluctuating demands and changing production parameters (especially authentic supply and products amounts) in real time was enabled.

In case of this model, despite of planning aspect (material and production resources, production processes, internal orders, production scheduling), for the first time ever, quality control aspect was considered (for production processes, internal orders execution, turnover and deployment of: materials, components and products in warehouses). Information given by controlling elements of model was next returned to central element of material requirements planning (and intermediately to production capacity planning element). Authentic materials, components and products balance are then available for system users, so better plan restructuring decision process could be done. This return information flow was closing information loop of MRP model. Closed Loop MRP was also improved on the previous version MRP I with functionality of planning necessary resources other tan components and materials (workforce, machines, equipment, tools, transportation etc.).

Next model development was MRP II called Manufacturing Resource Planning. In this model, Closed Loop concept was fully adopted, as well as new elements connected with sales processes and more strategic than operating (as it was before) decision-making processes like marketing planning, strategic planning or finance planning.

MRP II standard was defined and published in year 1989 by The Association for Operations Managements APICS (historically American Production and Inventory Control Society).

Besides controlling materials and components requirements as well as its stock and orders level, MRP II was also designed for workforce, machines and equipment planning. It is done by allocating subsequent jobs to manufacturing resources according with designed production process of single parts and final products (production scheduling). Moreover, throughput level for each manufacturing resource was shown, creating new controlling tool for managers.

Finally, as an upgrade of MRP II, Enterprise Resource Planning ERP model was developed. Sometimes it is also called MRP III – Money Resource Planning. Term ERP was proposed for the first time in year 1990 by analytical consulting corporation Gartner Group. These systems are adopting MRP II model and procedures, and further developing them with solutions supporting decision making processes, using enterprises know-how, along with artificial intelligence concept. Major task for ERP systems is to fully integrate all enterprises business activities: production, marketing, finance, logistics, strategic management, etc. Moreover, with mechanisms available in ERP systems, simulation of different business scenarios is given. These scenarios can be further analyzed from various points of view, also financial one (Gunia, 2010), (Gartner, 2004).

3. TRENDS IN THE DEVELOPMENT OF MANAGEMENT INFORMATION SYSTEMS

3.1. ERP II class systems

ERP II class systems are the next development stage of integrated MRP/ERP systems after level of ERP systems. Modern trends in enterprises structure evolution, connected with vertical integration and optimization-focused internal functions and processes, are development basis for systems class ERP II. Moreover, organizations endeavor to preserve flexibility of their core activities, and optimal positioning themselves, along the supply chain and value network. Fundamental aspect of this positioning, is not only participating in trading using computer networks (e-commerce, B2B, B2C), but rather commitment in c-commerce processes. C-commerce (collaborative commerce) means supporting electronic business interactions between enterprise personnel, clients and business partners in the context of one trading society. This society could be any industry, or one of their segments, as well as supply chain or even a part of a supply chain. In world of global collaboration, enterprises have to compete with each other's not only in the field of availability, quality or price of their products and services, but also in field of information. Especially speed of information and quality of information supported to co-operating partners is crucial.

Gartner Group has defined ERP II as a business strategy and collection of specific program applications for particular sectors, which generates value for clients and shareholders. It is done by mean of availability and optimization of both: internal processes and processes between co-operating companies (Genovese, Bond, Zrimsek & Frey, 2001), (Gartner, 2004) .

ERP II systems are orientated on external integration and developing solutions along with business partners, in contrast to classic ERP systems – orientated on internal business processes. Optimization of resources and process data processing, are in ERP II supported with extra information about resources involvement in companies' efforts, aiming extending cooperation with others enterprises. In this area, traditional ERP systems allows only for managing purchases and sales by means of e-commerce. Last but not least, internet-based, integrated architectures of ERP II products, are such different than monolithic ERP architectures, that they require overall transformation. Data treatment involves not as before collecting data inside enterprise, but managing data distributed along with trading society.

During its evolution, ERP II model absorbed functionality of SCM (Supply Chain Management), which was used for managing business partners supply chain as well as exchanging information within. In ERP II concept, functions of ERP /MRP II systems like production planning, logistic and inventories management, finance management, etc. were complemented with electronic offers, orders and invoices exchange, likewise electronic payments. In the close future,

e-procurement, automation in enterprise office materials and consumables supply, will be also absorbed and integrated in ERP II (Genovese at al., 2001), (Rzewuski, 2002).

In conclusion, it can be said that ERP II class systems are much stronger focused on reflecting market behavior and mutual relationships between cooperating companies, than on supporting and handling enterprises internal business processes. Evolution of Integrated Management Information Systems in the context of industrial revolutions timeline is presented on figure 1.

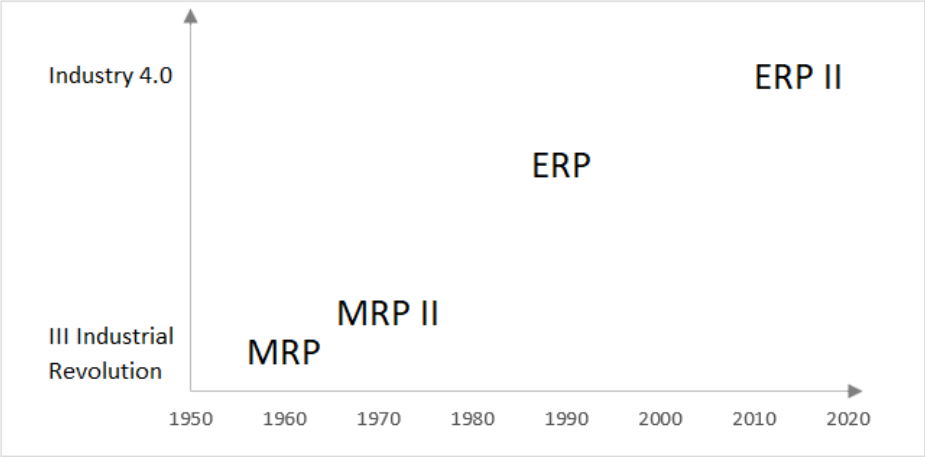

Fig. 1. Evolution of Integrated Management Information Systems

3.2. Electronic economy

With the large market competition and the fierce battle for the customer, enterprises have to seek new possibilities for promoting and advertising products and services, as well as fresh distribution channels and effective communication channels with business partners.

Expansion of worldwide Internet network, allowed for companies arisen, irrespective of their size, in the new digital reality, termed as "New Economy", where e-commerce, e-business, e-economy, etc. were developed (Gregor & Stawiszyński, 2002), (Kolbusz, Olejniczak, & Szyjewski, 2005). There is opinion in science literature, that development of informatic solutions, enabled new direction for economy development, but in the other hand, economy development forced new informatic tools emerging.

Term e-business is defined on many ways. On strategic level, e-business is understood as idea of reconstructing whole enterprise, for maximizing benefits from modern technologies utilization.

On lower management levels, e-business is understood as network involving issues, considering purchase and sales of products and services. Significant feature of e-business is that transactions between two sides are executed on-line, and main object of this trading is information.

E-business could be generally divided into three categories, differing with objectives and target group (Kolbusz at al, 2005): B2C (Business-to-Customer), B2B (Business-to-Business), B2P (Business-to-Public).

Business-to-Customer

B2C is designed for executing transactions between enterprises and customers (consumers). It is more likely organized as electronic trading (e-commerce, e-tailing) performed through online shops.

Fundamental tasks of B2C systems:

- enabling purchasing on-line,
- supporting supply processes,
- providing after-sales services,
- improving distribution,
- lowering transaction costs.

Electronic trading creates competitive environment, in which smaller enterprises are able to compete with giants. Geographical barriers are broken through this global environment, and nearly unlimited choice possibilities for customers are provided.

Business-to-Business

Model B2B is designed for transactions executing between companies. Analysts are expecting this category to have highest turnovers and profits, eventually even 90% of market income. Nowadays, US market is developing constantly in this direction, and the same could be observed through European Union countries. Integration supply processes named as Supply Chain Management (SCM), is considered to be essential element of B2B solutions. At this field, with properly utilized modern technologies, the best conceivable measurement results for enterprises, like cost reduction or logistics improvement can be obtained. Proper explored opportunities could be required to ensure competitive position preservation.

B2B development trends are driving enterprises effectiveness and efficiency improvement through increasing business processes integration. This results in automated data processing and again costs reduction.

Business-to-Public

At this field of e-business, relations between enterprises and their macro environment (especially social environment) are main objectives.

Fundamental tasks of B2P systems are:

- creating the company's image, profile and brand (not only on the Internet and in social media),
- brand and product promotion,
- creating social ties and improving links between company and its environment,
- last but not least attracting new customers.

Alongside with abovementioned, in the literature one can find spectrum of more specific models e.g. (Simon & Shaffer, 2002), (Koźmiński & Piotrowski, 2002): C2C (Customer-to-Customer), C2B (Customer-to-Business), B2E (Business-to-Employee), G2C (Government-to-Citizen), B2G (Business-to-Government). Nowadays electronic economy tools are linking nearly every possible entity as shown on Figure 2.

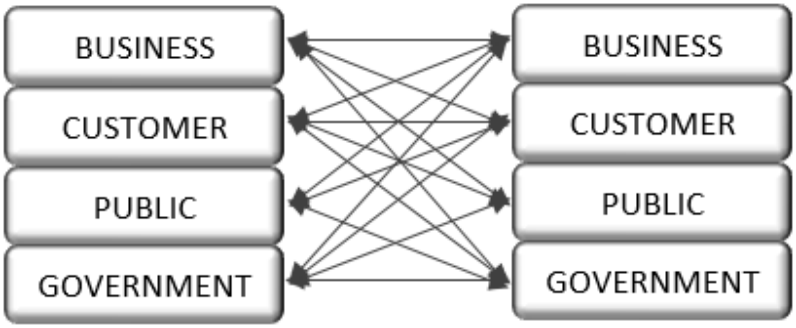

Fig. 2. Modern information flow with electronic economy tools

3.3. Product Lifecycle Management

Set of processes focused on issues related with product, from birth concept, through designing, manufacturing and selling, until aftersales service and disposal, are called Product Lifecycle Management (PLM). It is responsible for integrating key factors in the creation of product: data, resources and designing process. PLM is designed for enabling access to all product information, making them easier to manage. It is very important tool for Product Managers and is applied in many businesses.

PLM could be considered in two aspects:

1. As a concept, for supporting product lifecycle tasks, in a holistic manner, at any stage of its maturity, through:
   - procedures standardization,
   - collection, integration, and sharing data and knowledge about product,
   - automation and support of whole sets of functions and tasks,

- electronic data and documents exchange,
- automation of technical documentation workflow and process management,
- integration of the entities involved in various product lifecycle stages (traders, clients, designers, production processes organizers etc.).

2. As a tool – an informatic system (but more precise a collection of integrated applications). Its main objective is to integrate applications from the various action fields (supporting particular stages of product lifecycle) into well organized and coordinated, efficiently functioning entirety. This tool involves many systems as:
   - Computer-aiding – CAx,
   - Product Data Management – PDM,
   - Document Data Management – DDM,
   - modelling and simulation of production systems,
   - systems for supporting cost calculation,
   - project management systems,
   - etc.

4. INFORMATION SYSTEM TECHNOLOGY IN RELATION TO INDUSTRY 4.0

Definition of Industry 4.0, understood as fourth industrial revolution has very broad sense. It could be described as human, machines and digitally controlled devices network creation and systems integration. It is done by means of widely used Internet and Information System Technology. The rise of Industry 4.0 was made possible through widespread access to computer equipment in various forms. Equipment with very high computing power, where single units are connected with each other and are able to communicate in real time through global network. This idea is focused on information, its availability as well as sharing at any time and at any place.

Approximately at the same time as ERP model was defined, the most characteristic invention of Industry 4.0 – Internet was invented. It was one of main activators for vast electronic devices development and global data digitalization. Integrated Management Systems have benefit from this advancement, especially in the area of information flow and data collection. Progressive availability of informatic infrastructure was used by companies for building interior physical networks for the purpose of ERP software data feeds. From this moment, every single event in the enterprise operation could be recorded using reasonable workload. Later on, collected data is transformed into information links between company's personnel. Basically, Customer Service is informed about orders status and payments, Logistics is informed about needs and deliveries, Production

(orders executors) are informed about demands and plans, and last but not least Management is informed about expenses, costs, sales and profits, all of the above nearly in the real time and simultaneously. In this context, Industry 4.0 trends may be understood as sophistication in data collection and its transformation into information as well as sophistication in information display.

4.1. IST products development

From many areas of Industry 4.0, producers of Integrated Management Information Systems are mainly interested in their product development connected with: IT and automatics integration, Industrial Internet of Things (IIoT), Augmented Reality and cyber-security in industry. But manufacturing companies in developed countries have their own considerable demands. They endeavor to transform into integrated networks in which, with usage of Agile Manufacturing and Mass Customization strategies, their core competences will be united (Brettel, Friederichsen, Keller &Rosenberg, 2014). Purpose for this ongoing transformation lies in emerging competitive advantage resulting from customized products with fast time to market. This trend must be considered by IST producers as these corporations from developed countries constitute a large share of IST market. Moreover, and even more importantly for IST producers, no other enterprises can provide bigger scale funding of new technology applications. Considering all of the above, it is suspected that IST producers will adjust their product mix development strategies to the highlighted market needs. On the other side, there is virtually countless number of Small and Medium Sized Enterprises (SMEs) and less developed bigger companies waiting for budget, simple to implement, novel tools for their stage of advancement, which is mostly between 3rd Industrial Revolution and Industry 4.0. Observations of manufacturing practice have shown that SMEs believes in existence of universal, verified devices and software, with a touch of Industry 4.0 artificial intelligence, which can cure most of their operational difficulties. Obviously, nobody can clearly define what could it be and how would it work. But it should be considered, that maybe everyone in this market – producers and users are missing something crucial in IST development. Arguably it won't be a cure for everything but it could be a breakthrough for SMEs agile at operational level. It is well-known that SMEs are more effective at operational level than Corporations since their compact structure, but problem resides in chaotic execution based on aptitude of individuals. Novel advisory tools in ERP systems could stabilize decision making process at SMEs by means of Big Data and neural networks elements, all based on automatically collected data by IST networks.

When it comes to production supervision, development of IST is focused on integration of all processes in enterprise, executed with application of Internet and mobile technologies. Again, scope of processes is very wide, embracing customer service (quotation, order approval and order confirmation) through

manufacturing planning, throughput level and machines availability, Supply Chain and Logistics, ending with sales and distribution. Corporations are achieving significant progress in this area by thrusting particular software upon their smaller suppliers. For example, it is done with SAP in automotive business involving German enterprises. In many cases these suppliers are treated more favorably during SAP implementation process, receiving greater conceptual support, so it became a win-win situation. Corporation is executing orders, invoices and other necessary information flow with suppliers by means of mobile technology developed by SAP, and suppliers are acquiring best known operational techniques for their internal development (SAP, 2019).

4.2. Challenges for IST producers

First main area of challenges for IST producers are issues involving linking physical world of manufacturing resources with informatic systems or virtual either augmented reality. In context of Integrated Management Information Systems, studies have shown that there is no unified standard and protocol for machine-ERP communication but simultaneously ERP systems are considered technologically and operationally ready for Industry 4.0 (Gunia, 2010). Moreover, producers are obliged to keep up with development and autonomation of manufacturing resources, exacting interfaces improvement for integrated information flow between machines software and production planning systems. In this regard new open standards must be worked out, adjusting communication channels between manufacturing resources, software for production planning and data collection, as well as information exchange between cooperative enterprises. Nowadays IST designed for autonomous data collection from machines and workstations are formations separated from ERP and analysis of given information are hampered in context of production results. Again, scope of problem is different depending on enterprise characteristics. Corporations have their dedicated applications and controlling departments at this area, so analytics issue is not as problematic for them as for SMEs. With SMEs limitation in specialized human resources, their require information flow simple to processed and interpreted, with excluded unnecessary informatic infrastructure to purchase and maintain. In this context, important challenge for IST producers is in implementing visual process analysis and information display in their core products. It can be defined as fusion of Business Intelligence Systems and Management Information systems. Through this development direction, ERP systems could upgrade into flexible structures, adjusted to various unique management models as Theory of Constraints or Activity Based Costing (Cieśla & Kolny. 2019).

In theme of Industrial Internet of Things, two main areas can be highlighted to challenge with: manufacturing resources (machines, equipment, work stations) and production objects (materials, components, parts and products).

First area is connected with direct, both ways communication between manufacturing resources and operating personnel as well as data processing and collecting for major machines issues: maintenance, throughput efficiency and processes condition. The results of this data analysis should be used in the real time, for adjusting production plan, revealing causes of fluctuations of productivity indicators, revealing causes of equipment breakdowns. Very clear, and visual feedback should be given to all users. In this area support for Predictive Maintenance should be given as well. Predictive Maintenance is a strategy for Maintenance Departments, aiming optimal use of machinery and equipment, by eliminating possible breakdowns or performing maintenance tasks on basis of received technical condition data.

Field of production objects is developing in direction of current and automatic quality control of products, with real time feedback. Through this advancement, quality control process should become less expensive and less time consuming than nowadays. It can also enable economically reasonable defects detection after each production step. The effect would be in higher production automation as well as in higher efficiency of material requirement planning and warehouse documents flow connected with defects. Second research direction in field of production objects, connected with Factory of the Future concept, is economically rational technology of production autonomous actuator-sensor networks in the factories. The purpose for these networks is in knowing products history and routes so logistic chain is simplified and autonomously managed and controlled (Zuelhke, 2010). All of the above is mainly done with usage of: Radio-frequency Identification Technology (RFID), image recognition, image analysis and augmented reality.

5. CONCLUSIONS

Integrated Management Information Systems are nowadays on high development level. Through their five decades of evolution very compact and multifunctional structures were established. All of the above was done along with emerging markets needs and economic progress. In Industry 4.0 era, new circumstances and requirements appeared, related with instruments like (Industrial) Internet of Things, Big Date, Business Intelligence Systems etc. Customers, goods and manufacturing becomes global and widely available for instance with application of Electronic Economy tools. Companies producing EIST have opportunity to achieve new competitive advantage by developing product mix framework appropriate for present market 4.0 conditions. Authors believes that it could be done only through close collaboration with particular markets innovative representatives. Like in Lean Gemba Walk the best improvement ideas could come up from real work observation.

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