Enterprise information systems state of the art: Past, present and future trends

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ABSTRACT

This state-of-the-art paper is intended to set the scene for a special issue of the Computers in Industry Journal on "Future Perspectives on Next Generation Enterprise Information Systems". It gives a brief history of Enterprise Information Systems (EISs) and discusses various aspects of EISs, including EIS design and engineering, the impact of enterprise modelling, enterprise architecture, enterprise integration and interoperability and enterprise networking on EISs before concluding.

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1. Introduction

Enterprise Information Systems (EISs) are nowadays essential components of any enterprise system. According to systems theory [45,82], any complex system is made of three fundamental sub-systems: (1) a *physical sub-system* (i.e. the operative part made of physical components including human and technical agents as well as material and physical flows), (2) a *decision sub-system* (i.e. the control part where organisation, planning, decision and monitoring actions are made) and (3) an *information sub-system* (i.e. the data-processing part dealing with information flows as well as process, storage and retrieval actions on data, information and even knowledge). In complex systems, each of these sub-systems can itself be viewed as a complex system possibly made in turn of the three sub-systems.

Indeed, *Enterprise Systems (ES),* which are large socio-technical-economic systems, are themselves complex systems and, as such, comprise these three fundamental components. The situation can even be more complicated in the case of networked enterprises or large manufacturing supply chains made of several business entities (e.g. suppliers, manufacturers, assemblers, retailers . . .) and which become *Systems of Systems (SOSs)* as defined by Ackoff [2] and analysed by DiMario [16] in the context of collaborative systems. The focus of this paper remains on the information part of enterprise systems, be they manufacturing and production systems of goods, service enterprises or administrative organisations.

Enterprise Information Systems (EISs) can be defined as "software systems for business management, encompassing modules supporting organisational functional areas such as planning, manufacturing, sales, marketing, distribution, accounting, financial, human resources management, project management, inventory management, service and maintenance, transportation and e-business" [68]. They are made of computers, software, people, processes and data.

According to Xu [90], EISs have emerged in the last decades as promising tools used for integrating and extending business processes across boundaries of business functions, at both intra- and inter-organisational levels, in a worldwide economy with increasing global business operations. In this context, the development of Information and Communication Technologies (ICT), including Industrial Informatics (e.g. Industry 4.0), and the technological advances in EISs have provided a viable solution to the growing needs of information integration in both manufacturing and service industries, supporting the operations of global supply networks. This also applies to government and non-government administrative organisations. Furthermore, EISs have progressed in a constant interaction between changing business

requirements, technological and organisational maturity and software vendors' capabilities [89].

The aim of this paper is to provide introductory reading for a special issue of the *Computers in Industry* Journal on "Future Perspectives on Next Generation Enterprise Information Systems". It provides a state-of-the-art discussion on essential aspects of EISs and addressing some future trends. It first presents a brief history of EIS, then a discussion on EIS design and engineering aspects, followed by an analysis of the impact of Enterprise Architecture, Enterprise Integration, Enterprise Interoperability and Enterprise Networking (EAI2N) disciplines on EISs before concluding.

2. Enterprise Information Systems (EIS) history

Enterprise Information Systems (EISs) history started with the introduction of computers in industry in the early 60s, using their computing and recording capabilities to automate manual tasks and to replace paper-based systems such as book keeping. The first generation of EISs mostly consisted of stand-alone functional information systems, e.g. intensive data processing systems (for instance for human resources data, accounting data, finance data, invoicing . . .). Gradually, as the sophistication of computers, computer networks and database systems increased, EISs begun to take a more active role in supporting business processes, information flows, reporting and data analytics in organisations. In the late 60s, EISs took over the control of bills-of-materials processing, inventory systems and forecasts. Afterwards, in the 70s, the first *Management Information Systems (MISs)* appeared while other EISs started to support Material Requirements Planning (MRP) and a decade later, in the 80's, Manufacturing Resources Planning (MRP/II). The 90s gave born to Enterprise Resource Planning (ERP/I) packages, integrating databases and operational business functions in the back office and including support for human resources and quality management. In the 2000s, ERP solutions moved beyond enterprise boundaries to evolve to ERP/II, supporting the 'extended enterprise' and enabling inter-organisational collaboration embracing supply, design and engineering business functions [51]. Nowadays, ERP/III aims at creating a 'borderless enterprise', supporting collaboration within the enterprise business functions and across the supply chains, including customers and the sales side of the marketplace [35].

Because documenting in detail this section with relevant bibliographical references would amount to hundreds of citations, which is not the goal of this paper, essential readings in relation to this brief history of EISs can be limited to Xu [90] for a general state-of-the-art discussion on enterprise systems [58] on MRP [15], [54] on ERP and ERP/II, and [35] on ERP/III.

However, deeper attention with respect to the EIS history can be devoted to six particular types of enterprise information systems: Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Manufacturing Execution Systems (MES), Customer Relationship Management (CRM), Product Lifecycle Management (PLM) and Business Intelligence (BI).

2.1. Enterprise Resource Planning (ERP)

From a historical Information System (IS) application perspective, ERP/I comprised several integrated modules, including logistics, procurements, sales, marketing, human resources and finance, supporting intra-organisational collaboration. According to Callaway [8] and Møller [51], ERP/II, also known as extended ERP (eERP), offers the following Web-enabled modules: *e-Commerce* – including electronic catalogue, on-line purchasing and status checking facilities; *e-Procurement* – automating the business function from on-line ordering, order status, ship notice and electronic payment and invoicing; *Supply Chain Management (SCM)*

– featuring collaborative production planning and control functionalities; *Customer Relationship Management (CRM)* – allowing customer identification and service management; *Business Intelligence (BI)* – supporting decision making with data collected from the corporate datawarehouse; *Advanced Planning and Scheduling (APS)* – optimising the production capacity based on the forecasted orders, inventories and manufacturing capacity; *Corporate Performance Management (CPM)* – introducing dashboard functionalities to assess and analyse the health status of business functions; *Human Resources Management (HRM)* – featuring payroll, attendance, performance appraisal, benefits administration and recruitment support; *Product Lifecycle Management (PLM)* – enabling effective management of the full product (data) definition an extended enterprise context; and *Supplier Relationship Management (SRM)* – working with the supplier base as an analogy to the CRM. Next Generation ERP, or ERP/III, will encompass the integration of 'social media' with new 'marketplace intelligence' and analytics into the ERP/II. These new ERP/III functionalities, or extensions of existing ones, with even new modules, will help on the one hand to extend enterprise analytics beyond internal recorded events in a datawarehouse (business intelligence) to external information (market intelligence) stored in a kind of larger and augmented datawarehouse known as 'Big Data'. The benefits will be that decision makers can be provided with a more complete picture of the ongoing corporate performance and, on the other hand, 'social media' will create new and more direct marketing, communication and sales channels with customers [35].

Furthermore, from a historical Information and Communication Technologies (ICTs) perspective, ERP/I evolved from MRP/II enabled thanks to the advances on Database Management Systems (DBMS), computer networks, client-server architectures, technologies focusing on data and applications integration and automation (such as Enterprise Application Integration (EAI) platforms) as well as from the progress of Workflow Management Systems (WfMS) and technologies concentrating on intra-organisational business processes integration and automation. A decade later, the transition to ERP/II, and therefore to inter-organisational business processes, was allowed in a first instance by the advent of data exchange technologies such as EDI (Electronic Data Interchange) or ebXML and more mature WfMS technologies named Business Process Management (BPM), followed by IT architecture frameworks for business processes integration and interoperability along with more progressive and open data exchange technologies such as XML and Web Services to support the extended enterprise. Finally, the ERP/III is now becoming a reality thanks to a set of rapidly evolving and enabling technologies of the 'borderless enterprise' such as mobile, social media, SOA (Service Oriented Architecture) and other Web-enabled tools and Internet computing technologies. Moreover, within the ERP/III generation it is important to distinct three forms of ERP adoption, starting from the traditional on premise solution hosted at the enterprise ICT-infrastructure, followed by the such called 'cloud ERP' offered as a cloud application service under the Software-as-a-Service (SaaS) paradigm and the 'hybrid ERP' delivered as a combination of licensing options with on premise solution offerings.

2.2. Supply Chain Management (SCM)

Even though SCM origins can be traced back to the 40s at the intersection of industrial engineering and operations research, it was during the late 70s and 80s with the emergence of MRP and MRP/II that was born the *computer-based SCM,* with an initial scope for product information management and focus on inventories, production cost and capacity and throughput control for quality assurance and cost management (SCM/I). During the early 90s, the