MAPPING THE CONSTRUCTION ENGINEERING AND MANAGEMENT DISCIPLINE

By

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Abstract

The objective of the study was to map the structure of the construction engineering and management (CEM) discipline and its contents, trace its evolution, and to identify the most prevailing research areas in the discipline. The study entailed a review of the literature in construction engineering and management as well as two of the leading academic journals in the discipline, particularly a bibliometric study of the contents of the ASCE *Journal of Management in Engineering (JME),* as a case study of the CEM refereed journals.

The JME's contents were investigated from its onset in 1985 until 2002. The results of the analysis show that 70% of the published papers focused on four main subjects: management and organization of the firm, project management, industry structure and environment, and management of personnel. Considerable changes occurred within the subjects with the emergence of new topics and the decline of others over the eighteen years of publication. The study also analyzed the use of keywords, research methods, and identified authors, and the concentration of knowledge.

The *JME* is mainly concerned with the managerial aspects of engineering, while ASCE *Journal of Construction Engineering and Management (JCEM)* focuses more on construction and technical issues. Additional studies of the *JCEM*'s contents should be conducted for a complete mapping of the discipline in the USA.

Acknowledgements

"All praise is due to Allah, the Lord of the Worlds. The Beneficent, the Merciful." (Qur'an Ch1, v 2-3)

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Very special thanks to my parents for their love, care, and never-ending support. I really appreciate their willingness and encouragement to achieve my academic degree. I dedicate my thesis to my father, my role model, and to my mother, to whom there are no words that can express my appreciation for her help and support. Furthermore I would like to thank my father and mother in law for showering me with love, warmth, and kindness. To have such nice people is truly a bounty from Allah.

I would like to express my deepest affections to my lovely wife Hala, who stood by me in every step of the way, loving, caring, encouraging, and cheering.

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1 Introduction

There are few modern feats of engineering achievement that surpass the great pyramids of Ancient Egypt. The sheer scale of the technological and physical challenge facing the creators of these superstructures was immense. The management skills by those early engineers were equally impressive. The demands of the clients (the Pharaohs) had to be fulfilled while co-coordinating, controlling and monitoring the subcontractors (the artisans) and employees (the slaves), as well as ensuring the optimum use of material resources (Fraidoon Mazda, 1997).

Construction engineering and management (CEM) is no simpler today and both beginner and experienced engineers find it difficult to come to terms with this subject.

Today's construction industry has become more complex than ever before with the emergence of new business demands and challenges. Sophisticated clients and competitors will force civil engineering firms to adapt management concepts and theories to construction, and to shift their focus from the traditional project management approach to new management focus areas. With the beginning of the 21st century, there is a true need for long-term strategic planning to take place in civil engineering organizations to provide them with greater chances and abilities to compete in the global economy. In this era of technological innovation and emerging global economy, there is a growing need for professionals possessing a unique set of business and engineering competencies.

CEM is still a relatively new discipline in the civil engineering realm. In the USA, it started with the development of pioneering master's programs approximately 45 years ago, followed by PhD programs 5 years later (Carr, 1997). Today CEM is an established academic and research area that builds upon a long series of publications of scholarly work and debate (Pietroforte, 2002).

Objectives

Within all fields of study there is a need for knowing the ways in which an academic discipline develops and for strategic overviews of main dimensions representing the subject matter and classifications of relevant research methods and tools (Betts & Lansley 1993).

This study seeks to provide a partial map of the discipline of the construction engineering and management, which might be very useful for industry and/or educational institutions. It will also fulfill the intellectual curiosity of the people involved with construction management, whether academicians or practitioners.

The main goals of this research are:

- Mapping the structure of the Construction Engineering and Management discipline and its contents
- Tracing its evolution through the analysis of referred journals and textbooks
- Identifying the most prevailing research areas in the discipline

Scope of the work

The study encompassed the following tasks:

- A review of the construction engineering and management literature;
- An overview of two of leading academic journals in the discipline
- A comparison between the focus of the selected journals and that of the examined literature
- A development of a database to record the data of the study
- A bibliometric study of the contents of the ASCE *Journal of Management in Engineering,* as a case study of the CEM related refereed journals

Review of relevant books

The first phase of the research included a comprehensive literature review of relevant documents and textbooks. A sample of 24 books was investigated. Their contents were examined to identify the descriptors of the CEM discipline based on the frequency of occurrence of subjects and topics.

Overview of leading academic journals

A search was conducted to select the most relevant refereed journals that contain research articles dealing with the CEM discipline in the USA. The *Journal of Management in Engineering* (*JME*) and the *Journal of Construction Engineering and Management* (*JCEM*) were selected. The history, focus, and evolution of these two journals as well as the typical contributors were reviewed. Finally, the descriptions of the discipline, as they were found in the examined books and journals were compared.

Development of the database

The data were collected using the American Society of Civil Engineers online database and were entered in the newly developed database to record the complete references of the *JME*'s articles, including title, year of publication, keywords, subject of the article, author/s, their affiliation and country of origin. The system used to classify the publications of the JME was drawn from a previous study conducted by Prof. R. Pietroforte.

Bibliometric study of the JME

The analysis of single mainstream journals as case study is well established and occurs in most scientific and social science disciplines (Betts & Lansley, 1993). The final task of

the research was the bibliometric analysis of the JME's contents to map the evolution of the journal from its onset in 1985 until 2002, and in a broader sense the evolution of this subsector of the CEM discipline.

Bibliometrics is the study of publication patterns. It uses statistical and mathematical methods to analyze the literature of a discipline, as it is patterned in its bibliographies. These types of studies are useful indicators of scientific trends, emphasis of research in various disciplines, and of researchers' preferences for publication outputs. Results of such studies may be very supportive in decision making in research administration and planning. These results, in addition, enable policy makers in different organizations and funding agencies to evaluate their decisions on the awarding of grants to individuals and institutions (Jacobs, 2001).

Mainstream academic journals have been analyzed for setting more rigorous research efforts, mapping existing areas of research and changes in a discipline, detecting emerging research topics and patterns of collaboration and, occasionally, establishing future editorial policies, among others (Pietroforte, 2002). Typical examples can be found in logistics (Mentzer and Khan 1995), chemical engineering (Peters and Van Raan 1992a, 1992b), environmental management (Shogren and Durden 1991) and artificial intelligence (Courtial and Law 1989). Journals in the field of construction-related research areas have been investigated to provide a partial map of the discipline of construction management and project management (Betts and Lansley 1993; Betts and Lansley 1995).

In addition, bibliometrics provides a method for examining communication among scholars in a field through their scholarly publications (Subramanyam, 1983). Documented communication may offer important insights into patterns of relationships, research focus, interdisciplinary links, and changes in communication over time.

The findings of these studies may comprise emerging research topics, relationships between themes of research, and possible points of growth for the future development of research in the area as a whole (Courtial and Law, 1989). In this regard, tools to be used is the co-word analysis, a method that is based on the counts of papers indexed by a pair of keywords and the assumption that the higher frequency of these keywords underlines a strong link between the subjects or topics they represent (Courtial and Law, 1989). In addition, the contribution of specific research groups to these is included in the findings of this study.

2 The discipline of construction engineering and management

2.1 Introduction

Construction Engineering and Management (CEM) is the art of bringing the project on time and within budget despite all the variables and specialties within a project as well as the high fragmentation within the construction industry (Bennett, 1996).

This chapter presents a general definition of the construction engineering and management as a discipline. To develop a better understanding of this matter, a literature review of relevant documents and textbooks was conducted. This search yielded a sample of 24 books whose contents were examined to identify the descriptors of the CEM discipline, based on the frequency of occurrence of subjects and topics. The information drawn from these publications suggests that the CEM discipline is basically concerned with two major areas, namely the management of construction projects and that of engineering and construction firms.

The first section introduces the management process of projects with some reference on the role of designers and contractors in the process. The following section presents the management of engineering and construction firms, in terms of the operational structure. It summarizes the macro activities, sub-activities, concepts/tools, and supporting functions of the engineering firm and construction company as well.

2.2 The construction engineering and management discipline

From the days the Egyptian pyramids were built until the early eighteenth century, the architect was the master builder. He solely performed the major activities during the pre-construction phase, such as project design, materials purchasing, and craftsmen hiring. Faced with simple technology, less variety of construction materials, and owners' lack of sophistication in the delivery of projects, his role expanded to include the management

of the construction process. As clients progressively demanded more different and complex buildings and facilities, the need for new construction methods and management techniques, coupled with advancement in technology, fostered the development of the general contractor. The design and construction function was subdivided into many engineering specialties and trade activities respectively. Managing the multitude of parties and workers involved in modern projects together with the adversary relationships among the architect, engineer, general contractor and owner, is not an easy task. This paved the way to the emergence of construction engineering and management as a discipline, which is a set of professional management activities that must be carried out to minimize the risks of the uncertainties of time and cost, thereby enhancing the probability of the successful completion of a project (Stanley Goldhaber et al., 1977).

2.3 The management of projects

Since projects vary in size and complexity, they need a much more sophisticated approach to their organization, planning, execution, and control of resources. A large number of engineering and construction activities must be carefully planned, in addition to cost and schedule systems and resource allocation. There is therefore the need for the application of project management techniques, also because a project is built, reaches maturity, and is completed in a short period of time, probably 3-5 years. The task of project managers is not an easy one, as they deal with many different disciplines in managing a large project team and leading it to a successful project outcome in the end.

The role of designers (A/E), namely architects and engineers, is of tantamount importance in the first three phases of a project life cycle, as shown in Figure 2.1. During

the feasibility phase the A/E is involved with the owner in defining the project, discussing the scope, and analyzing the owner's needs and requirements. In the planning phase, the consultants accomplish their mission of defining the project's objectives, selecting the alternatives, and preparing preliminary estimates with the assistance and cooperation of the owner himself or his staff. The designer develops a solution to the owner's requirements, which comprises drawings, specifications, and schedules. The management of design, starting with the conceptual design, followed by the design development drawings, and finally the complete set of contract documents, is the responsibility of the A/E.

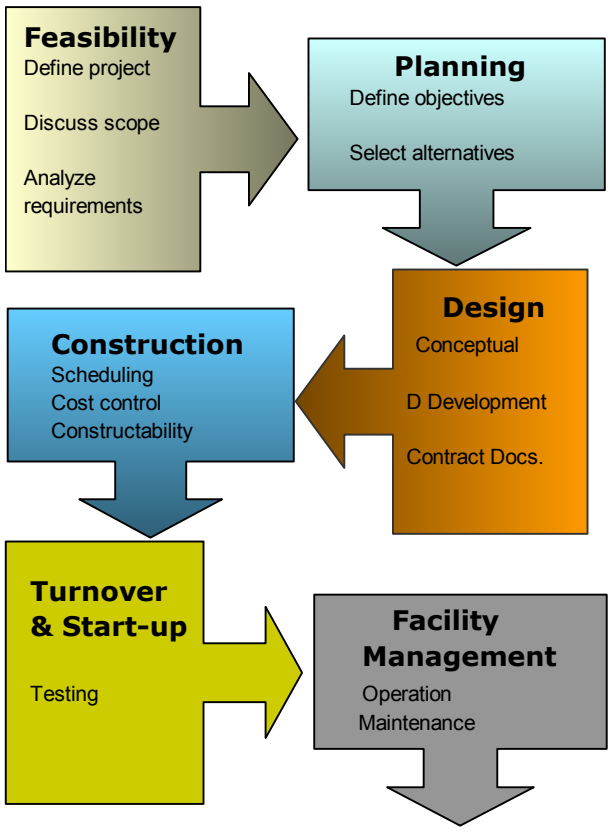

Figure 2-1. ***Project life cycle***

On the other hand, the General Contractor's (GC) contribution starts only when he/she is awarded the construction contract. However, the owner may involve the GC in an early stage, as the design process develops, for the sake of value engineering and constructability. The role of the designer does not end with the submission of the contract documents, but it continues into the construction phase, including construction contract supervision and administration services. Usually the designer is also responsible for planning and executing the testing and turnover of the facility from the GC to the owner at the end of the project. Upon completion of the facility, the owner may retain the services of the GC for the operations and maintenance (O&M) of the building. In many cases the owner hires a construction manager for the supervision, coordination, and administration of the project. This approach consecutively narrows down the responsibilities of the A/E to purely design related functions. However, according to the AIA Project/Service Delivery Think Tank, "the concept of architectural services now extends through the conception, financing, design, construction, and lifetime operation of a facility-related aspect that makes the client's life better and more productive" (Demkin, 2002).

2.4 Management of firms: Engineering and construction

The review of the literature, a collection of 24 reference books and textbooks in the construction engineering and management discipline, conveyed a basic understanding of the areas of interest frequently addressed by the various authors. It should be noticed that a change in both the numbers and biases of the books gathered by the author, might slightly change the description of the discipline. Table 2-1 shows the subjects and topics that make up the contents of the books as well as the frequency of their occurrences over the years. The observed period of the sample (1966-2000) was

divided into two phases. The first phase (1966-1989) is compared with the second phase (1990-2000) to examine trends and patterns. The most popular topics in the first phase were “organization long-term stability and growth”, “engineering organization structure”, “accounting and financial management” and “engineering managers’ responsibilities”. In the second phase several topics, in addition to the previously mentioned ones, gained more attention by the authors of the examined sample, such as “budgeting”, “strategic planning and management”, “communication”, “cost control”, “project control”, “effective public relations”, “education and professional development”, “marketing of professional services” and “leadership”. In addition, some new topics like “partnering”, “managing CADD use”, “information management”, “benchmarking” and “TQM: principles and techniques” emerged in the Nineties.

The outside environment (e.g. market, economy, regulations, institutions, etc.), of construction related firms, has a profound impact on their operations. In general, the organization structure of firms cannot be expected to be the same for every business, yet firms working in the same industry usually have some elements in common according to the industry they belong to. In this study the A/E firm and the construction company are considered. The primary responsibility of the A/E firm is to transform the owner’s requirements into drawings, schedules, and specifications according to which a project is ultimately constructed. Additional responsibilities encompass the selection of qualified construction companies and administering the contract between the selected company and the owner so to assure the quality of the work. Construction companies’ prime task, on the other hand, is to execute projects while meeting the owner’s expectations and obtain a profit at the same time. In order to better understand the anatomy of engineering and construction firms, a closer examination of the construction industry is needed.

Subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	# of counts	
	1966-1989										1990-2000															
Accounting for managerial control																										**24**
Accounting		x	x				x	x	x	x									x	x	x				9	
Accounting techniques	x						x	x											x						4	
Budgeting	x	x						x	x			x						x	x					x	8	
Cash management and collection								x	x			x													3	
Organizing and organizations																										**52**
Engineering organization structure	x		x		x	x	x			x		x	x		x		x	x	x		x	x	x	15	
Organization long-term stability and growth																			x	x	x		x		4	
Relationships within/outside organization								x	x								x	x	x			x			6	
Corporate strategy		x								x	x						x				x				5	
Strategic planning and management				x	x	x					x						x		x		x		x	x	9	
Planning of firm's operations		x	x		x	x						x							x						6	
Organizational pathologies: resistance to change		x		x		x					x										x				5	
Partnering																	x		x						2	
Communications, Internal and External																										**10**
Communication	x			x	x			x				x					x	x	x		x		x		10	
Computers and Computer Systems																										**15**
Managing CADD use												x							x						2	
Information revolution management												x							x		x		x		4	
Decision support systems						x		x											x						3	
Management information systems (MIS)						x		x															x		3	
Impact of technology																			x		x		x		3	
Controls and Control Systems																										**23**
Cost control							x	x	x			x			x			x	x		x	x			9	
Project control		x		x	x	x									x				x			x			7	
Project scheduling			x						x						x										3	
CPM, PERT	x			x		x																			3	
Project status reporting												x													1	
Customer relations																										**7**
Effective Public relations								x	x			x		x		x	x		x						7	
Decision Making and Problem Solving																										**4**
Decision-making methodologies				x	x	x		x																	4	
Development and Training																										**13**
Education and Professional development					x									x				x	x	x	x				6	
Training					x																				1	
Engineering management skills development	x				x						x		x					x			x				6	
Economic Factors																										**8**
Innovation and technology transfer								x																	1	
Forecasting business conditions								x						x											2	
Competitive advantages		x									x		x	x							x				5	
Facilities and Equipment management																										**1**
Equipment costs and productivity			x																						1	
Financial Management																										**8**
Financial management		x	x				x	x		x									x		x			x	8	
Human resources																										**33**
Personnel management								x		x		x					x		x	x	x			x	8	
Human behaviour: Motivation				x	x			x				x						x			x		x		7	
Productivity measures		x						x											x						3	
Performance evaluation		x		x				x					x			x			x						6	
Compensation and incentive plans								x											x					x	3	
Employee relations																			x						1	
Labor relations, cost and productivity			x					x							x										3	
Safety issues			x												x										2	
Management concepts and definitions																										**45**
Delegation	x							x										x				x			4	
Leadership		x		x	x			x									x	x	x		x		x		9	
Supervision	x																							x	2	
Professional ethics								x										x	x						3	
Neogotiation	x							x										x							3	
Engineering managers responsibilities	x	x			x	x				x			x				x	x					x		9	
Organizational concepts of project management			x	x	x	x						x	x		x		x	x			x				10	
Project management						x									x		x			x					4	
Benchmarking																	x								1	
Quality control and management																										**15**
Value engineering	x											x				x									3	
Design management	x														x	x			x						4	
TQM: priciples and techniques																x	x	x							3	
Effective proposals and bids	x						x		x						x				x						5	

Table 2-1. ***Subjects covered in the sample of the examined books***

Subjects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	# of counts	
	1966-1989										1990-2000															
Marketing																										**19**
Marketing of professional services								x	x			x		x		x	x		x	x	x				9	
Positioning								x					x	x											3	
Marketing research								x						x										x	3	
Project selection and procurement							x									x			x		x				4	
Production/operations management																										**9**
Managing production operations	x							x														x		x	4	
Plant operation and maintenance management	x																							x	2	
Materials management			x																					x	2	
Bureaucratic rules: external & internal forces		x																							1	
Contract administration																										**19**
Contracts and specifications	x		x				x																		3	
Contract performance							x												x						2	
Engineering and construction contracts															x			x							2	
Legal issues				x			x					x			x			x							5	
Liability							x					x							x						3	
Dispute resolution							x					x						x	x						4	

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22. Stephen Wearne 1, *Engineering Management, Principles of engineering organization, 2nd edition*, Thomas Telford, London, 1993.
23. Robert Newcombe, David Langford, and Richard Fellows, *Construction Management 1, Organization Systems,* Mitchell, London, 1990
24. Robert Newcombe, David Langford, and Richard Fellows, *Construction Management 2, Management Systems*, Mitchell, London, 1990

Table 2-1. ***(Continued) Subjects covered in the sample of the examined books***

The construction industry has its own unique aspects that differentiate it from other industries. Geographical dispersion of operations, fixed site location, complex and expensive processes are among the major characteristics of the industry. The fact that every project is one of a kind, demand is not continuous, and that different resources are required during a project life cycle, creates great challenges in the allocation of human and physical resources. These factors create management problems that are specific to the construction industry.

Figures 2-2 and 2-3 show the operational structures of typical engineering and construction firms respectively. The charts were developed on the basis of the contents of the examined books. Although engineering and construction firms differ in terms of organization and operations, for illustration purposes the charts share three major activity levels, or macro activities: corporate planning, planning of production, and execution of production. Each macro activity is composed by sub-activities as well as the concepts and tools that are used for their implementation. These macro activities are complemented by the supporting functions, which serve the entire organization and are inter-related as well. These functions encompass accounting, human resources, marketing and management of information systems (MIS) in the case of engineering firm. MIS is replaced by procurement in the case of a construction firm. The supporting functions of a firm are subdivided into sub-activities and supporting concepts and tools. The activities of engineering and construction firms are affected by the environment in which they operate, namely regulations, technology, economy, competitions, etc. Some differences are noticed due to the nature of each firm. For instance, professional ethics are one of the main aspects of the engineering firm's environment, while market conditions and trade unions have significant impact on the operation of a construction firm.

Although the charts show a similar organizational structure for both engineering and construction firms, they are different in some aspects according to the type of business they are in. In the following section the various elements that structure an engineering/construction organization are discussed.

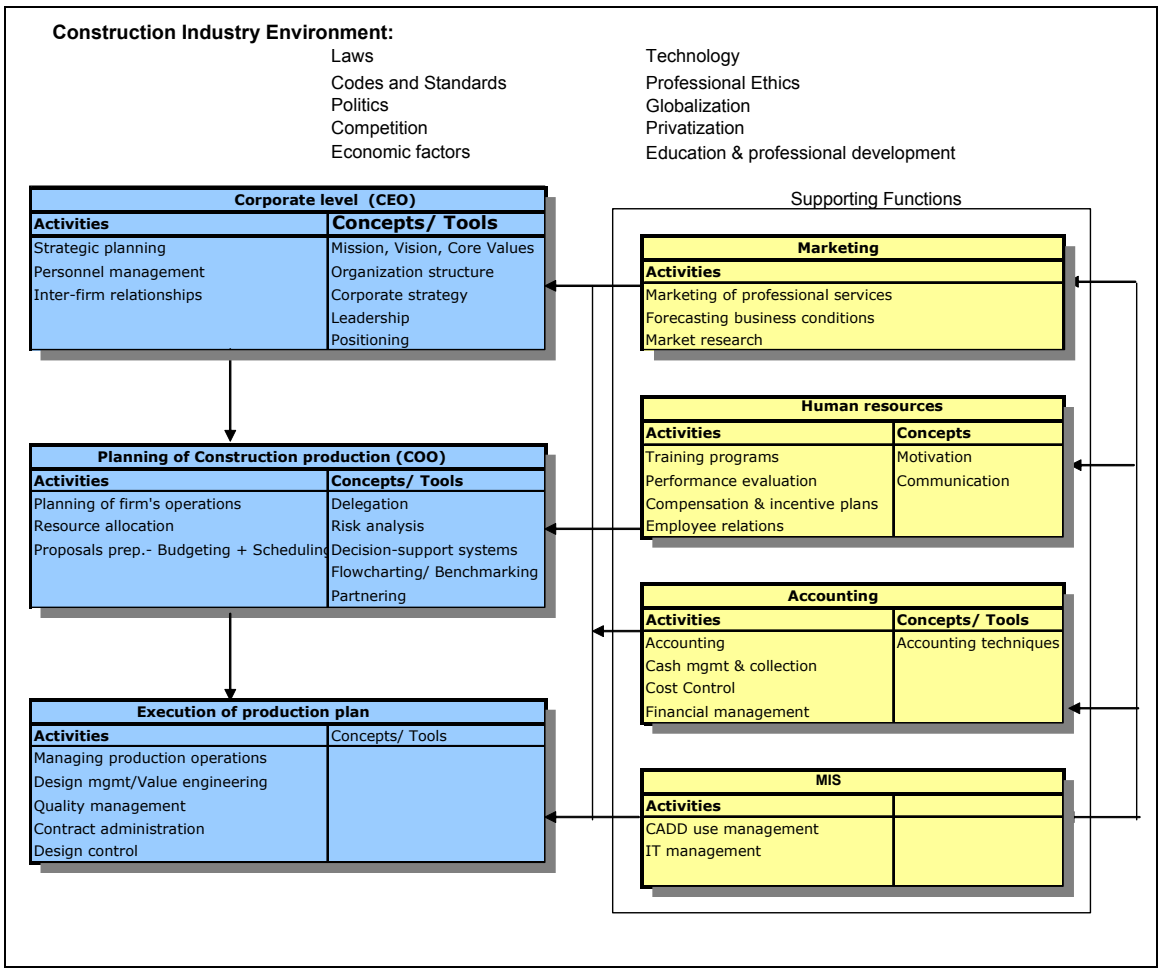

Figure 2-2. ***The operations of engineering firms***

2.4.1 Corporate Level

Activities

At the *corporate level* (CEO) the main activities are strategic planning, personnel management, and inter-firm relationships.

Strategic planning is a key activity in both engineering and construction firms. Since technology is moving so rapidly, achieving market leadership should be the ultimate goal. Unless an organization focuses on retaining its existing market position, it may end up losing profitability. Because technological innovations, communication revolution and

economic advances have globally changed the ways engineering and construction organizations conduct their businesses, the consideration of strategic management in a broader sense is fundamentally required. Otherwise it will be very hard for any organization to survive the waves of change. Modern organizations should be able to manage organizational change, forecast emerging technologies, understand new employee issues, and meet evolving corporate demands.

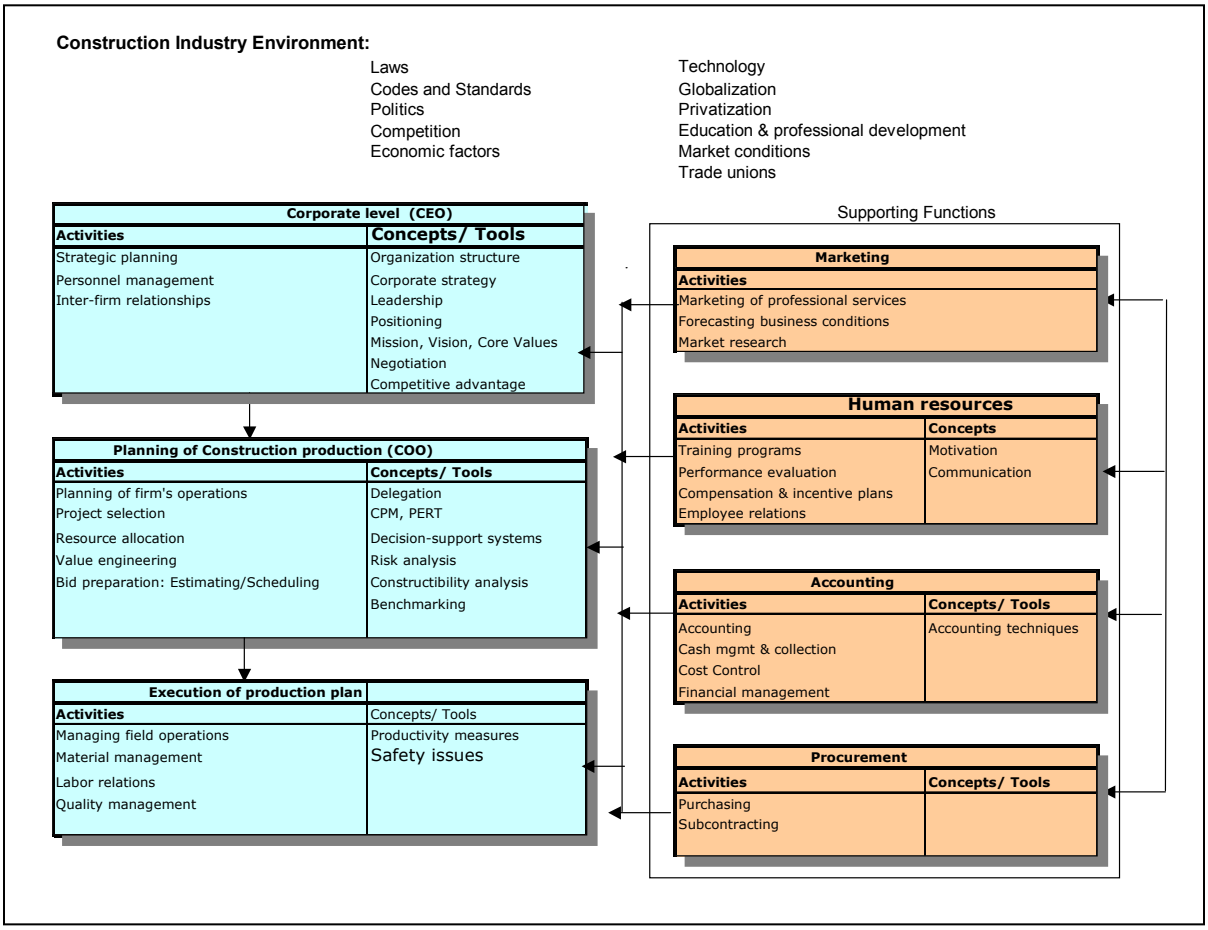

Figure 2-3. ***The operations of construction firms***

In regard to *personnel management*, organizations have to prepare themselves to cope with today's rapidly changing business environment by generously investing in the

training and professional development of *human assets* that are the core asset of civil engineering and construction organizations.

A growing number of firms are engaged in collaborative efforts with other firms. The fragmented nature of the construction industry puts emphasis on the need for inter-firm relationships. Firms have to develop trust with each other for creating better value and sustaining competitive advantage.

Concepts and tools

The managerial *concepts* that inform corporate management activities are in many respects very similar in both engineering and construction firms, except for some cases which may only apply to construction firms, such as negotiation and competitive advantage.

Organization structure

Organization structure is concerned with the integration and coordination of the different activities of an engineering/construction firm in a balanced way. Environmental and organizational characteristics as well as current activities and stakeholders attitudes have an impact on the organization structure (Newcombe, et al., 1990).

Corporate strategy

It is important for engineering firms, as well as construction firms, to identify clearly what business are they in, the position they occupy in that business, and who are their current and potential competitors. This is the context to which *corporate strategy* is applied. It encompasses the determination of the short and long-term objectives of a firm and the means these objectives are to be achieved. It also includes financial and marketing strategies (Ramsay, 1994).

Leadership

Leadership is of great importance to the success of civil engineering organizations. The role of a manager as a leader is much beyond the development of the organization's visions, strategies and objectives. Its role includes inspiring and motivating individuals as well as promoting creativity and achievement. He is responsible for preventing the organization from losing focus on its goals.

Positioning

Positioning is the act of determining a firm's choices either to operate in many segments of the market or to focus on one or two segments.

Competitive advantage

Competitive advantage is obtained when a firm is superior to its competitors. It is identified by three main aspects. The first one encompasses cost reductions, which is particularly relevant to construction firms because projects are usually awarded to the lowest bidder. On the contrary, engineering firms are selected on criteria other than price. The other two aspects pertain to differentiation from competitors and focusing on a particular market segment respectively.

Mission, vision and core values

These concepts act as an organization roadmap to the employees, managers, and executives to guide them in short and long-term decisions. Providing a reason and a common focus for achieving long-term goals is essential for establishing the spirit of cooperation that is the hallmark of great organizations (Riggs, 1995).

2.4.2 Planning level

Planning is a major element in any organization's functioning regardless of its specialty. It includes activities that lead a firm to achieve its goals, such as execution of operations and proposal preparation in the case of the engineering firm, and bid preparation in the case of a construction company. In addition, the planning process encompasses the process of resource allocation, which will definitely contribute to the fulfillment of the organization's goals and objectives.

Activities

Planning of operations

In no way a firm can accomplish its business goals and objectives without undergoing a comprehensive planning process. The planning of a firm's operations should be based on the corporate strategies and policies, the availability of human and physical and capital resources, and the consideration of the environment in which the firm operates.

Resource allocation

The allocation process is designed to incorporate both top down and bottom up resources and to ensure that operational and financial plans are integrated and sustainable within the existing availability constraints.

Value engineering

Value management is a disciplined method for identifying areas of potential cost optimization, considering alternatives, analyzing them, and selecting preferred options (Bowen, 2002).

Project selection

Pursuing projects that do not meet the firm's marketing strategy is time, money, and energy consuming. This can also distract the firm from obtaining work that is more suited to its goals. Declining an opportunity for submitting a proposal or bid is essential for maintaining the focus and growth of a firm (Stasiowski and Burstein, 1994).

Proposal/Bid preparation

An effective proposal/bid confirms the firm's perception of the client's needs, and their ability to meet those needs. It is also a sales tool as well as a technical document. A well-written proposal/bid minimizes surprises, simplifies the decision-making process, and helps in justifying the selection of the winning firm (Clough and Sears, 1994).

Budgeting

Budgeting is the forecasting of future business activities of the firm in terms of revenues, expenses, and profits. Additionally, it is the development of a plan for undertaking future activities and planning expenditures of time or money (*AIA Architect's Handbook, 2002*).

Concepts/tools

Delegation

This managerial concept is about authorizing another person to be one's representative. It involves distributing decision making among qualified employees. Even though proper delegation can greatly assist in the in the allocation of managers' time, sometimes they fail to put it in practice.

CPM and PERT

The Critical path method (CPM) and Program Evaluation and Review Technique (PERT) are among the most widely known planning and control techniques for projects. They are developed by examining a project to determine the approach, methods, and technology to be used and then breaking it down into activities for planning and scheduling purposes (Cleland and King, 1983).

Risk analysis

The probability of an undesirable outcome is typical of construction projects. Therefore it is essential for engineering firms as well as construction companies to perform project risk assessment to complete projects successfully and profitably. The analysis consists of a four-step process: identifying, assessing, responding to and controlling the considered risk.

Decision support systems

Decision Support Systems (DSS) enables quick access to critical information when a management team needs to make sound decisions.

Constructability analysis

A constructibility analysis is performed from the construction standpoint. The task encompasses the review of the design specifications, drawings, and construction schedule. A multidisciplinary constructibility team reviews the project documents to: 1) find overlooked problems that can increase cost; and 2) assure coordination among documents. The review is the single best assurance that a highly efficient construction process occurs (http://www.lza.com/lza/vs/cs.html).

Benchmarking

This is an example of total quality management tools and techniques. Benchmarking entails the comparison of the operational processes and procedures of an organization with those of another. The goal is to find ways for improving internal processes and procedures (Bennett, 1996). It can be carried out at several levels (Cecil and Ferraro, 1992), varying from the entire engineering or construction firm to a particular department within firm.

Partnering

It is a long-term commitment between two or more organizations for the purpose of achieving specific business objectives by maximizing the effectiveness of each participant's resources. It has become an important new method in the management of engineering projects. The economies of time, resources, and costs are enhanced by cooperation, especially in large-scale endeavors (Brooke and Litwin, 1997).

2.4.3 Execution Level

The execution level of an organization is the context of implementation of all corporate planning activities. It is the translation of concepts and ideas into reality. Of all the sub-activities of engineering and construction firms, those at the execution level are the most time and resource consuming.

Activities

Managing production and field operations

In managing engineering and construction organizations, the need for maintaining and improving production and field operations is always emphasized. To obtain better results

in this process factors such as schedules, quality control, costs, and quantities are carefully considered.

Design management

Effective design management is important for meeting both project's goals and firm's objectives. It includes production planning and documents coordination.

Quality management

The understanding of principles such as: 1) continuous improvement, 2) focus on customer, 3) the importance of teams, and 4) management leadership, support and involvement provides the basis for enhancing the performance of engineering and construction operations (Bennett, 1996).

Material management

The primary objective of this activity is "to bring to the project the appropriate materials at the right time, quantity and price to enable the construction work to proceed according to program and the necessary quality standards."(Newcombe, et al., 1990)

Contract administration

This task includes the general administration of the construction contract such as, reviewing and certifying amounts of work done on site, approving the contractor's submittals, and conducting site inspections.

Design control

The ability of an organization to implement an effective design control system is critical to meet customers' expectations. Constant review and coordination among the different

disciplines of the project as well as full monitoring of costs and schedules are very important in the design control process.

Labor relations

The labor component of construction is the most variable and unpredictable one. Therefore, the management team must be aware of the interaction between labor organization, law, cost, and productivity in order to use human resources effeciently.

Concepts/tools

Productivity measures

Management teams generally focus on high-priority areas for productivity improvement and criteria for measuring such improvement effectively.

Safety issues

The construction company is held responsible for providing a safe working environment for its working force and the public as well. Injuries or fatalities at the site have negative impacts on a project at all levels.

2.4.4 Supporting Functions

Supporting functions or departments allow a firm to operate properly because they provide the basis, support and resources for sustaining the continuity of operations. The most common functions in engineering and construction firms are accounting, human resources, marketing, management of information systems, and procurement.

Marketing

Marketing is a series of steps that firms take to attract clients and gain the projects they need to maintain their practice (Pickar, 2002). Management skills and technical capabilities are the common denominators of engineering and construction firms.

Because engineering and construction services are generally sold before their actual implementation, traditional marketing techniques must be modified and adjusted to the particular needs of this type of market.

Human resources

People are the most important assets of a firm. Effective human resources management plays a vital role in corporate success. Needless to say, a committed staff is the best marketing tool of a firm (Maurel and Dreyer-Hadley, 2002). *Motivation*, a keystone of supporting corporate functions, is supposed to increase personnel performance, which does make a great difference in achieving organizational success. Thus, it is the engineering managers' responsibility to provide means that fulfill employees' motivation needs. Human resources management encompasses a variety of activities ranging from recruiting of new employees to maintaining and enhancing their skills. When human resources management is strongly linked to corporate strategy, value is automatically added to the firm. Eventually, activities such as professional development opportunities, reward and recognition, and compensation and benefits plans result in motivated individuals and better corporate performance, reduced turnover, and ultimately higher profitability.

Accounting and financial management

Managing a firm's finances and keeping track of its financial health is one of the pillar functions of a successful organization. Firms generally develop a financial management

system as well as an accurate way of monitoring the financial performance of their projects and firm itself to meet economic targets, including making a profit (Getz, 2002). Any successful organization must have a solid financial status that enables it to explore new market opportunities. Profit rather than revenues is generally the focus that leads to sharing internal costs and inefficiencies. Effective financial management helps a firm to achieve its business goals.

In addition to accounting, cash management, financial management and cost control are considered the main activities within an accounting department. The latter is responsible for monitoring progress by comparing actual with budgeted costs, and suggesting or implementing corrective measures as required.

Management of Information Systems (MIS)

Computer technologies offer designers powerful tools for carrying out their daily tasks with greater effectiveness and efficiency. Emerging digital technology also allow these professionals to leverage their talents and expand their sphere of practice (Tardif, 2002). A firm with the ability of managing digital building information, on behalf of a client, is able to offer its customers valuable services beyond the deliverables of plans and specifications (Tardif, 2002).

Procurement

The purpose of procurement activities is to help the owner in attaining effective construction services. It provides the General Contractor with well-qualified sub-contractors and suppliers including services and materials at reasonable cost.

2.4.5 Construction industry environment

Organizations operate in an environment by which they are inevitably influenced through a wide variety of sophisticated factors, such as: global competition, rapid advances in technology, technologically skilled and educated workforce, codes and regulations, and laws that govern the engineering and construction process. Local, political and economic factors, at the same time, represent an additional challenge for construction related organizations. The following notes summarize some of these environmental factors.

Technology

A firm's evaluation process of its technology needs is usually an intimidating task. However, determining the appropriate hardware and software systems, their flexibility, requirements, costs and long-term benefits, is extremely helpful for a firm particularly in regard to technological obsolescence (Chinowsky, 2000).

Laws

Never before in its history has the engineering profession faced the legal exposure that it does in modern society. The rapid expansion of technology has fostered parallel developments in the law (Cleland and Kocaoglu, 1981).

Organization education and professional development

One of the key factors in the success of an engineering or construction organization is the continuous pursuit of human resources development through both formal and informal education strategies. An engineering organization can no longer survive in today's fiercely competitive market without ongoing educational investments for its

personnel. The choices in education implementation and professional development vary from university graduate programs to professional journals and Internet-based education.

Globalization

In today world, a thriving company must address the globalization of markets, procurement and of intellectual capabilities. The keys to success are: 1) Engineers who are broadly based and value broad-based skills and world opportunities. 2) Personnel who believe not only in reengineering the company, but also in regularly re-engineering themselves. Otherwise, civil engineering companies remain stuck in the present and are to repeat the errors of the past (Engen, 2000).

Privatization

Privatization, the sale of state-owned enterprises or assets to the private sector, has grown worldwide since the early 1980s -- beginning in Great Britain and continuing in the 1990s in developing countries. More than 100 countries are engaged in privatization initiatives. This fact shows the increasing use of market forces to allocate resources. Research supports the claim that privately owned firms are more efficient and more profitable than otherwise-comparable state-owned firms. (Megginson and Netter, 2001).

Codes and standards

Building codes and standards establish significant restraints to the design of buildings and structures. It is mandatory that designers comply with building codes and standards. Otherwise the public safety of the building users is jeopardized and designers will be exposed to legal liabilities.

Politics

The construction industry is affected by a large number of political factors, most notably pertaining economic, employment and industrial policies (Newcombe, et al., 1990). Thus construction related organizations are affected by politics at any level, local, national, or even international in a positive or a negative manner depending on situations.

Competition

With the ever-shrinking world we are living in these days, the traditional competition with similarly positioned local or even national firms is no longer an option. International competitors are expanding their services to cover new territories posing a real threat for small sized engineering and construction firms. This trend imposes the need for a reevaluation process at the corporate level and the establishment of new policies and strategies to defend market positions of great importance, and maintain profitability.

Economic factors

The construction sector is constantly affected by changes in material prices, labor availability, and availability of capital. These changes may arise unexpectedly, due to regional, national and global factors, and consequently they have negative impacts on anticipated projects.

Trade unions

Labor organizations have been created to protect and improve the interests of its members by negotiating agreements with employers on wages and conditions of work. Unions may also provide legal advice, financial assistance, health benefits and

education facilities. They could have a considerable impact on projects in terms of cost and time overruns, due to potential strikes and demands for higher wages.

2.5 Conclusions

A brief historical background of the CEM discipline has been introduced in this chapter. The literature review has revealed that the center of gravity of the discipline lies between two major areas: the management of projects and that of firms, both of engineering and construction nature. The analysis of the literature has identified the most important subjects and topics of the discipline as well as their number of occurrences over the years. This task facilitates a better understanding of the organizational structure of engineering and construction firms, of their major activities and functions, how they operate, and relate to their internal and external environment. Two charts that summarize the operations of engineering and construction firms were developed. They show that the operational structure of typical engineering and construction firms, despite their differences in terms of organization and operations, share three major activity levels, namely corporate planning, planning of production, and execution of production. At the corporate planning level the main activities are strategic planning, personnel management, and inter-firm relationships. The planning level includes activities such as planning of operations, resource allocation and proposal preparation, in the case of the engineering firm, and bid preparation in the case of a construction firm. The execution level encompasses activities such as managing of production or field operations, quality management, design management and control for engineering firms and material management and labor relations for construction firms. In this chapter, in addition, the

construction environment, its components, such as technology, laws, politics, competition, and economic factors, and its impact on firms have been briefly analyzed.

In the next chapter the contents of a typical academic journal in the field of CEM are analyzed and compared with the findings of this chapter.

3 The description of the discipline in academic journals

3.1 Introduction

Academic journals play a much bigger role than just facilitating communication. Publication in academic journals is viewed by those controlling research policies at a national and institutional level and those who manage careers as an indication of the quality of research (Betts and Lansley, 1993).

The purpose of this chapter is to explore how the construction engineering and management (CEM) discipline has been portrayed in leading academic journals and compare these findings with those of the previous chapter. In this regard, a search was conducted to select the most relevant refereed journals that contain research articles dealing with the CEM discipline. The search considered the Project Management Institute (PMI), which publishes the *Project Management Journal* (*PMJ*), and the American Society of Civil Engineers (ASCE), which publishes both the *Journal of Management in Engineering* (*JME*) and the *Journal of Construction Engineering and Management* (*JCEM*). And since the ASCE journals are considered among the eminent academic journals in the civil engineering related fields, in addition to the availability of their main data through the ASCE's on-line database, the two ASCE journals have been chosen as a focus of the study.

The first section of the chapter introduces the history, focus, and evolution of the two journals, the *JME* and *JCEM*. In the second section a brief review on the typical contributors is presented. Finally, the contents of these journals are compared with the contents of the literature examined in the previous chapter.

3.2 History of the two journals

3.2.1 The Journal of Management in Engineering (JME)

The first issue of the ASCE *Journal of Management in Engineering* (*JME*) was published in January 1985. As far as the size of contributions is concerned, 526 papers were published in 85 issues, which were issued on a quarterly basis during the period of 1985-93, followed by bi-monthly issues from 1994 until 2002. The total number of authors reaches the number of 827 with a remarkable increase in international authors' participation, as shown in Table 3.1. The time of observation was divided into six 3-year parts, as well as two equally divided periods, of the first 9 years (1985-1993) and the last 9 years (1994-2002), so to trace the evolution of contents over time.

JME	**85-87**	**88-90**	**91-93**	**94-96**	**97-99**	**00-02**	**85-93**	**94-02**	**85-02**
Issues	12	12	12	18	18	14	36	50	86
Number of papers	88	104	89	80	91	74	281	245	526
Number of authors	114	144	131	99	181	158	389	438	827
Number of international authors	6	15	19	18	42	61	40	121	161
Percentage of international authors	0.20	0.10	0.15	0.18	0.24	0.39	0.10	0.28	0.20

Table 3-1. ***The size of the journal over the 1985-2002 period***

The *JME* was founded by Melville D. Hensey with the intention to use the journal as a forum for sharing the unique contributions of engineering managers to the practice, art, and science of management. According to Hensey, the journal was to provide the opportunity for all managers to gain knowledge from the management practice and research of others. At that time the areas of interest of the JME included general management, project management, department, branch and office management, financial management, marketing and sales management, computer systems management, budgeting, scheduling, planning, management development, training, organization design, risk management, strategic planning, and performance

improvement. In April 1988, as stated by Mel Hensey in an editorial, the JME had become an international journal with the contribution of authors from Australia, Canada, China, Saudi Arabia, the United Kingdom, including many parts of the United States as well.

At the beginning of the year 1990 the editorship passed to Gary D. Bates for another five and a half years. During that period nearly 150 peer-reviewed papers and feature articles were published in subjects that pertain to role of management in an engineering environment (Bates, 1995). During the first ten-year period neither the explicit objectives nor editorial policies of the journal changed significantly.

By the end of 1995 Jeffrey Russell took over and seeked opportunities to improve the *JME*. Two additions to the contents of the journal took place in the last issue of the same year: *The Guest Editor's Letter*, where practitioners offer their perspectives on current management issues, and the *Forum*, where readers submit short tips, observations, feedback, summaries of industry surveys, cartoons, illustrations, and other items. His prime objective was to create links between academia and industry. Although from the start the journal aimed at balancing the different needs of its readers and still maintaining the high quality of an archival journal, the results were not satisfactory for those readers who happened to be practicing consulting engineers, not academicians.

Against an increasing pressure from the readers, who wanted more practice oriented articles that could be of use in their professions, a new ASCE publication, the *Leadership and Management in Engineering (LME)* was born in January 2001. The new practice oriented journal incorporated parts such as *the Forum*, *the Editor's Letter*, and *the CEO Corner* from the *JME*. The JME therefore centered its focus on research studies and the usual peer-review process.

In January 2001, as a result of the appointment of John V. Farr as a new editor in chief, the scope of interests of the journal was expanded to a wider range of issues in

leadership and management, such as partnering and professional practice and development. With the first issue of 2002 Irtishad Ahmad began his editorship of the *JME*.

3.2.2 The Journal of Construction Engineering and Management (JCEM)

"The journal was first published with the title, *Journal of Construction Engineering and Management*, in March, 1983, namely in Volume number 109, whose three digits show the continuation of a long publishing tradition of construction-related papers that dates back to the late nineteenth century. Before 1983 these papers had been published in journals with different titles; the last one before 1983, the *Journal of Construction Division*, began publication in 1957. Under the editorship of Robert Harris, the aims of JCEM was "to advance the science of construction engineering, to harmonize construction practices with design theories and to further education and research in construction engineering and management." The focus on construction engineering reflected the civil engineering base of the contributors to the journal, whose original editorial objectives have remained the same over the years and contents have been enriched by a growing number of new topics" (Pietroforte, 2002).

3.3 Focus and evolution of the *Journal of Management in Engineering*

The JME publishes peer-reviewed papers and case studies to provide a comprehensive review on topics ranging from project management to budgeting and strategic planning with a focus on the practicing consulting civil engineer.

The first page of each *JME* issue illustrates the areas of interest reflected in the published papers. These data were summarized in Table 3.2, which shows some noticeable changes in the focus of the journal over the years. First of all, areas such as general management, scheduling, and planning are no longer the focus of the journal

since the year 1989. While the topic, “training”, disappeared in the same year, it was introduced once again in the year 2001. Similarly, the topic “Marketing and sales management” was changed to just “Marketing”, leaving “sales management” out of the picture in 1989. Then, in the year 2001 “Marketing” returned to its original format in combination with “sales management”.

Astonishingly computer systems management, management development, and performance improvement, which were on the list of the areas of interest of the journal since its foundation, were discarded in 2001. “Productivity management”, first introduced in 1989, as well as “quality improvement”, introduced in 1994, were no longer considered in 2001.

In the same year a new set of interests emerged, such as leadership issues, teamwork, team building, mentoring, coaching, and diversity. Other added management issues include: partnering, professional practice and development, recruitment and retention of human resources, career growth management, life-long learning, ethics, technology and innovation management, business process reengineering, motivational theory, incentives, education, negotiating, globalization, networking, and change management. Also papers that discuss the role of civil engineering in the political process, legal and regulatory issues, and corporate and public policies are of interest.

***JME* Areas of Interest**	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
General management	x	x	x	x														
Project management	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Department, branch, and office management	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Financial management	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Marketing and sales managemenrt	x	x	x	x													x	x
Marketing					x	x	x	x	x	x	x	x	x	x	x	x		
Computer systems management	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Budgeting	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Scheduling	x	x	x	x														
Planning	x	x	x	x														
Management development	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Training	x	x	x	x													x	x
Organization design	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Risk management	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Strategic planning	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Performance improvement	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
Productivity management					x	x	x	x	x	x	x	x	x	x	x	x		
Conflict management									x	x	x	x	x	x	x	x	x	x
Quality improvement										x	x	x	x	x	x	x		
Teamwork																	x	x
Team building																	x	x
Mentoring, coaching, and diversity																	x	x
Partnering																	x	x
Professional practice and development																	x	x
Recruitment and retention of human resources																	x	x
Career growth management																	x	x
Life-long learning																	x	x
Ethics																	x	x
Technology and innovation management																	x	x
Business process reengineering																	x	x
Motivational theory																	x	x
Incentives																	x	x
Education																	x	x
Negotiating																	x	x
Globalization																	x	x
Networking																	x	x
Change management																	x	x
Role of CE in the political process																	x	x
Legislature and regulatory issues																	x	x
Corporate and public policy																	x	x

Table 3-2. ***Areas of interest in the JME***

The Journal of Construction Engineering and Management was assessed with the same procedure, as that used for the JME. Table 3.3 shows that the areas of interest of the journal remained consistent over the years. Topics include construction material handling, equipment, production planning, specifications, scheduling, estimating, cost control, quality control, labor productivity, inspection, contract administration, construction management, computer applications, and environmental concerns.

CEM Areas of Interest	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Construction material handling	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Equipment	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Production planning	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Specifications	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Scheduling	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Estimating	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Cost control	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Quality control	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Labor productivity	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Inspection	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Contract administration	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Construction management	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Computer applications	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Environmental concerns	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 3-3. ***Areas of interest in the JCEM***

The analysis shows that there is some deviation between the editorial areas of interest and the actual topics of the papers published in the JME. In other words, these topics reflect more the personal interests of the authors, whether they are academicians, practitioners, government or military personnel, than the intents of the journal.

The *JME* has been constantly trying to sharpen its focus over the years, which may also reflect the numerous changes in its editorships. The several attempts to modify its scope, in 1989, 1993, 1994, and finally in 2001 indicate that the journal has difficulties in finding a consensus about the "structure" of "Management in Engineering" discipline among its readers, notwithstanding a growing number of contributions.

Differently, the Journal of Construction Engineering and Management (*JCEM*) completes the picture of the construction engineering and management discipline with subjects that mainly focus on its technological and construction components. Both *JME* and *JCEM* have published a large number of articles in the management of human resources area, one of the greatest assets in engineering and construction firms.

The most important observations about the JME can be summarized as follows:

1. The first focus change appeared in 1989 with the disappearance of interests, such as general management, sales management, scheduling, planning and training topics. Productivity management was added.
2. The second focus change happened in 1994 due to the addition of conflict and quality management.
3. And finally, the most significant change in the journal's history occurred in 2001 by expanding the list of interests with more than 20 new topics.
4. Apparently these changes coincided with the frequent ones in the editorship of the journal.

3.4 A comparison of the contents of the selected journals and those of the examined literature

Textbooks and reference books play a pivotal role in describing and defining the scope of any given discipline. It was essential for the study of the CEM discipline to explore this type of literature. A sample of 24 books was investigated for the purpose of mapping the discipline based on the number of occurrence of subjects and topics in those books. Table 2-1 of the preceding chapter summarizes the data extracted from the books. Organization related topics, such as organizational structure, strategic planning and management, are the most frequent subjects published in the examined books. This group is followed by a set of management concepts and definitions, which include topics such as organizational issues in project management, leadership, and engineering manager's responsibilities. Furthermore, the subject of human resources, namely personnel management, motivation and performance evaluation, has been published frequently in several books. Additionally, accounting for managerial control, financial management, controls and control systems, marketing, quality control and management, managing production operations, and contract administration receive considerable

attention in the examined sample. The picture that emerges is that CEM is a very broad discipline centered on the consideration of people and techniques and whose implementation requires quantitative and qualitative approaches. The application of CEM principles is complemented by topics that help to understand the environmental factors that affect managers and firms, such as communication, competitive advantage, effective public relations, education and professional development and information management.

The comparison between the contents of the books and those of the two journals suggest the following considerations:

1. As shown in Figure 3.1, both books and journals share common topics such as:
    - Project management
    - Quality control
    - Contract administration
    - Productivity management
    - Construction management
2. The combination of the subjects covered in the JME and JCEM journals produce a comprehensive representation of the CEM discipline. This picture was completed with the introduction of new interests in the *JME* journal in 2001.
3. In the period from 1985 to 2001 the subjects covered in the *JME* lacked many topics such as:
    - Partnering
    - Education and professional development
    - Innovation and technology transfer
    - Human behavior, motivation
    - Compensation and incentive plans

- Professional ethics
- Negotiation
- Legal issues

These topics had been covered by the examined books since the late Seventies and were added only in 2001 in the examined journal.

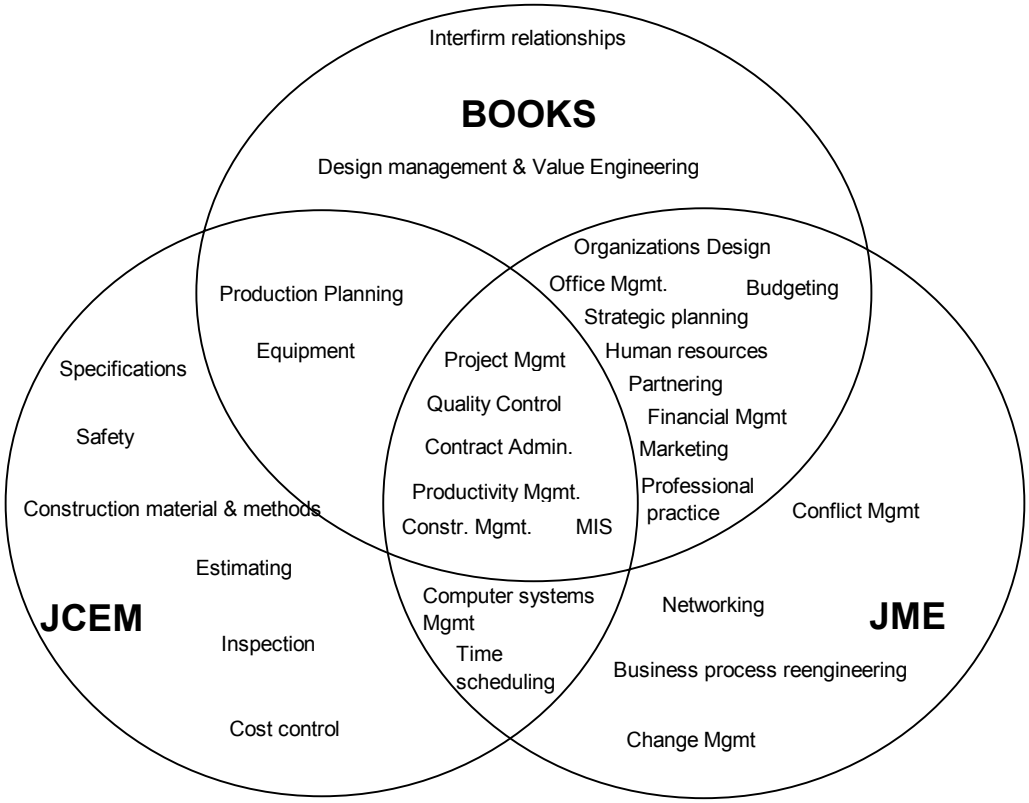

Figure 3-1. ***Shared areas of interest among examined books and journals***

3.5 Typical contributors

The Journal of Management in Engineering publishes papers of interest to managers of a wide range of organizations: private, public, for-profit; educational, research, design,

construction, operations and maintenance, large and small. The typical contributors are similar to those found in the Journal of Construction Management and Engineering. Recently, some criticism was leveled towards the ASCE's journals, namely that they are academically oriented and too theoretical, and not useful to practitioners. This criticism reflects the fact that most of the authors are academicians whose career advancement depends on refereed publications. On the contrary, practitioners find less rewarding in publishing in academic journals. Given the overwhelming number of contribution by academicians, the journal's contents presented show a gap between theories and techniques and practical needs of the industry.

3.6 Conclusions

Currently, and especially after the 2001 focus change of the *JME*, the *JME* and *JCEM* convey a fair description of the CEM discipline, and there is a consistency among editorial interests and contents of published papers.

In the period from 1985 to 2001, there was a remarkable number of issues, related to leadership and modern management, that were missing from the radar screen of the *JME*, even if these topics had received attention in the examined books. There is a large area of shared areas of interest between books and journals, which includes project management, quality control, contract administration, productivity management, construction management and management of information systems (MIS). The JME is trying to satisfy its readers by providing them with practical papers that could be of use to the typical consulting civil engineer, and still maintain a high quality archival journal (Farr, 2001). The typical contributors of the journal are a mix of academicians and industry professionals of US and international origins.

The next chapter presents an analytical review of the JME's contents, the criteria according to which the contents are classified and changes in the subjects and topics of the papers published over the years.

4 The review of *the Journal of Management in Engineering* contents

4.1 Introduction

After defining the CEM discipline and reviewing its contents in books and leading academic journals in the previous two chapters, the contents of the *Journal of Management in Engineering* are analyzed to draw a relatively detailed, but partial, map of the discipline from the engineering management standpoint. The analysis focuses on the following issues:

- Classification of subjects and topics: the areas of interest of the papers published in the journal.
- Contributors and their affiliation: the location of the repositories of knowledge within the CEM discipline as well as the strength of the cooperative links between academia and industry.
- Keywords: the possible correlation between the use of keywords and the evolution of subjects over the years.
- Research methods: the most prevailing research methods that underpin the studies published in the JME.

The journal's contents are investigated over a period of 18 years. Their possible changes reflect important trends and patterns in the discipline. In addition, the findings of this analysis are the informative basis about the CEM discipline from an engineering management's perspective. In order to accomplish this study, a new customized database was developed by gathering and entering the relevant data of the journal.

This chapter addresses the classification criteria of the journal's contents, the development of the new database, the evolution of the journal's contents, the use of

keywords as well as of research methods over the years, and typical contributors and their affiliation.

4.2 The classification system

The classification framework for assessing the content of each paper was previously developed by Prof. R. Pietroforte in a similar study of the contents of the *Journal of Construction Engineering and Management*. The original intent was not to develop a meta-classification of the discipline but, less ambitiously, its partial mapping, as it is reflected in the contents of the journal. The main analytical thrust was to group the papers by main subject areas. In this regard, thirteen subjects were identified:

1. Construction time scheduling
2. Project management
3. Construction contracts development and administration, Contract formulation and documentation
4. Management and organization of firm
5. Human Factors, Management of safety and labor relationships
6. Construction operations, methods and materials
7. Management of personnel
8. Trends in research & development
9. Construction costing and control
10. Project delivery systems and purchasing of construction services
11. Site, material and equipment management, Mobilization and logistics
12. Industry structure and environment
13. Construction planning and control

Each of the above subjects was subdivided into many composing topics in order to obtain more accuracy and a higher level of precision. The number of these topics

exceeded 140. Appendix 1 shows the identified subjects and their related topics. Because the *JME* is mainly concerned with the managerial aspects of engineering and the *JCEM*'s focus is more on the actual construction issues, it was expected that subjects such as:

- Construction time scheduling
- Human Factors and management of safety and labor relationships
- Construction operations, methods and materials
- Construction costing and control
- Site, material and equipment management; mobilization and logistics

would receive less attention or no attention at all in the contents of the *JME*. The 526 papers were examined and classified according to one of the 13 subjects by reading the title, the abstract, and the keywords of each paper first and then by addressing the abstract.

4.3 The development of the new database

4.3.1 The gathering of the journal's data

The main source for gathering the journal's data was the ASCE online civil engineering database (http://www.pubs.asce.org/cedbsrch.html), which enables researchers to look for papers published in any of the ASCE's publications.

By entering the journal's code, issue number, and year, a list of hyper-linked titles of the papers published in any given issue is available. To view the abstract, the author(s) and the keywords, just a click of the title is needed. These steps are illustrated in Figures 4-8, 4-9, and 4-10. In addition, the full text of the papers is available online for the issues published from 1995 to date. This database, however, could not be used directly

because its design did not match the purpose of this study. Modifications to the structure of the ASCE's database, such as new fields to assign each paper to a subject according to the given classification system, and record the affiliation of the authors, i.e., whether from academia, industry, military, or government agencies, were needed. In addition, new features for retrieving specific pieces of information were required. In any case, the ASCE's civil engineering database is a dependable resource for searching ASCE publications. The features of the newly developed database fully reflect the specific objectives of the study.

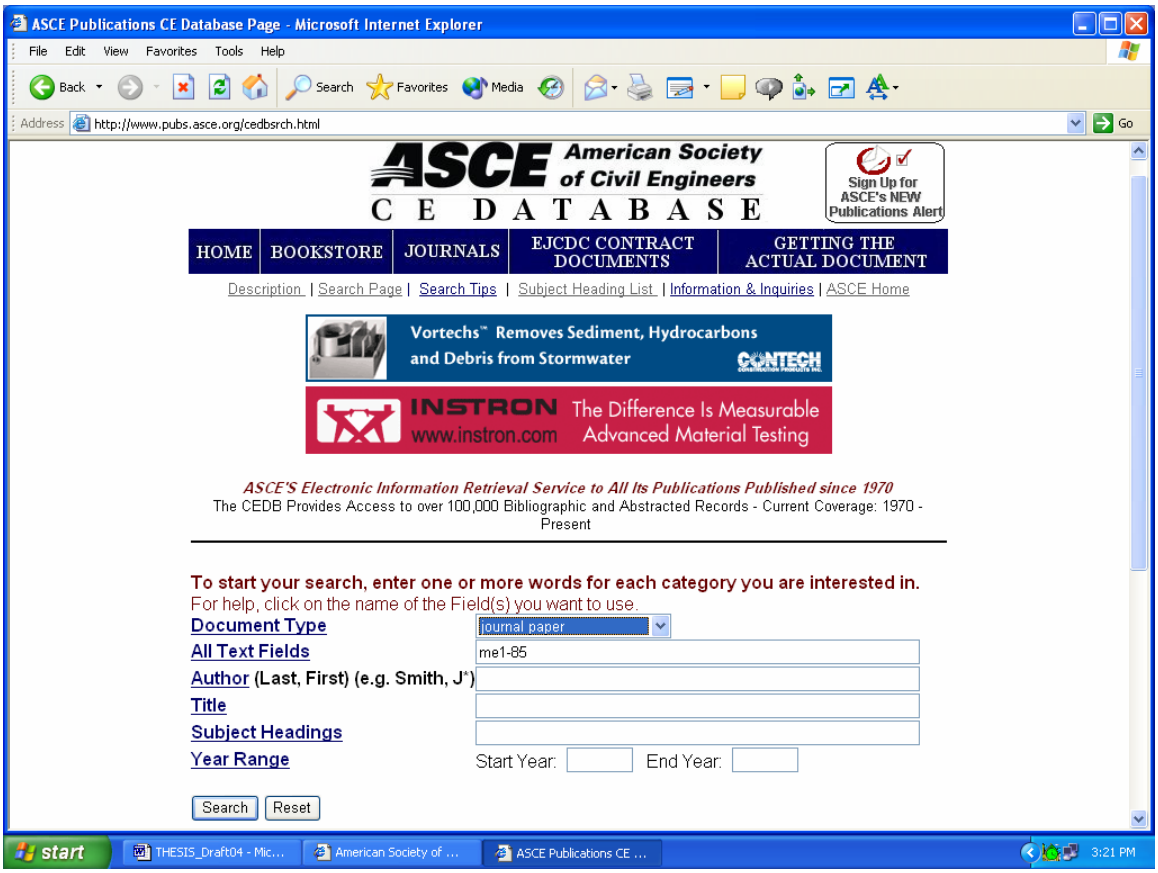

Figure 4-1. ***The result screen of the ASCE's database***

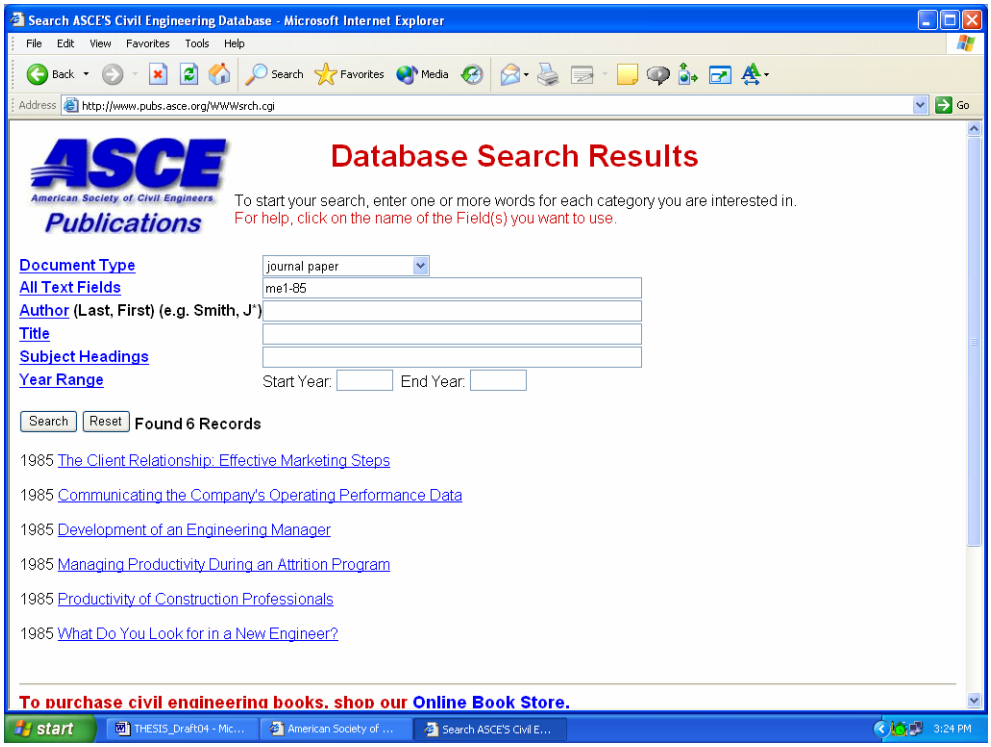

Figure 4-2. ***ASCE's database search results screen***

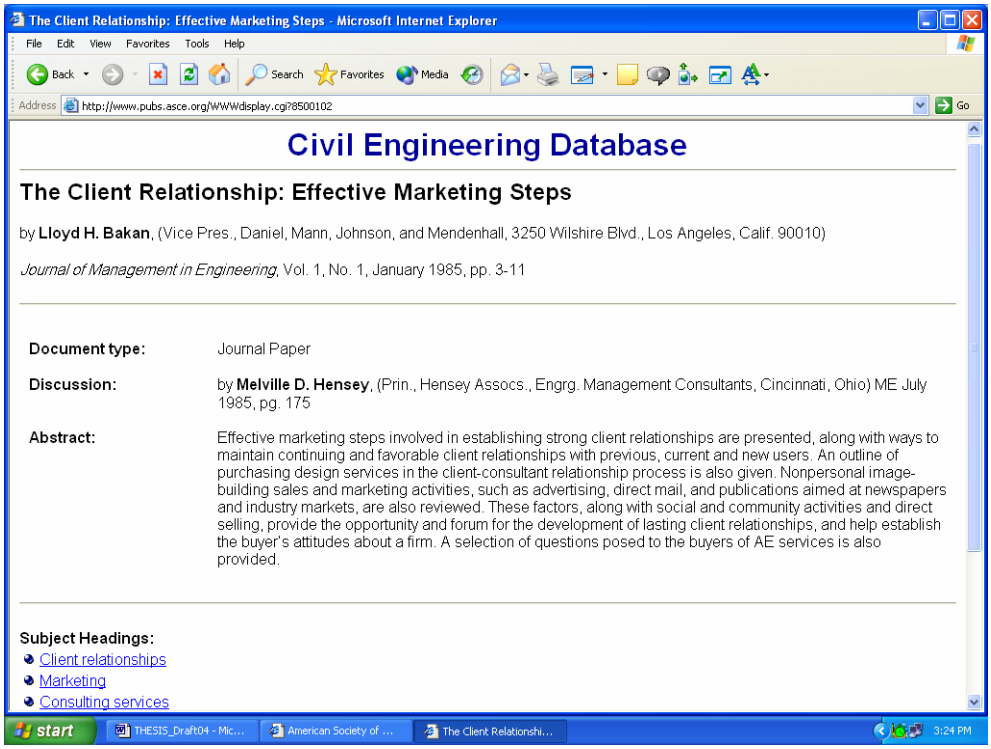

Figure 4-3. ***Summary of the article's information***

4.3.2 Development criteria and capabilities of the database

A relational database model by Microsoft Access was used to record the data of the study. The first step in this process started with the following question: What am I looking for? By listing the anticipated outcomes of the database, a clearer vision of its features was gained. For instance, in order to show the distribution of the papers' content according to the thirteen subjects, a specific table containing all the information related to each paper was created, in addition to a field for classification by subject. Another example is the table that shows the relationship between articles' table and authors' table. Thus, from the database it is possible to develop tables of articles, authors, keywords, classification by subject, universities, and countries. The former were designed in a flexible way to eliminate redundancy and simplify the retrieval of the required information. The primary capabilities of the new database are the following:

- An organization screen at the start up of the program facilitating the search process (Fig. 4.1).
- Easy-to-read forms for articles and authors containing all the related data (Fig 4.2, Fig. 4.3).
- Ability to search by classified subject/topic, keyword, author, university, or country (Fig. 4.4).
- Ability to create tables containing the frequency of any subject/topic or keyword over time (Fig. 4.5).
- Expandability: unlimited addition of information for future articles, authors, keywords, universities, and countries.

The queries were formulated to trace the different patterns in the *JME's* content, such as the number of papers published as well as the amount of contributions by authors, universities, and countries in a particular subject and/or topic. This large amount of

information can be easily viewed from different angles. The search can be performed through articles, authors, keywords, classification, countries and universities, yielding very important hints about the distribution of covered subjects as well as the location of the *JME's* contributors. One of the useful features of the database, as shown in Figure 4.4, is to retrieve both the papers and keywords classified according to a certain topic by a click of a button. Additionally, all the papers written by a particular author can be immediately sorted by clicking the "papers" button in the authors' screen (Fig. 4.6). This feature shows the frequency of publishing by a particular author as well as his preferred area of interest.

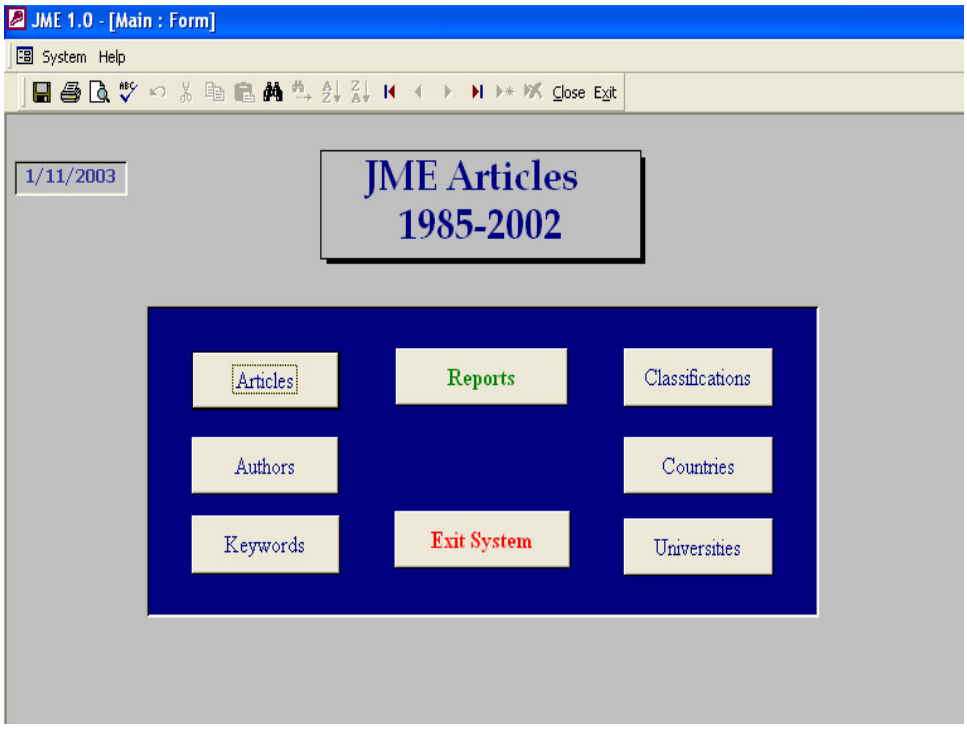

Figure 4-4. ***Organization of data***

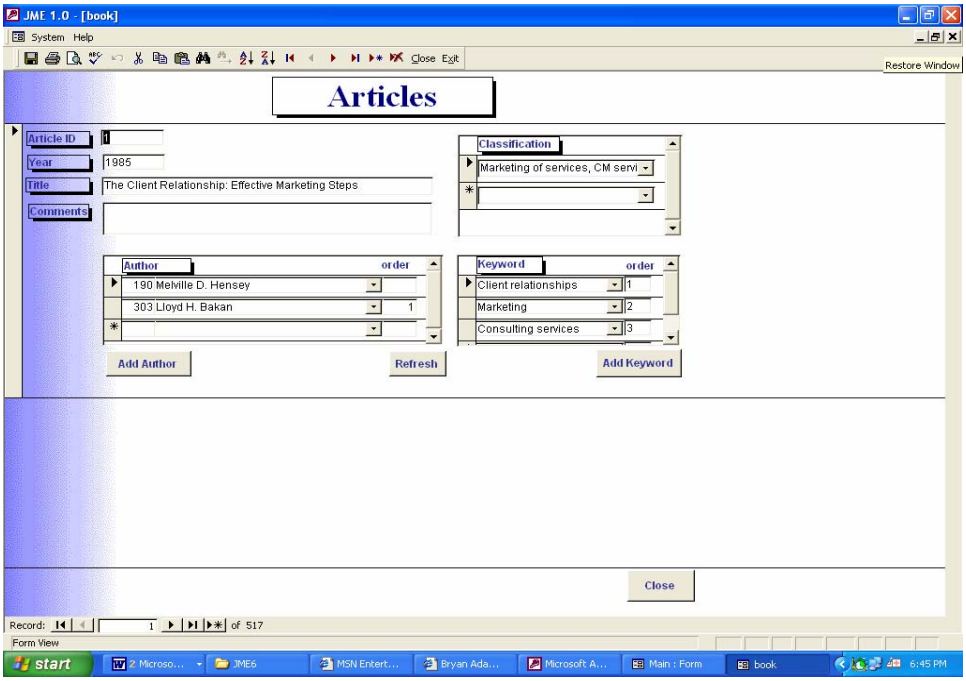

Figure 4-5. ***The articles' screen of the new database***

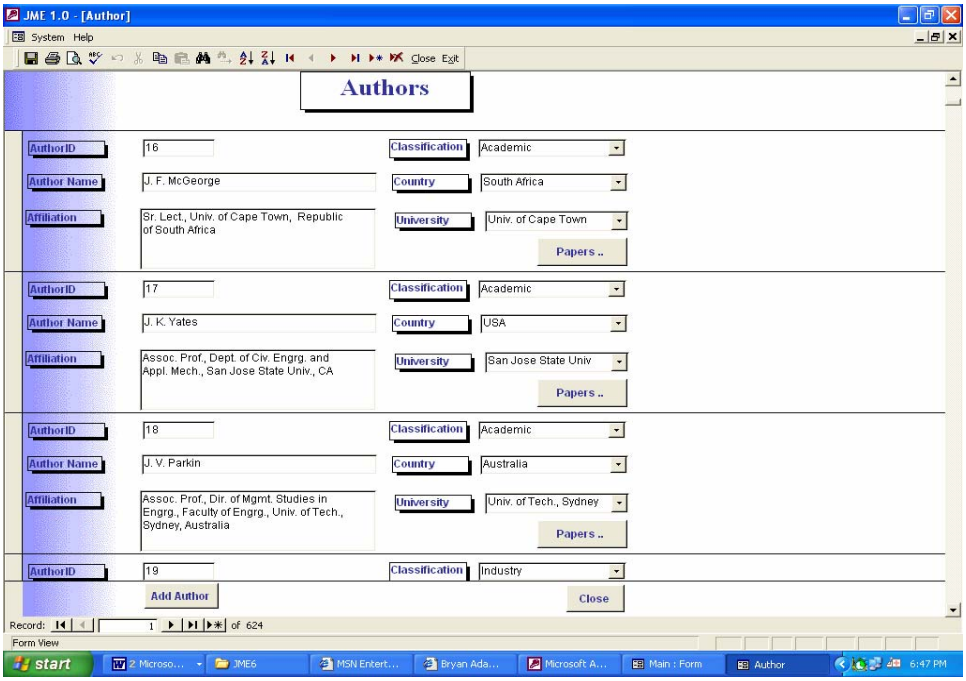

Figure 4-6. ***The authors' screen of the new database***

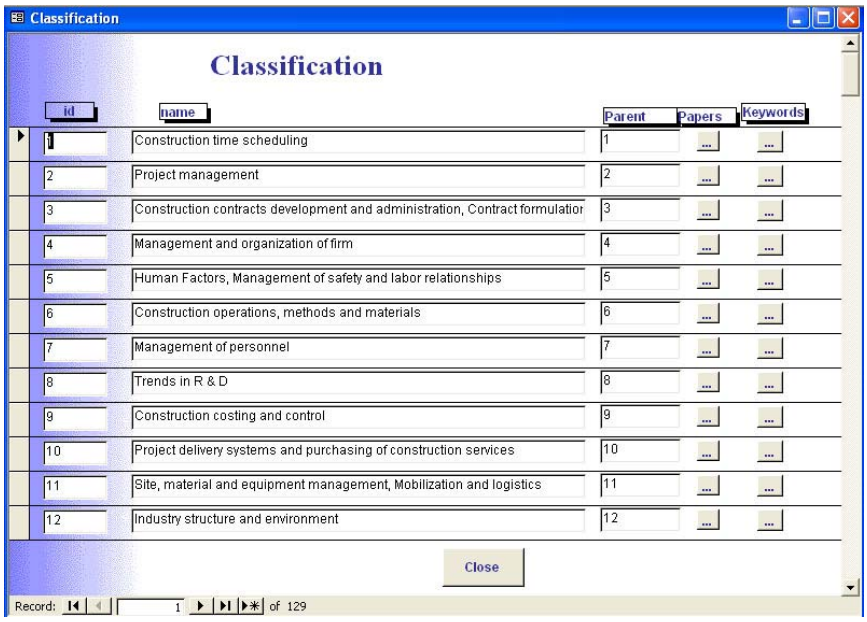

Figure 4-7. ***The classification screen of the new database***

Another practical feature is the search for articles, author, keyword, university, country. This information can be retrieved by clicking on the “details” button located next to the paper’s title (Fig. 4.5).

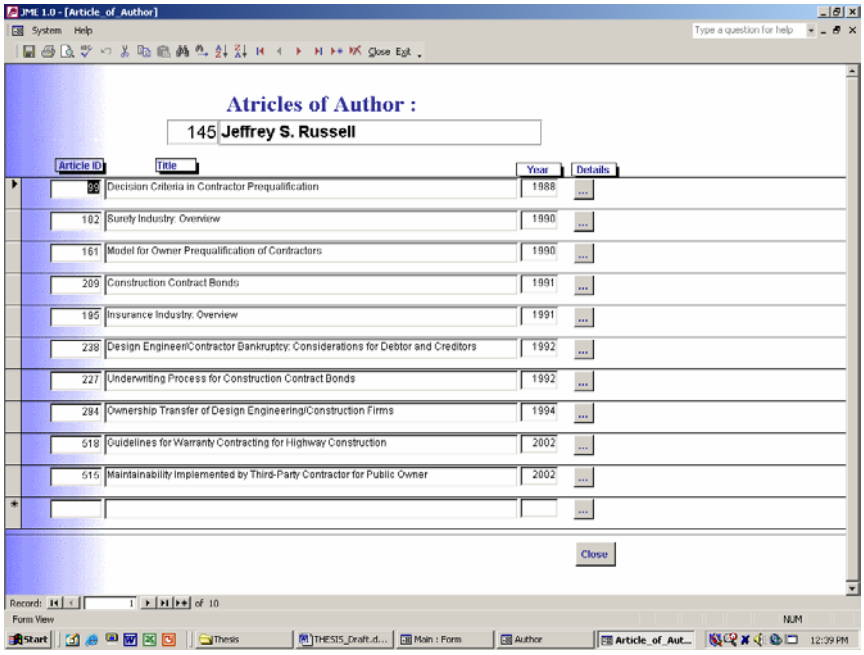

Figure 4-8. ***Articles by a chosen author screen***

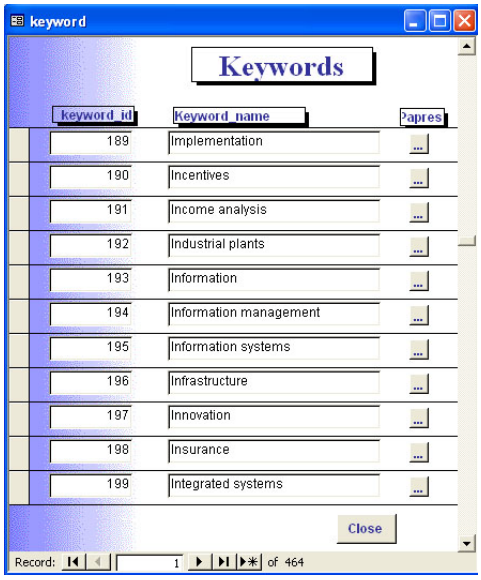

Figure 4-9. *Keywords screen*

In addition, the new database has the ability to display the frequency of the different topics within a particular subject as well as the number of occurrences of keywords in the *JME* articles over the years (Fig. 4.7).

JME 1.0 - [Report042_Genarl_classification_Articles_Years_details : Crosstab Query]

System Help

Close Exit

Classification	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Accounting and financial management	1					1	1	3		2		1				2	1	
Adoption of innovation	1		2	1	1			2	2			1		1				1
Bidding activities and strategies, Tendering practices				1														
Bonding issues (contractor's risk), Insurance and Wor						1												
Business strategy, competitive factors and performan												1	3		2	2	2	1
Corporate programs, eg. TQM					1	2	1	4	5			1		2	3	1		
Firm organization and culture					1	1	2		1		1		2	1	1	2	1	
Inter-firm relationships, Partnerships, joint ventures, s			1		3	2	1				1		2	1				
Management of Information Systems, IT applications				1	1		2			1					1	1	1	
Management of the firm	1	1															1	1
Marketing of services, CM services, as business line	1			2	1		2				1							
Planning of the firm's operations	2	3	2		6	1	2	1	1	3						2	1	
Reengineering and change of firm							1			1	1		2		1	1	1	
Risk evaluation and management, Project selection, s			2				2		1			1	1					

Figure 4-10. *Occurrence of topics over the years*

The data were collected using the ASCE online database and were entered in the newly developed database to record complete references about the *JME*'s articles including the title of the paper, the year of publishing, keywords, the classification of the article, the

author/s, their affiliation, and country of origin. The abstracts were printed separately to be easily read for the purpose of classification. The total number of inputs to the database required approximately 5,000 entries.

4.4 The evolution of the journal content

In order to investigate the evolution of the journal's contents and identify new developments and emerging topics, a thorough analysis of the major subjects was performed by counting the number of related papers. Four main subjects were identified: management and organization of the firm, project management, industry structure and environment, and management of personnel. Table 4.2 shows the percentage of *JME*'s papers classified under each of the 13 subjects over the observed period (1985-2002) that was divided into 3-year sets. The first 9 years (1985-1993) are compared with the last 9 years (1994-2002) of observation to examine trends and patterns. Considerable changes across the eighteen years of publication were noticed.

The subjects are divided into three categories with regard to the frequency of publication in the journal. The first category includes: management and organization of the firm (27%), project management (16%), industry structure and environment (14%), and management of personnel (13%). The second category includes project delivery systems (8%), construction contracts development and administration (6%), construction planning and control (5%), and trends in R & D (4%). Finally the third category encompasses construction time scheduling (2%), construction costing and control (2%), human factors, management of safety (1%), site, material, and equipment management (1%), and construction operations, methods and materials (0%). As stated before, the results of the third category were expected, because the JME's areas of interest are concerned with management rather than with construction issues.

Table 4-1 shows the subjects that more often receive attention by the authors. It also shows the development of the various subjects over the years. For instance, the subject of project management grew remarkably over time, while management of personnel reached its peak in the period of 1991-93 and started declining thereafter. Similarly, the subject of industry structure and environment was at its highest point in the period of 1994-96, but plunged afterwards. Interestingly, the subject of management and organization of firm seems to be evolving through cycles over the years. The first cycle took place in the first 9-year period (1985-93), when it started with 20% and ended with 38%. Similar pattern is found in the second half of the examined eighteen-year period, as the percentage of papers written in this subject started again with 19% and climbed afterwards until it reached 29% by the end of the year 2002.

	Subjects	85-87 %	88-90 %	91-93 %	94-96 %	97-99 %	00-02 %	85-93 %	94-02 %	85-02 %
1	**Construction time scheduling**	0.01	0.03	0.02	0.01	0.02	0.01	0.02	0.02	0.02
2	**Project management**	0.08	0.15	0.13	0.18	0.16	0.25	0.13	0.20	0.16
3	**Construction contracts development and administration**	0.09	0.08	0.02	0.06	0.06	0.05	0.06	0.06	0.06
4	**Management and organization of firm**	0.20	0.26	0.38	0.19	0.26	0.29	0.28	0.25	0.27
5	**Human Factors, Management of safety**	0.01	0.00	0.00	0.01	0.02	0.00	0.00	0.01	0.01
6	**Construction operations, methods and materials**	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
7	**Management of personnel**	0.30	0.15	0.15	0.08	0.07	0.03	0.20	0.06	0.13
8	**Trends in R & D**	0.00	0.08	0.04	0.01	0.02	0.09	0.04	0.04	0.04
9	**Construction costing and control**	0.03	0.02	0.02	0.00	0.04	0.01	0.03	0.02	0.02
10	**Project delivery systems**	0.05	0.10	0.02	0.10	0.10	0.08	0.06	0.10	0.08
11	**Site, material and equipment management**	0.00	0.01	0.02	0.03	0.02	0.00	0.01	0.02	0.01
12	**Industry structure and environment**	0.21	0.10	0.09	0.23	0.18	0.05	0.13	0.16	0.14
13	**Construction planning and control**	0.02	0.03	0.09	0.09	0.06	0.03	0.05	0.06	0.05
	Number of papers per period	87	104	89	79	90	77	280	246	526

Table 4-1. ***Classification of the journal's papers by subject***

The subject of project delivery systems has increased dramatically, from 1 to 9% in the last two years of observation. Differently, the subject of R & D was relatively popular in the late eighties, but declined to 1% during the last decade. Finally, the subject of

construction planning and control reached its peak in the early nineties and then started declining since 1997.

This distribution of subjects was expected if factors such as the nature of the journal's readers, mainly practitioners and the primary focus of the journal are considered. The management of engineering/construction firms is basically concerned with organizational effectiveness and profitability of projects. These firms operate in an industry environment that influences the management of organizations and projects. Firms' operations are also affected by personnel's motivation and performance. It is clear that these four major subjects: management and organization of the firm, project management, industry structure and environment, and management of personnel receive most of the attention by authors.

4.4.1 Changes within the subjects over time

The observed changes in the subjects over the years are reflected in the counts of the topics (shown in Appendix B) that make up each subject. The four major subjects mentioned before were the focus of the analysis. Figure 4.11 shows the evolution of the topics that make up the subject of management and organization of firm. The topics that are the major sources of growth are the following:

- Business strategy, competitive factors and performance
- Reengineering and change of firm

The major sources of decline, instead, are the following:

- Planning of the firm's operations
- Adoption of innovation
- Corporate programs, eg. TQM
- Marketing of services and CM services, as a business line

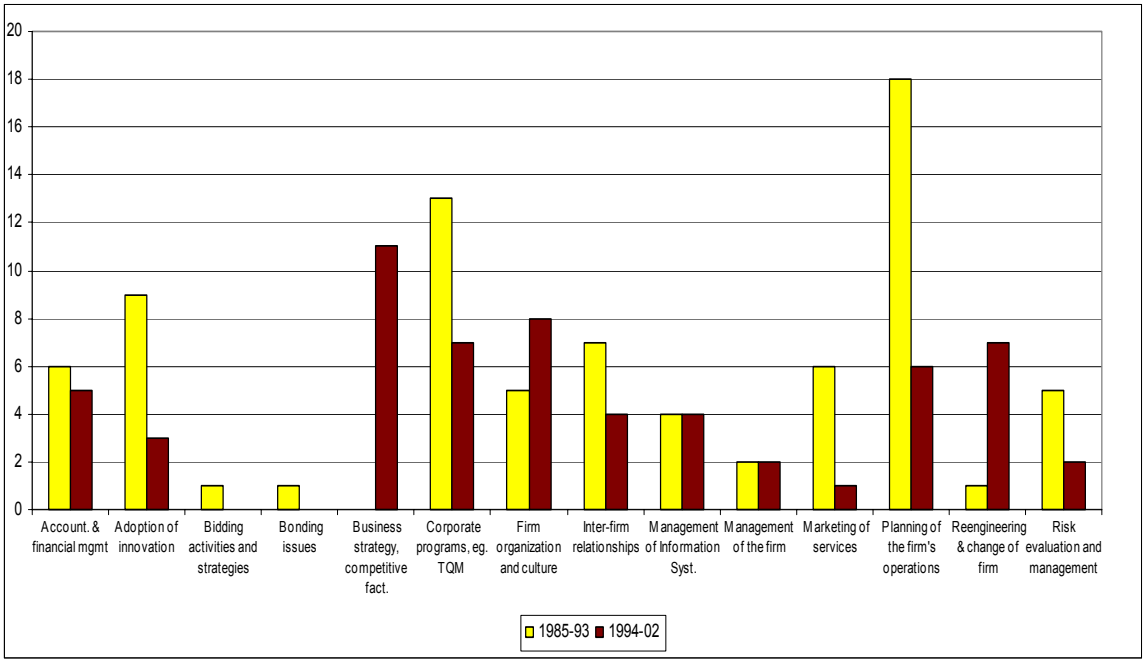

Figure 4-11. ***Management and organization of firm***

Within the subject of management and organization of firm, there has been a shift from topics such as 'adoption of innovation', 'corporate programs', 'marketing of services' and 'planning of the firm's operations' in the first part of the targeted period (1985-93) to a new set of topics that include 'business strategy, competitive factors and performance', 'firm organization', and ' reengineering and change of firm' in the second part of the observed period (1994-02). A possible driver of this change is the proliferation of management theories in the Nineties. After all, the journal would not achieve its ultimate goal of spreading the knowledge among its readers, and be a genuine source for problem solving if there were not a complete awareness of the new management trends and issues in the civil engineering arena. Actually, in the Eighties and the early Nineties, the common theme within the management and organization of the firm subject was the improvement of corporate operations and capabilities, so to increase profitability. From

the mid Nineties to date managerial attention has shifted to the survival of engineering/construction firms in a fiercely competitive global market.

Project management

As shown in Figure 4.12, the major sources of growth in the subject of project management are the following topics:

- Partnering and cooperation, leadership and negotiation
- Project quality planning and control

Differently the major sources of decline are:

- Project planning and organization, Project models, Project scope definition.

In this subject, topics like 'partnering and cooperation' and 'project quality planning and control' are the main drivers of change in the second part of the observed period (1994-02), which again reveals the highly competitive nature of this era. In these days engineering and construction firms pursue all management avenues, including merging with other co-operations and implementing quality planning and control techniques, to achieve their strategic goals.

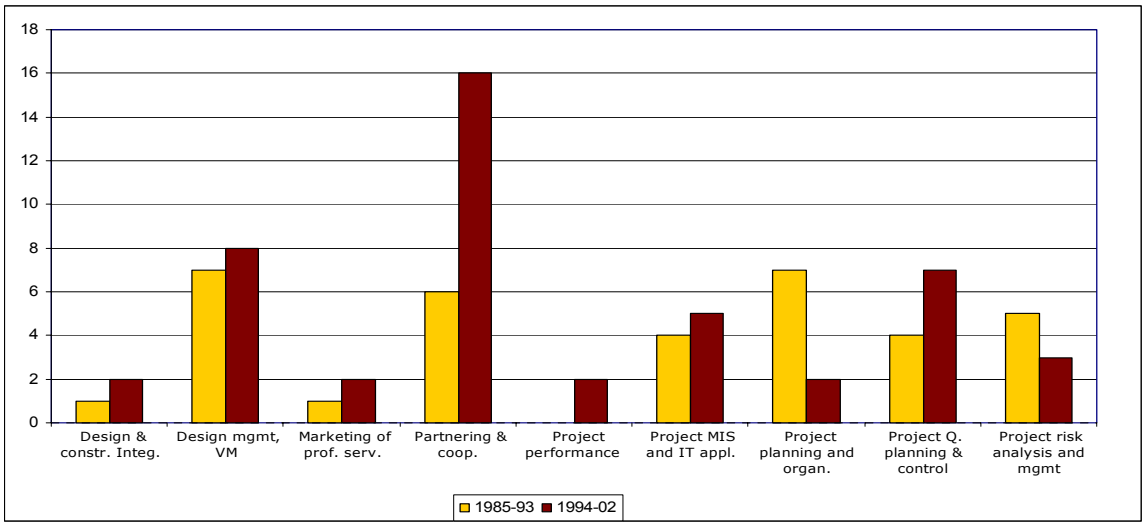

Figure 4-12. ***Project management***

Management of personnel

In considering the topics pertaining the subject of management of personnel one clear trend is their decline in terms of counts. Although this subject is one of the four most popular ones within the *JME*, it has lost a great deal of attention in the last decade. A possible reason is that the subject was extensively investigated in the period of 1985-93, as shown by the number of papers. In that period the most popular topics were 'factors influencing human performance, motivation, teamwork, leadership', 'performance improvement, quality circles', and 'engineering manager's characteristics and recruitment issues'. On the other hand, topics such as 'communication, learning and training', 'engineering managers characteristics and recruitment issues', and 'performance improvement, quality circles' were characterized by the biggest decline in the years of 1994-02.

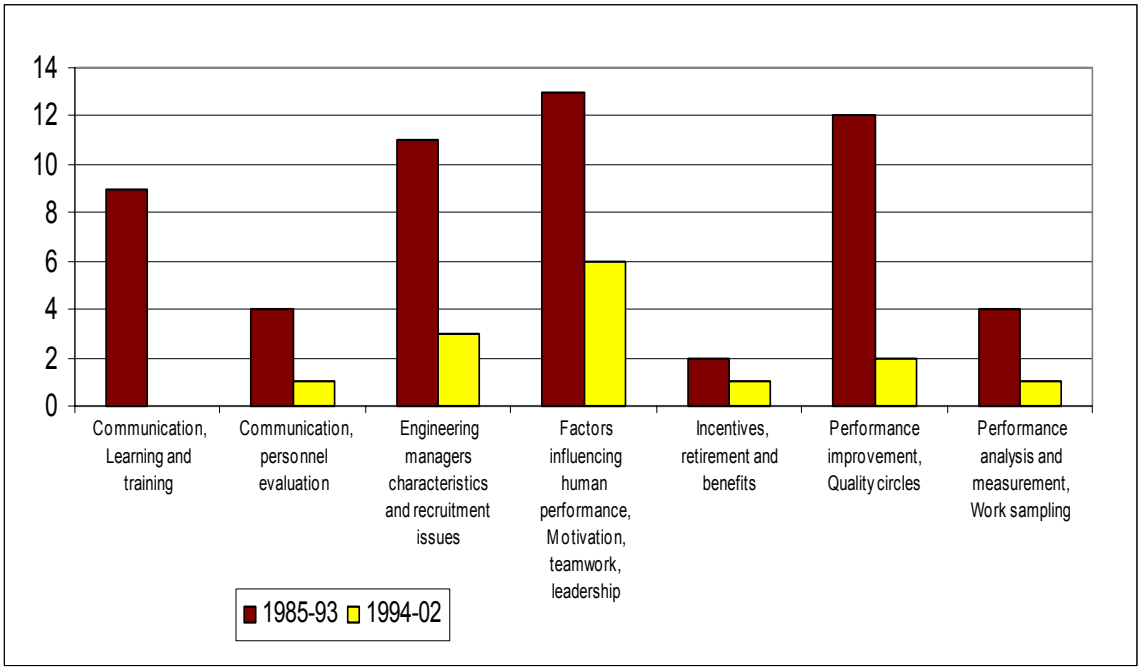

Figure 4-13. ***Management of personnel***

Industry structure and environment

Figure 4.14 shows that 'education and professional development' is the thrust of the subject, industry structure and environment. For a long time, this topic has been hotly debated with a focus on the role and responsibilities of universities and academic institutions, employers, employees, and construction industry environment as a whole. The number of papers written in all these years suggests that this topic continues to receive attention by scholars.

The number of published papers in two other topics, 'domestic industry issues and practices' and 'codes, standards, and information systems' is noticeably growing from 2 papers to 4 and 6 respectively in the observed period (1994-02).

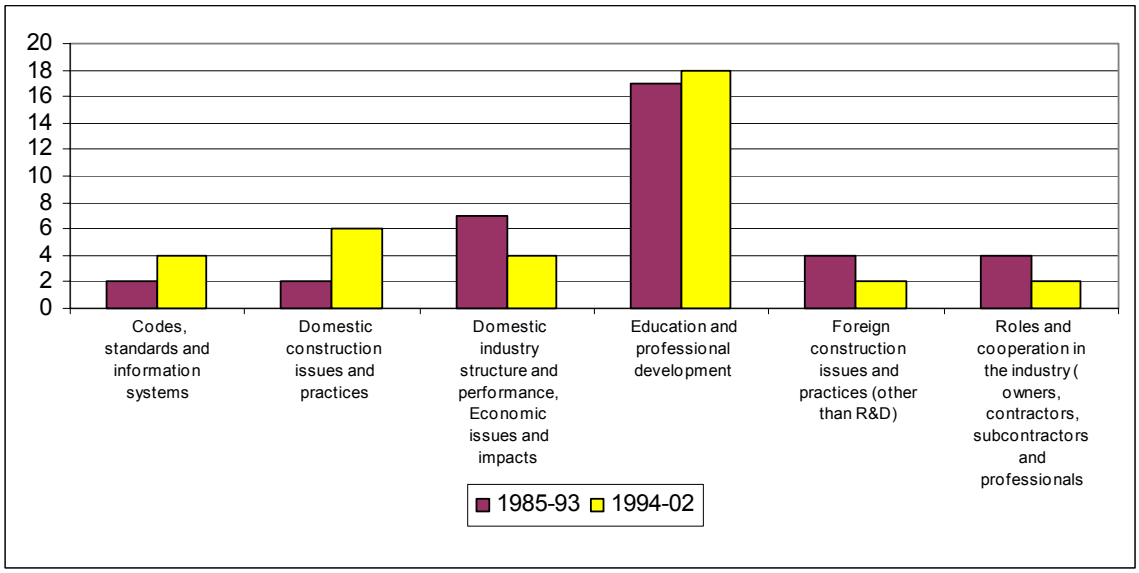

Figure 4-14. ***Industry structure and environment***

4.5 Changes in the use of the keywords over the years

Because keywords are considered to be descriptors of the topics in which they appear, it was essential to investigate the patterns of occurrence as well as the evolution of the keywords over the years. The following four figures present the development of the top

sixteen keywords in the most prominent subjects of the *JME* papers, management and organization of firm, project management, management of personnel, and industry structure and environment. The targeted period 1985-2002 is equally divided into three phases: 1985-90, 1991-96, and 1997-02.

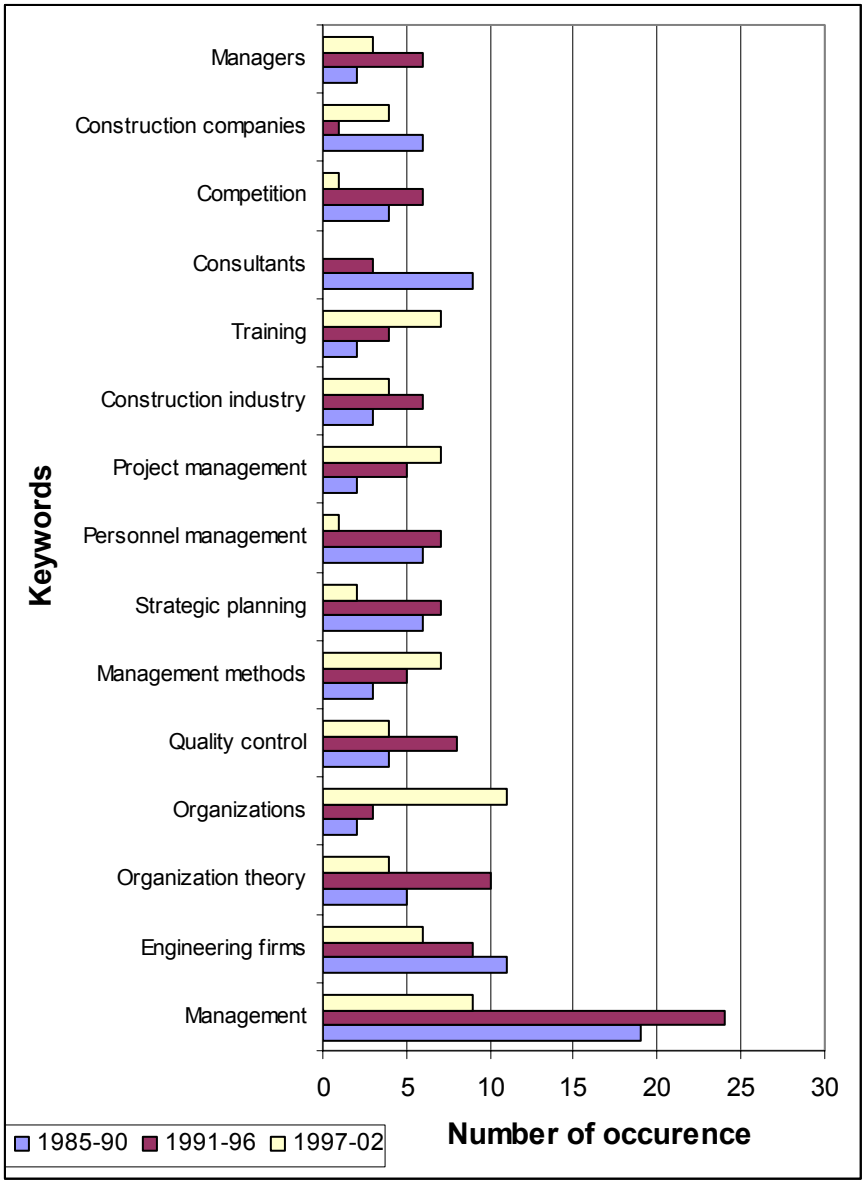

Figure 4-15. ***Keywords associated with the subject of "Management and organization of the firm"***

Figure 4-15 shows the evolution of the keywords, related to the subject “Management and organization of firm” over the years. The majority is present during the whole period with the exclusion of “consultants” which disappeared in the third phase (1997-02). Training, project management, management methods, and organizations were the most frequently used keywords. The number of “management”, “organization theory”, “strategic planning”, “personnel management”, and “competition” dropped in the final phase (1997-02) after reaching their peak in the second phase (1991-96). Similarly, “managers” and “construction industry” reaches a maximum in the 1991-96 period.

In order to define links between keywords and the subjects they describe, a new feature was added to the database that lists all the keywords and co-words (keywords that are repeatedly indexed with a particular keyword (Courtial & Law, 1989)) associated in the papers. For each subject, the most frequent keyword (in terms of occurrence) was chosen to investigate other keywords that are closely linked to it, how do they tie different concepts and ideas together, and how these clusters of words change over time, which can be regarded as a semantic representation of knowledge structures (Tijssen & Van Raan, 1994) . The keyword “management”, the most frequent keyword in the subject of “management and organization of firm” is shown in Table 4.2, which lists all its associated words throughout the observed period. The words that appeared only once within any of the six-year period were not considered. In the first phase words such as “consultants”, “engineering firms”, and “Personnel management” show a strong relationship with the word “management”. In the second phase (1991-96), the words “personnel management”, “quality control” and “organization theory” are strongly associated with the word “management”. Finally, in the third phase (1997-02), the word “construction” as well as “government agencies” emerge. It should be noticed that

keywords such as “teamwork” and “performance evaluation” are always associated with the keyword “management” throughout the whole period (1985-02).

Keyword: Management					
1985-90		**1991-96**		**1997-02**	
Consultants	6	Quality control	9	Construction	4
Engineering firms	6	Organization theory	8	Government agencies	3
Personnel management	6	Personnel management	7	Organizations	3
Competition	4	Human behavior	5	Performance evaluation	3
Innovation	4	Professional development	5	Training	3
Professional practice	4	Professional practice	5		
Strategic planning	4	Project management	5		
Technology	4	Construction industry	4		
Communication	3	Engineering firms	4		
Engineering education	3	Management methods	4		
Leadership	3	Strategic planning	4		
Marketing	3	Teamwork	4		
Organization theory	3	Conflict	3		
Performance	3	Consultants	3		
Performance evaluation	3	Corporate planning	3		
Professional development	3	Engineers	3		
Profits	3	Innovation	3		
Project management	3	Leadership	3		
Quality control	3	Managers	3		
		Planning	3		
		Working conditions	3		

Table 4-2. ***Keywords in the subject of Management and organization of firm***

Figure 4-16 shows the top sixteen keywords associated with the subject of project management and their change over the years. The keywords are divided into three

groups. One group is characterized by the existence of the keywords over the complete study period (1985-2002) whether in a form of growth or decline in occurrence over the years. The other group includes keywords that stopped appearing since the mid Nineties; and finally the group of keywords that emerged after the year 1996. In the first group, keywords such as “project management, partnerships, project planning, construction industry, and construction” grew gradually in terms of number of occurrence over the years, while the keyword “management” was going in the opposite direction. “Organizations” remained unchanged for the first two thirds of the whole period, but increased noticeably in the remaining third one (1997-02). Meanwhile, the chart illustrates that keywords, such as “professional practice and quality control” are the most prominent in the period of 1991-96 compared to “decision making” which had the least number of occurrences in the same period.

In Table 4.3, the keywords that were associated with the most frequent keyword “project management” are recorded. The latter was linked to the word “scheduling” in the mid Eighties until the early Nineties. Afterwards, most frequent association is with“ quality control, management, construction, and consultants”. However, words like “construction industry, partnerships, conflict, and organizations” joined the list of co-words associated with “project management”.

Engineering and construction firms have realized that the survival in today’s highly competitive global market requires additional external efforts such as “partnerships” together with the internal efforts of implementing “quality control”.

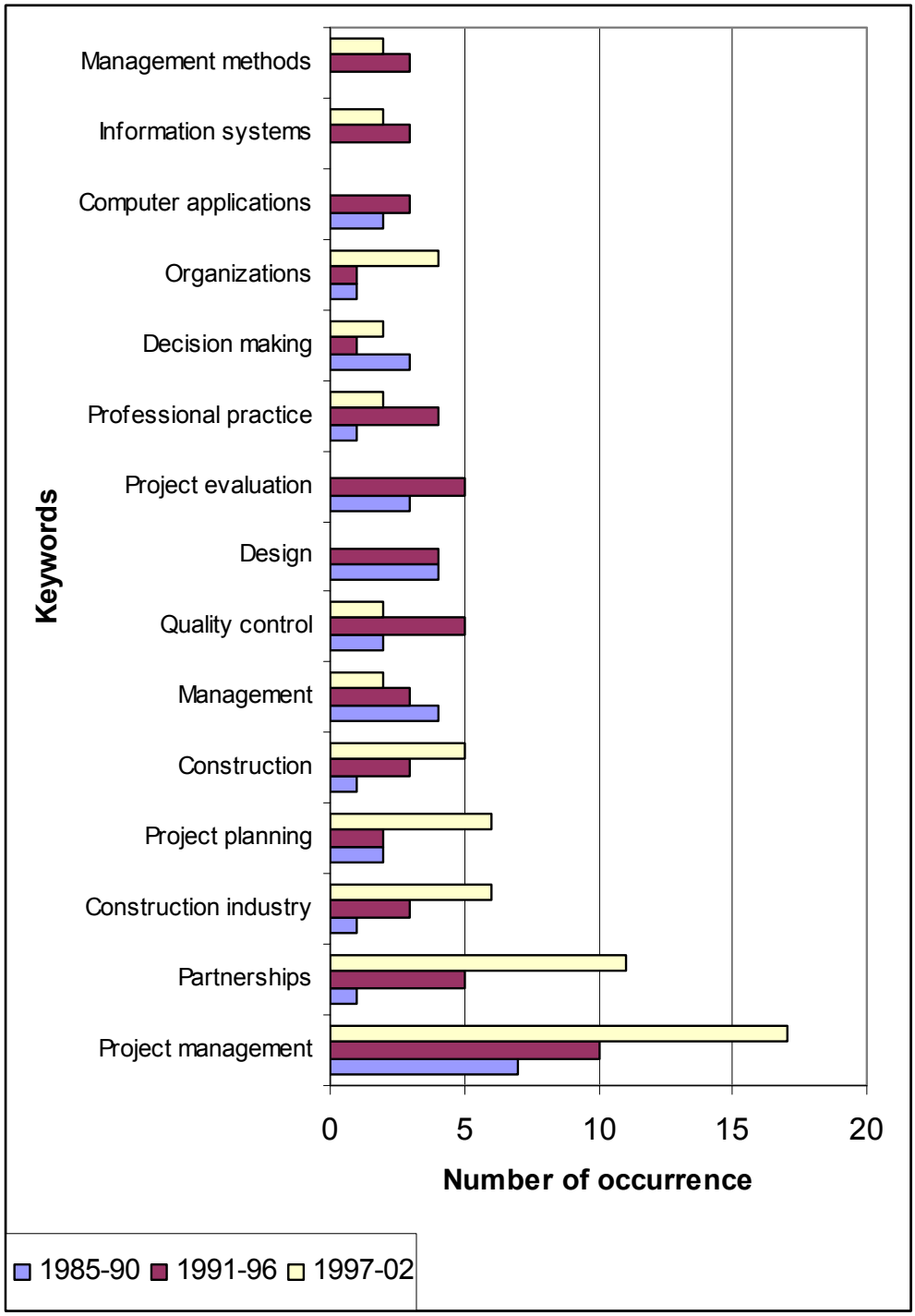

Figure 4-16. ***Keywords associated with the subject of "Project management"***

Keyword: Project management					
1985-90		**1991-1996**		**1997-02**	
Scheduling	4	Quality control	6	Construction industry	7
Communication skills	3	Management	5	Construction	6
Cost control	3	Construction	4	Partnerships	6
Management	3	Consultants	4	Performance evaluation	5
Project evaluation	3	Construction management	3	Conflict	4
Project planning	3	Contractors	3	Cost control	4
		Contracts	3	Managers	4
		Management methods	3	Organizations	4
		Managers	3	Teamwork	4
		Planning	3	Delivery	3
		Project planning	3	Leadership	3
		Scheduling	3	Project planning	3
		Teamwork	3	Quality control	3

Table 4-3. ***Keywords in the subject of Project management***

As far as the keywords associated with the subject “management of personnel” are conserned (Fig.4-17), there is one group of keywords, such as “project management”, “leadership”, “performance evaluation”, “management”, “productivity”, and “personnel management”, that declined gradually in terms of occurrence over the years. The number of counts of “Teamwork”, “management methods”, and “motivation” remained steady for the phase of 1985-1996, and then decreased notably in the last period of observation. In the case of “professional development” the rate of occurrence was relatively high, dropped remarkably in the second section (1991-96), and then regained its momentum again in 1997-2002. “Communication skills” is characterized by the same pattern except for the fact that this keyword totally disappeared in the second phase of observation (1991-96). “Training” and “employee relations” are no longer present after the year 1996.

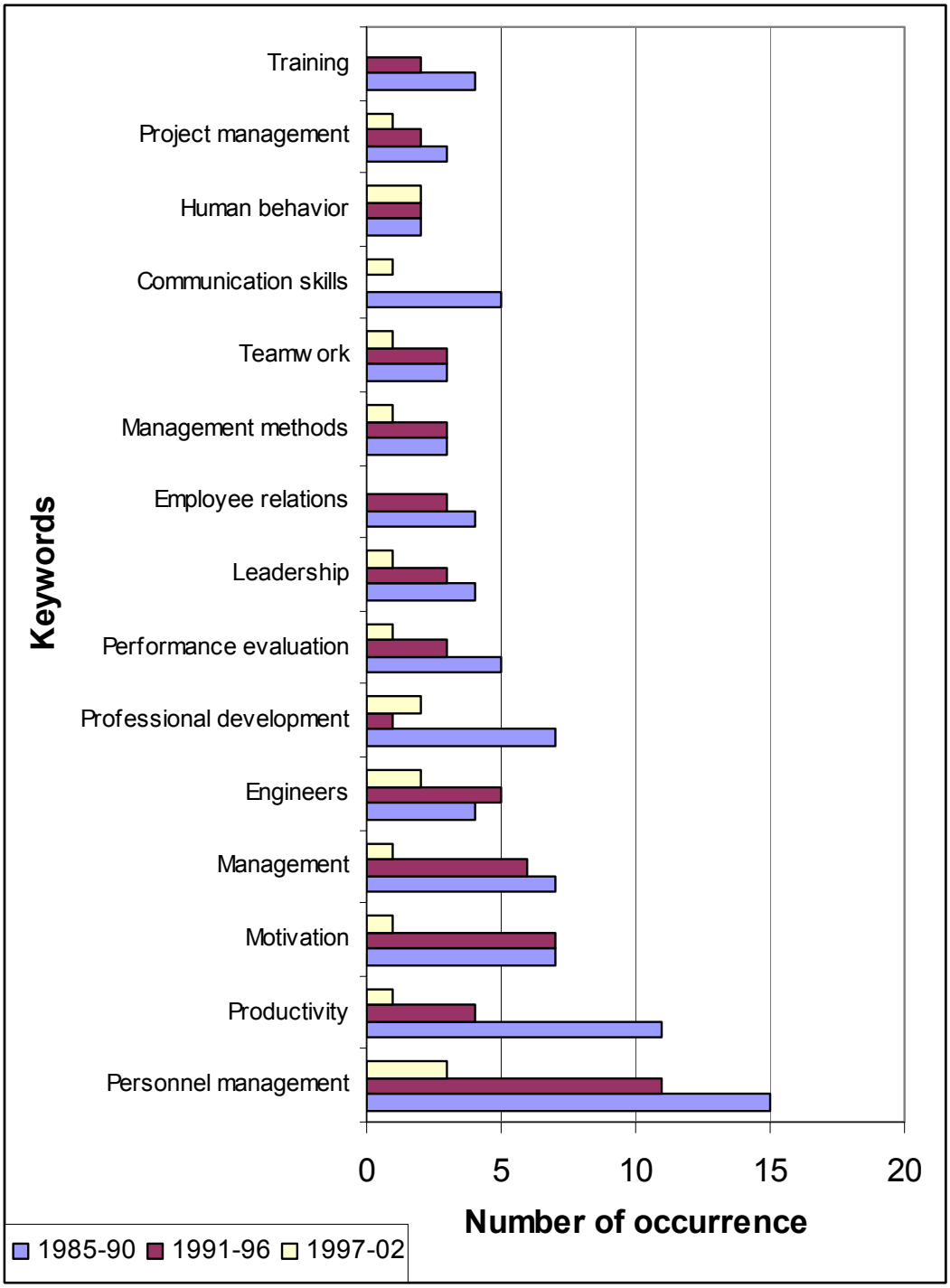

Figure 4-17. Keywords *associated with the subject of "Management of personnel"*

Keyword: Personnel management					
1985-90		**1991-96**		**1997-02**	
Management	6	Management	7	Benefits	1
Professional development	6	Motivation	5	Compensation	1
Communication skills	3	Employees	4	Consultants	1
Construction management	3	Human behavior	4	Employment	1
Engineering firms	3	Management methods	4	Engineering profession	1
Engineers	3	Training	4	Human factors	1
Motivation	3	Conflict	3	Minority groups	1
Performance evaluation	3	Employee relations	3	Professional development	1
Professional personnel	3	Employment conditions	3	Professional personnel	1
Teamwork	3	Engineers	3	Project management	1
		Managers	3		
		Quality control	3		

Table 4-4. ***Keywords in the subject of Management of personnel***

Table 4-4 shows how tight some keywords are bound to the keyword “personnel management”. In the 1985-90 period, “management” and “professional development” were strongly interconnected with “personnel management”. New words such as “motivation, employees, human behavior, management methods, and training” appear in the second period (1991-96). Although the number of keywords linked to “personnel management” decreased dramatically due to the decline in the number of papers focusing on this subject, some words such as “benefits, compensation, employment, engineering profession, and minority groups” emerged in the last period of observation (1997-02).

Finally, Figure 4-18 shows the pattern of keywords within the subject of “Industry structure and environment”. It was not until 1991 when “continuing education” and “decision making” appear for the first time, while “civil engineering” and “engineering firms” are absent from 1991 until 1996. On the other hand, keywords such as “engineering education”, “professional development”, “training”, “construction industry”, “management”, “project management”, “construction”, “quality control”, “leadership”,

"design", and "standards" are present during the whole observed period, but in different patterns of occurence.

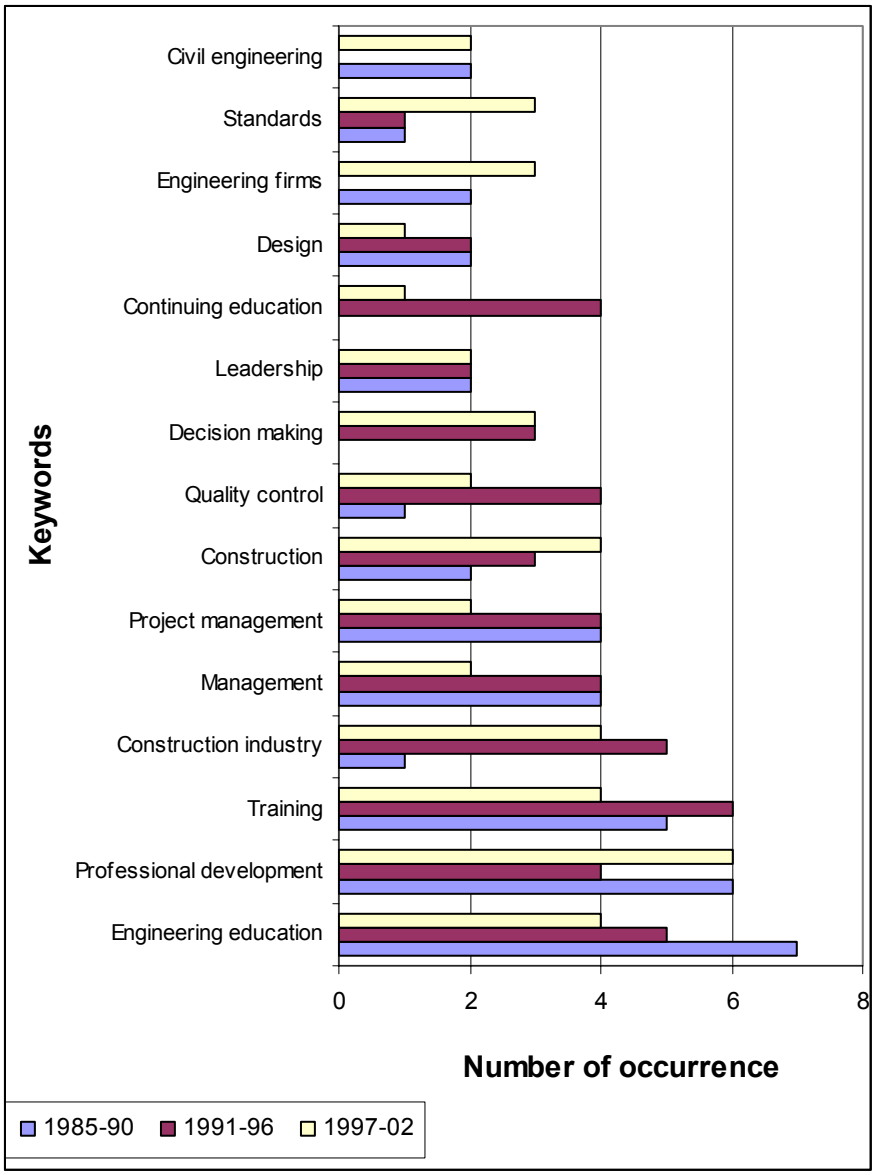

Figure 4-18. ***Keywords associated with the subject of "Industry structure and environment"***

Table 4-5 reflects the co-words analysis of the last subject "Industry structure and environment" with particular reference to the association with the word "engineering education". The following observations can be made. "Training" is closely interconnected to the previous keyword throughout the whole period (1985-02). "Management" and

"competition" appear in the first and second period (1985-1996), while "communication" and "students" appear only in the first period. "Professional practice", "continuing education", "international factors", and "telecommunication" are added to the list of words in the 1991-96 period, whereas "curricula" and "professional development" were only added in the last period (1997-02).

Keyword: Engineering education					
1985-90		**1991-96**		**1997-02**	
Management	3	Professional practice	3	Curricula	2
Training	3	Training	3	Professional development	2
Civil engineering	2	Communication	2	Training	2
Communication	2	Competition	2		
Competition	2	Continuing education	2		
Leadership	2	International factors	2		
Students	2	Management	2		
		Telecommunication	2		

Table 4-5. ***Keywords in the subject of Industry structure and environment***

4.5 Research methods used in the published papers

The investigation of the most prevailing research tools used in the *JME* papers is an indicator of the type and nature of the subjects published in the journal. Research methods are divided into quantitative and qualitative approaches. "Quantitative approaches seek to gather factual data to study relationships between facts and how such facts and relationships accord with theories and the findings of any research executed previously" (Fellows and Liu, 1997). On the other hand, "qualitative approaches seek to gain insights and understand people's perception of "the world", whether as individuals or groups" (Fellows and Liu, 1997). In this regard, an attempt was made to find out the distribution of quantitative and qualitative research approaches to the studies published in the JME. By focusing on the top four subjects: project management, management and organization of firm, management of personnel, and

industry structure and environment, which together encompass 70% of the journal's contents, a complete list of the keywords that occurred within these subjects was obtained from the database. Successively, the search was narrowed to keywords that reflect quantitative approaches to research. Table 4-6 shows these keywords as well as their number of occurrence in the top four subjects.

Having counted the total number of keywords, the percentage of the quantitative approaches was calculated for each subject separately. The results, which varied from 2% to 5% (Table 4-6), show that the most research methods used in the papers published in the JME are of the qualitative nature. This finding supports the thesis that the management knowledge is basically gained through experience and can not be fully formalized. However, some authors tried to utilize quantitative approaches to management-oriented research in the attempt to link management and engineering issues.

Research Methods related Keywords	Project management	Management & organization of firm	Management of personnel	Industry structure & environment
Case reports	2	8	0	3
Models	2	3	1	0
Questionnaires	0	3	0	2
Surveys, data collection	0	3	3	5
Algorithms	0	2	0	3
Comparative studies	0	2	1	0
System analysis	0	2	0	0
Uncertainty analysis	0	2	0	0
Computer models	0	1	0	0
Expert Systems	0	1	0	0
Markov chains	0	1	0	0
Monte Carlo method	0	1	0	0
Statistical analysis	1	1	0	0
Three-dimensional models	0	1	0	0
Measurement	1	0	1	0
Quantitative analysis	1	0	0	0
Reports	1	0	0	0
Sensitivity analysis	1	0	1	0
Simulation models	0	0	1	0
Cost analysis	0	3	0	0
Total number of occurrence	9	34	8	13
Total number of keywords	386	690	297	720
Percentage of RM keywords	**2%**	**5%**	**3%**	**2%**

Table 4-6. ***Research methods used in published papers***

4.6 Contribution of academic institutions

The institutional origins as well as the magnitude of contributions to the *JME* articles were part of the objectives of this chapter. Table 4-7 shows that almost two thirds of the papers' authors have academic affiliations. Practitioners, military, and government agencies produced the rest of the papers. Yet, it should be mentioned that this was not the case at the mid Eighties when the journal was founded. In the 1985-87 period the contributions by practitioners reached 53% of the total, those by academicians and government agencies were 31% and 14% respectively.

In addition, the average number of authors per paper has increased from 1.3 in 1985-1987 to 2.32 in 2000-2002 period.

	85-87	88-90	91-93	94-96	97-99	00-02	85-93	94-02	85-02
Education	0.31	0.43	0.38	0.52	0.60	0.66	0.37	0.59	0.48
Industry	0.53	0.50	0.51	0.38	0.28	0.29	0.51	0.32	0.41
Military	0.02	0.04	0.02	0.05	0.03	0.00	0.03	0.03	0.03
Government agencies	0.14	0.04	0.09	0.06	0.09	0.04	0.09	0.06	0.08
Average author/paper	1.30	1.38	1.47	1.24	1.99	2.32	1.38	1.85	1.62

Table 4-7. Breakdown of the journal's contributors

In general, 132 academic institutions were involved throughout the whole 1985-2002 period with a production of approximately 293.25 weighted papers. A weighted paper is a fraction dependent upon the number of authors (Betts and Lansley, 1993). The top 30 publishing universities yielded almost 171.17 weighted papers, approximately 58% of the total number of weighted papers produced by all academic contributors. Table 4-8 shows that there are 8 foreign institutions among the top 30 list. The number of papers produced by five of universities such as, King Fahd Univ. of Petrochemicals and Minerals, Hong Kong Polytechnic, Univ. of Hong Kong, Univ. of Wolverhampton, and City Univ. of Hong Kong has dramatically increased, while the production rate of the

Univ. of Sydney, Nanyang Tech. Univ, and the Univ. of New Brunswick has considerably decreased in the 1994-2002 period.

The same table also shows the leading universities in terms of number of weighted papers over the observed period. The top five universities are the University of Wisconsin, Texas A&M University, Stanford University, Purdue University, and the University of Maryland at College Park. A closer look at the table shows that the contribution of the universities varies over the years.

	Universities 1-15	**85-02**	**85-93**	**94-02**		**Universities 16-30**	**85-02**	**85-93**	**94-02**
1	Univ. of Wisconsin	14.00	7.00	7.00	16	Univ. of Cincinnati	5.00	4.00	1.00
2	Texas A&M Univ., College Station	12.33	3.00	9.33	17	Univ. of Wolverhampton	4.67	0.00	4.67
3	Stanford Univ	10.00	4.50	5.50	18	Univ. of Alaska	4.50	2.00	2.50
4	Purdue Univ	9.00	6.50	2.50	19	Univ. of California, Berkeley	4.50	0.50	4.00
5	Univ. of Maryland at College Park	8.00	6.00	2.00	20	Univ. of Sydney	4.50	3.00	1.50
6	Iowa State Univ	7.00	6.00	1.00	21	North Carolina State Univ	4.00	3.00	1.00
7	Univ. of Hawaii at Manoa	7.00	1.00	6.00	22	San Jose State Univ	4.00	1.00	3.00
8	Colorado State Univ	6.50	3.50	3.00	23	United States Military Acad	4.00	0.00	4.00
9	Univ. of Washington	6.50	3.50	3.00	24	Univ. of Colorado	4.00	1.00	3.00
10	King Fahd Univ. of Pet. and Minerals	6.00	1.00	5.00	25	Univ. of New Mexico	4.00	1.00	3.00
11	Univ. of Texas at Austin	6.00	3.00	3.00	26	City Univ. of Hong Kong	3.50	0.00	3.50
12	Hong Kong Polytechnic	5.67	1.00	4.67	27	Nanyang Tech. Univ	3.50	3.50	0.00
13	Clemson University	5.50	2.00	3.50	28	Univ. of New Brunswick	3.50	2.50	1.00
14	Univ. of Hong Kong	5.50	0.00	5.50	29	Pennsylvania State Univ	3.33	1.33	2.00
15	Massachusetts Inst. of Technology	5.17	0.00	5.17	30	Case Western Reserve Univ	3.33	3.33	0.00
						Total weighted papers/period	174.50	74.16	100.34

Table 4-8. ***Top 30 publishing universities by weighted papers***

Some universities, such as the University of Wisconsin, Stanford University, Colorado State University, and the University of Washington produce a constant amount of papers over the years. The rate of contribution by some other institutions, such as Texas A&M University, University of Hawaii, King Fahd University, and the Massachusetts Institute of

Technology increased dramatically since 1994. Quite the opposite is found in other universities, such as Purdue University, University of Maryland, and Iowa State University, which contributed generously in the 1985-1993 period, but not as much afterwards.

Table 4.9 contains the overall distribution of each subject according to the percentage of weighted papers published by universities. Each subject is given a number according to its code in the classification system.

University	Subjects												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Air Force Inst. of Tech., OH				1%					40%				
American Univ. of Beirut			8%	1%									
Aristotle Univ. of Thessaloniki		2%											
Arizona State Univ.		2%											
Auburn Univ				1%			3%					2%	
Carnegie-Mellon Univ		2%								5%		2%	
Case Western Reserve Univ	83%			1%				7%					6%
Chalmers Univ. of Technol.												2%	
City Univ. of Hong Kong		5%								5%			
Clarkson Univ		2%											
Clemson Univ		5%	8%	1%							20%		6%
Colorado State Univ				7%								5%	
Concordia Univ				1%									
Deakin Univ.		2%											6%
Duke Univ., NC											20%		
Florida Intl. Univ.		2%											
George Mason Univ.											20%		
George Washington Univ.		2%		1%									
Georgia Inst. of Technol.				2%				7%				2%	
Heriot-Watt Univ				1%									
Hong Kong Polytechnic		5%								7%		5%	
Hong Kong Univ. of Sci. and Technol		2%											
Illinois Inst. of Tech		2%		1%								2%	
Illinois State Univ							3%						
Indonesia Inst. of Technol.		2%											
Iowa State Univ				5%			5%					5%	11%
Jacksonville Univ							3%						
King Fahd Univ. of Pet. and Minerals			8%		20%					5%		5%	
King Saud Univ., Riyadh										2%			
Lafayette Coll				2%									
Lesley Coll							3%						
Loughborough Univ. of Tech		2%	8%										6%
Louisiana Tech Univ				1%									
Massachusetts Inst. of Technol		2%		2%						11%			
McMaster Univ											20%		
Milwaukee School of Engineering				1%									

Table 4-9. ***Distribution of knowledge among universities***

University	Subjects												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Monash Univ.													6%
Nanyang Tech. Univ		2%							20%	2%		2%	
North Carolina State Univ		5%		1%									
North Dakota State Univ										2%		2%	
Northeastern Univ							3%	7%					
Northwestern Univ							3%	7%					
Nova Southeastern Univ.				1%									
Oklahoma State Univ.							3%						
Oregon State Univ		2%					3%						
Pennsylvania State Univ		5%								5%			
Pepperdine Univ., Malibu, CA				1%						2%			
Polytechnic Univ., Brooklyn				1%						2%		2%	
Portland Community Coll												2%	
Princeton Univ.				1%									
Purdue Univ		3%		1%			3%	13%		9%	20%		
Rensselaer Polytechnic Inst												2%	
Rutgers-The State Univ. of New Jersey		2%											6%
Saitama University		2%											
San Diego State Univ				1%			3%						6%
San Jose State Univ				1%			3%			2%		2%	
Southeastern Univ. , AZ				1%									
St. Mary's Univ								7%					
Stanford Univ		6%		8%									
State Univ. of New York at Buffalo								7%					
Stevens Inst. of Tech		2%											
Technion-Israel Inst. of Technology												2%	
Texas A&M Univ., College Station		3%	8%	6%			3%					5%	22%
U.S. Air Force Academy		2%					3%						
U.S. Military Acad												2%	
United States Military Acad				2%								5%	
Univ. Católica de Chile										2%			
Univ. of Manchester										2%			
Univ. of Akron, Akron												2%	
Univ. of Alabama in Huntsville				1%									
Univ. of Alaska		2%		1%			3%					5%	
Univ. of Alberta							5%	7%					
Univ. of Arizona							3%						
Univ. of Atma Jaya Yogyakarta							3%						
Univ. of California, Berkeley		2%		1%				7%		2%			6%
Univ. of Cape Town		2%											
Univ. of Cincinnati				2%				7%				5%	6%
Univ. of Colorado								7%		7%		2%	
Univ. of Connecticut												2%	
Univ. of Delaware							3%						
Univ. of Dundee,Scotland												2%	
Univ. of Florida							3%						
Univ. of Hawaii at Manoa				6%			5%						
Univ. of Hong Kong		5%	8%	1%									6%
Univ. of Illinois at Urbana-Champaign		2%					3%						
Univ. of Kentucky		2%		1%								2%	

Table 4-9. (Continued) ***Distribution of knowledge among universities***

University	Subjects												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Univ. of Lagos		2%											
Univ. of Leeds			8%							2%			
Univ. of Louisville				1%									
Univ. of Maryland at College Park				5%			8%					2%	
Univ. of Massachusetts				1%									
Univ. of Miami							3%						
Univ. of Michigan					20%								
Univ. of Missouri					20%								
Univ. of Moratuwa		2%											
Univ. of Nebraska												2%	
Univ. of New Brunswick	17%			2%			3%		20%				
Univ. of New Mexico		2%		1%								2%	6%
Univ. of New South Wales				2%	20%								
Univ. of Oklahoma										2%			
Univ. of Salford										2%			
Univ. of South Carolina			8%										
Univ. of Southampton		2%		1%									
Univ. of Southern California				1%			3%						
Univ. of Southern Maine				1%									
Univ. of Southern Queensland		2%											
Univ. of Sydney		5%	8%	1%						2%			
Univ. of Tech., Sydney							3%					2%	
Univ. of Texas				1%									
Univ. of Texas at Austin		6%					3%			2%			
Univ. of Texas at El Paso												2%	
Univ. of Virginia		2%		1%									
Univ. of W. Florida												2%	
Univ. of Washington			8%	1%	20%		3%	7%	20%				6%
Univ. of Waterloo								7%					
Univ. of Western Ontario								7%					
Univ. of Wisconsin				3%			3%			11%		5%	
Univ. of Wolverhampton		3%	8%	1%			3%			2%		2%	
Univ.of Manchester										2%			
Univ.of Salford				1%									
Utah State Univ							3%						
Vanderbilt Univ.				1%									
Virginia Polytechnic Inst.			8%				3%						
Virginia Tech		3%										2%	
Number of weighted papers	2.5	54.9	7.8	77.8	5.0	0.0	33.6	10.3	3.5	39.0	3.5	37.8	14.2
Number of contributing universities	2	42	12	52	5	0	33	14	4	25	5	35	14
Index of concentration	**1.25**	**1.3**	**0.65**	**1.5**	**1**	**0**	**1.02**	**0.74**	**0.88**	**1.56**	**0.7**	**1.08**	**1.01**

Table 4-9. (Continued) ***Distribution of knowledge among universities***

The table shows the research interests of these universities and therefore the repositories of knowledge in the discipline of engineering management. In addition, it offers an indication of new emerging topics that might be of interest in the near future in the engineering management discipline. The table also displays the tendency of some universities to concentrate on specific subjects, which reflects their area of expertise, for

example, Stanford University produced 6% and 8% of the weighted papers in the areas of “project management” and “management and organization of firm” respectively. Finally, the index of concentration, the number of weighted papers classified under a given subject divided by the number of contributing universities is shown in the table. This index gives an indication of the concentration of knowledge in subjects, whether it is distributed among a relatively large number of universities or not. For example, as shown in Table 4-9, the index of concentration of the subjects “project management” (2), “management and organization of firm” , “management of personnel” (7), “Project delivery systems” (10), and “industry structure and environment” (12) is more than 1. It reflects that these areas of research were explored by several universities. On the contrary, the index of concentration of the subjects “contracts development and administration” (3), “trends in R&D” (8), “construction costing and control” (9), and “site, material, and equipment management” (11) is less than 1, which in turn indicates that the investigation of these areas were limited to a smaller number of universities.

In order to find out the causes of this phenomenon, further investigation into the size of the faculty in the considered universities as well as their areas of expertise was conducted. The size of faculty is not a relevant factor in the amount of produced papers; it is rather the enthusiasm and motivation of particular faculty members that count in the end. For instance, the University of Wisconsin, that leads all the other universities in the amount of weighted papers, has just two members: Jeffery Russell and Awad Hanna. Moreover, Jeffery Russell, who contributed from 1988 until 2002, wrote almost 70% of these papers produced by his university. Another example is the Texas A&M University with five faculty members. The number of published papers started to grow significantly from the time Stuart Anderson joined the Civil and Environmental Engineering Department in 1994. He had written almost 75 % of these papers. As far as Stanford University is concerned, C. B. Tatum was a major contributor to the *JME* particularly in

regard to the topic of “Innovation”. This author specializes in technological innovation in construction. His research interests include mechanisms and strategies for innovation in construction and for design/construction integration. Professor Tatum worked for 15 years on heavy and industrial construction projects before joining the Stanford faculty in 1983 (http://www.stanford.edu/dept/cee/faculty/tatum/). Later, another colleague, Martin Fisher contributed with papers concerning the management of information systems issues, which are his main research interests. Raymond Levitt, who studies artificial intelligence techniques and their application to engineering and management activities, publishes his papers in refereed journals other than the *JME*. Likewise, no papers by Boyd C. Paulson, a faculty member at Stanford since 1974, were found in the *JME*. This also explains the fact that Stanford University is represented in the JME in two subjects only.

Univ. of Washington, Texas A&M Univ., College Station, Purdue University, and the Univ. of Wolverhampton are the institutions involved in several subjects (6-7), while universities, such as Stanford University, Univ. of Hawaii at Manoa, Colorado State University, North Carolina State University, United States Military Academy, City Univ. of Hong Kong, and Pennsylvania State University limit their interests in only two subjects. The fact that the University of Washington is one of the most prolific universities with a wide distribution of interests is explained by the fact that the faculty consists of four members, Dunston, Hinze, Jahren, and Palmer. The research concentration (in terms of subjects) ranges from a minimum in the subject of “Construction time scheduling” (1 university) to a maximum in the subject of “Management and organization of firm”(23 universities).

4.7 Cooperation in writing papers

This section reflects the author's intellectual curiosity about collaborative efforts in the published papers. Another feature was added to the database to list all the papers that were written by authors with different affiliation throughout the observed period. The results are presented in the following chart (Fig. 4-19). Collaborative efforts between authors of both academic and industrial background are increasing.

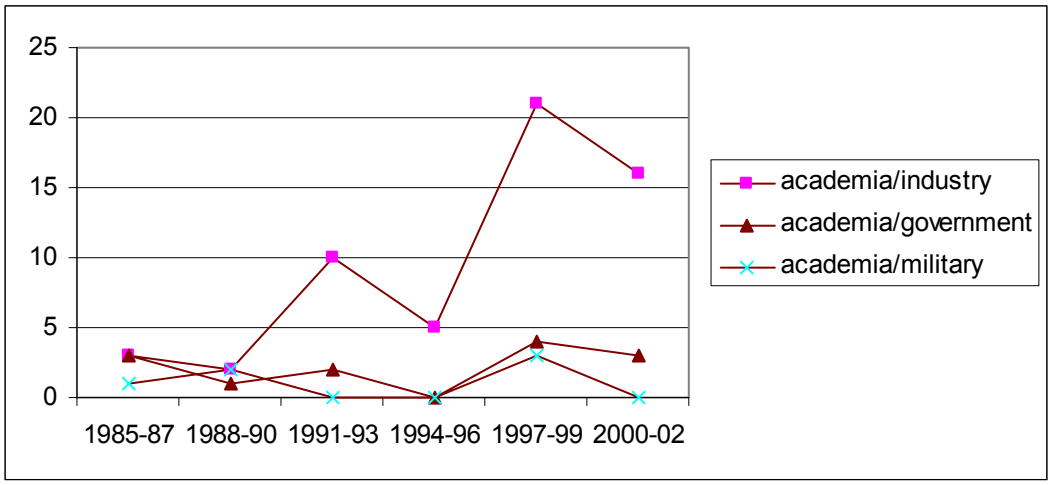

Figure 4-19. ***Collaborative efforts between authors of different affiliation***

This is indeed a promising sign for the enhancement of practical knowledge. It should be noticed that the consideration of authors with an industrial affiliation is limited to those with no previous connections to their academic partners (e.g. former students).

4.8 Conclusion

The analysis of the JME's contents in terms of subjects, topics, keywords, research methods, and academic contributions shows the following findings.

Subjects

Four main subjects yield the higher number of papers throughout the observed period:

- Management and organization of the firm (27%)

- Project management (16%)
- Industry structure and environment (14%)
- Management of personnel (13%)

These subjects are the kernel of the engineering management discipline as it is represented in the journal.

Topics

The pattern of the publications within the four main subjects has changed throughout the observed period. As far as the subject of “management and organization of firm” is concerned, the common theme that existed in the Eighties and the early Nineties was the enhancement of firms’ operations and improvement of its capabilities to increase or at least maintain profitability. Since the mid Nineties this theme has evolved with the application of new management theories that focus on the inter-firm relationships of firms. Their success or survival depends on collaborative undertaking with clients and competitors. In the subject of “project management” topics like ‘partnering and cooperation’ and ‘project quality planning and control’ are the main drivers of publications in the second part of the observed period (1994-02). This interest reveals the highly competitive nature of construction market. Currently, engineering/construction firms seek all avenues, including mergers and strategic alliances, and quality planning and control, to achieve their strategic goals.

The number of papers in the subject, “management of personnel” has been decreasing over the years. Although this subject ranks as one of the top four most popular ones, it has lost a great deal of attention in the last decade. A possible reason is that the subject was exhausted with a large amount of publications encompassing almost all its topics in the 1985-93 period.

As far “industry structure and environment” is concerned, the thrust of this subject was “education and professional development”. For a long time, this topic has been hotly

debated with reference to the role and responsibilities of universities and academic institutions, employers, employees, and the construction industry environment as a whole. The number of papers written in all these years suggest that this topic continues to receive attention by scholars.

Keywords

The use of keywords has changed from period to period. Some new words have emerged, for example “human behavior” and “professional development” within the subject of “management and organization of firm”. Others have disappeared, such as “communication skills” in the subject of “project management”. On the contrary, others remain strongly linked to the subject over the years, such as “training” in the subject of “industry structure and environment.

Research methods

The analysis shows that the most prevailing research methods used in the published papers are of the qualitative nature. This result was expected, because management theories are difficult to be formalized and quantified. Some authors, however, try to use quantitative approaches in management-oriented studies in the attempt to link management theory and engineering science.

Academic contributions

The study shows that almost two thirds of the journal’s authors are academicians. Practitioners, military, and government agencies produced the rest of the papers.

The study displays the tendency of some universities to concentrate on specific subjects, which reflect their area of expertise. This gives an indication of the concentration of knowledge in certain subjects, whether it is distributed among a relatively large number

of universities or not. The size of the faculty is not a significant factor in the number of published papers by universities. Production is rather the result of the enthusiasm and motivation of a particular faculty member.

Collaborative efforts between authors of both academic and industrial background are increasing. This is indeed a promising sign for the enhancement of practical knowledge. It is an indication that the research contents are bridging the gap between theory and practice.

5 Conclusions and direction of future work

The main purpose of this study was to map the structure of the construction engineering and management discipline and its contents, as it results from the analysis of selected referred journals and textbooks, to identify the most prevailing research areas and to trace their evolution over the years. The analysis was accomplished through a review of the literature in construction engineering and management books as well as two of leading academic journals, and through a bibliometric study of the contents of the ASCE *Journal of Management in Engineering* as a case study of the CEM refereed journals. Bibliometric studies play an important role in developing means for visualizing and analyzing a discipline's structure, its nature, descriptors, and stage of development.

The analysis of the selected literature suggests that the construction engineering and management discipline consists of two major areas: the management of projects and that of firms, both of engineering and construction nature. The first area focuses on the planning and execution of a project's engineering and construction activities by applying different techniques of project management to optimize cost, schedule, quality, and the allocation of project's resources. On the other hand, the second area focuses on the firms, their organizational structure, operations, and supporting functions, and interactions with both internal and external environmental issues.

The main subjects of the management of projects focus on the roles of designers, project managers and contractors, and their activities namely planning, cost estimating, scheduling, design management, value engineering, constructability, cost control, project control, construction contract supervision and administration, testing and turnover of the facility and operations and maintenance (O&M) of the building.

On the other hand, the main subjects of the management of firms are "organization long-term stability and growth", "engineering organization structure", "accounting and financial

management" and "engineering managers' responsibilities", "strategic planning and management", "communication" and "effective public relations", "education and professional development", "marketing of professional services", "management of information systems", and "quality management".

The findings suggest that the term construction engineering and management encompasses a broader range of issues, well beyond its traditional focus on the technological and organizational aspects of a construction project. Over the years the scope of the term, in fact, has been extended to include the management of firms. The extension of the meaning of the term was expected because the performance of projects is directly correlated with the performance of the firm that undertakes them.

The analysis of the *JME*'s contents in terms of subjects, topics, keywords, research methods, and academic contributions shows the following.

Subjects

Four main subjects yield the higher number of papers throughout the observed period, management and organization of the firm (27%), project management (16%), industry structure and environment (14%), management of personnel (13%). In terms of growth, the subject of project delivery systems is the fastest growing subject among the thirteen subjects of the classification system.

Topics

With the emergence of the topics of "design/build" and "project delivery systems and contracts" in the mid Nineties, the number of papers published in this subject has increased dramatically.

In the Eighties and the early Nineties the most common themes, within the subject of "management and organization of firm", were the enhancement of firms' operations and

capabilities. Since the mid Nineties this theme has evolved with the application of new management theories that focus on the inter-firm relationships. Their success or survival depends on collaborative undertaking with clients and competitors.

The noticeable presence of topics like ‘partnering and cooperation’ and ‘project quality planning and control’ within the subject of “project management” as main drivers of publications in the second part of the observed period (1994-02), reveals the highly competitive nature of today’s construction market. Currently, engineering/construction firms seek all avenues, including mergers and strategic alliances, and quality planning and control, to achieve their strategic goals.

The decreased number of published contributions on the subject of “management of personnel” over the years, despite its overall top ranking in the *JME*, shows that recently this subject lost significant interest among authors. A possible explanation is that the subject was widely discussed with a large amount of contributions covering almost all its aspects in the 1985-93 period.

The thrust of the subject of “industry structure and environment” was the topic of “education and professional development”. This topic has been hotly debated for a relatively long time with emphasis on the role and responsibilities of universities and academic institutions, employers, employees, and the construction industry environment at large. The constant number of papers published over the years suggests that this topic is still quite popular among authors.

Keywords

The use of keywords, which reflects conceptual relations between the topics of a given subject and its evolution process, has changed over time. The subject of “management and organization of firm” has evolved from being strongly related to engineering firms and personnel management in the 1985-90 period, to a focus on intra-organizational

issues, such as quality control and organization theory, in the 1991-96 period, and finally to inter-organizational issues in the 1997-02 period. As far as the subject of project management is concerned, its relationships with other descriptors has shifted from "scheduling" to "quality control" and "construction industry". The subject of personnel management has showen strong relations with "management" and "professional development" at the beginning of the observed period. In the early Nineties, "motivation" was linked to the word "personnel management".

Research methods

The analysis of the research methods used in the *JME's* papers supports the argument that management theories are difficult to be formalized and quantified. It shows that the percentage of the quantitative approaches varied from 2% to 5% with regard to the four considered subjects. Most of the published papers use research approaches of qualitative nature. Some quantitative approaches are used in management-oriented studies in the attempt to link management theory and engineering science.

Academic contributions

Two thirds of the journal's authors are academicians. Practitioners, military, and government agencies produced the rest of the papers. Some universities have the tendency of concentrating on specific subjects, which reflects their area of expertise. This gives an indication of the concentration of knowledge in certain subjects, whether it is distributed among a relatively large number of universities or not.

The size of the faculty is not a significant factor in the number of published papers by universities. Publication productivity is rather the result of the enthusiasm and motivation of a particular faculty member.

Collaborative efforts between authors of both academic and industrial background are increasing. This is indeed a promising sign for the enhancement of practical knowledge. It is expected that the published topics will raise the interests of a broader range of readers and hopefully bridge the gap between theory and practice that generally characterizes the contents of academic journals.

Directions of future research

Since the *JME* is mainly concerned with the managerial aspects of engineering and the *JCEM*'s focus is on technological and construction issues, additional studies of the *JCEM*'s contents and other international journals, such as the Journal of Construction Management and Economics (CM&E) should be conducted for complete mapping of the discipline. CM&E is the leading European journal that targets all researchers in academic and research organizations. The development of a database that includes the contents of these journals would be the basis for developing a more comprehensive mapping of the discipline.

"Data mining", which derives its name from the similarities between searching for valuable information in a large database, can be applied to the database of these journals. Data mining, *the extraction of hidden predictive information from large databases*, is a powerful new technology with great potential that helps to focus on the most important information in the databases. Its tools predict future trends and behaviors, allowing policy makers to make proactive, knowledge-driven decisions. They can also answer questions that traditionally were too time consuming to resolve. The automated, prospective analyses offered by data mining move beyond the analyses of past events provided by retrospective tools typical of decision support systems. They scour databases for hidden patterns, finding predictive information that experts may miss because it lies outside their expectations (Thearling, 1997).

Data mining, therefore, can be used for predicting the future evolution of the CEM discipline and at the same time finding new or neglected areas of research.

Data mining techniques can be implemented rapidly on existing software and hardware platforms to enhance the value of existing information resources. Actually, this technique has become an active area of research, attracting people from several disciplines including: database systems, statistics, information retrieval, pattern recognition, AI/machine learning, and data visualization (Chaudhuri, 1998).

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APPENDIX I. Classification method by subject and topic

1. Construction time scheduling	**2. Project management**
Time scheduling and control techniques	Project planning and organization
Modeling and simulation applications	Project models
Critical Path method	Project scope definition
Pert and Gert	Project quality planning and control
Comparisons of CPM and others	Project performance and feedback
LOB, linear scheduling	Design management
Network planning and analysis	Value engineering and management
Time duration estimate, variability	Pre-design and design estimates
Deterministic time scheduling techniques	Design and construction integration
Other non-deterministic time scheduling techniques	Project MIS and IT applications
Cost/time scheduling optimization	Database and communication systems
	Project risk analysis and mangement
	Partnering and cooperation, leadership and negotiation
3. Construction contracts development and administration	**4. Management and organization of the firm**
Contractual clauses and risk allocation	Firm organization and culture
Incentives and disincentives	Re-engineering and change of firm
Insurance issues	Management of the firm
Plans and specifications	Planning of the firm's operations
QA/QC, performance based specifications	Business strategy, competitive factors & performance
Claims and disputes, negotiation and resolution	Risk evaluation and management (project selection)
Liability issues	Inter-firm relationships (Partnerships, joint ventures, subcontracting)
Construction delays	Accounting and financial management
Management of contractual clauses and contingencies	Corporate programs, e.g. TQM
Staffing for contract administration	Bidding activities and strategies, practices
Inspection and testing	Bonding issues (Contractor's risk)
Responsibilities of project team members	Insurance and worker compensation
Contract performance	Management of Information Systems
	IT applications
	Marketing of services
	Adoption of innovation
5. Human factors	**6. Construction operations, methods and materials**
Management of safety and labor relationships	Foundations and temporary retention walls, excavation
Safety programs, management	Formwork, shoring and temporary structures
Safety performance and indicators	Tunnels
Accident data	Bridges
Injury analysis and cost	Marine related facilities
Organized labor related issues	Buildings
	Other facilities
	Applications of construction automation and robotics
	Construction failures
	Materials, properties and admixtures, design
	Construction of facilities
	Construction methods
	Installation procedures
	Placement of concrete and related materials
7. Management of personnel	**8. Trends in R & D**
Craft force characteristics and recruitment issues	Research and development issues, research needs

Incentives, personnel evaluation)	Innovation and technology transfer, analysis & mechanisms
Factors influencing human performance (motivation, teamwork, learning, training, leadership, communication)	Construction automation and robotics, trends
Management of human-machines interfaces	New material and component technologies, trends
Performance analysis and measurement	IT based integration and communication + GPS
Work sampling	Overview of AI applications
Performance improvement	Classification systems of advanced or new technologies
Quality circles	Evaluation of new technology (industry level)
	Foreign R&D practices
9. Construction costing and control	**10. Project delivery systems**
Deterministic estimating techniques, procedures	Analysis and selection criteria (delivery systems and contracts)
Non-deterministic estimating techniques	Design/Build
Cost modeling, cost data	Evaluation of capital investments
Life cycle costing	Financial evaluation of contractors, failures
Time/cost considerations	Project delivery systems with owner financing
Cost control, project cash flow	Project delivery systems with private financing (BOT)
Cost performance	Selection and evaluation of bids and proposals
	Selection and evaluation of contractors
11. Site, material and equipment management	**12. Industry structure and environment**
Conditions assessment (site, subsoil, existing structures)	Classification and information systems
Site preparation and layout	Codes, standards and laws
Work area planning, space use	Data about business failures
Mobilization and logistics	Domestic construction issues and practices
Demolition and decommissioning	Domestic industry structure and performance (economic
Preservation of historic sites and buildings	indicators)
Earthmoving	Education and professional development
Environmental contamination issues and management	Environmental issues in the industry (energy issues)
Waste disposal and management	Foreign construction issues and practices
Noise and pollution control	Industrial relations, union and non-union construction
Equipment costing, selection and management	Roles and cooperation in the industry (owners, professionals,
Equipment maintenance and replacement	contractors and subcontractors)
Equipment operations and performance	
Material and component management and handling	
Bar coding	
Field data collection, management and information systems	
Production plants	
13. Construction planning and control	
Planning of the construction process (phasing, selection	
of procedures and methods, WBS, factors affecting planning)	
Evaluation of established construction technologies	
Approaches to modularization and prefabrication	
Resources planning and allocation	
IT applications, simulation	
Process modeling(static)	
Process simulation for planning	
Constructability analysis	
Quality programs and control, TQM	
Inspections	
Production control systems, standards and criteria	
Organization and use of project information	

APPENDIX II. Classification of the journal's papers by topic

Topic	85-93	94-02	85-02
1. Construction time scheduling			
Comparisons of CPM and others	2	0	2
Construction time scheduling	1	0	1
Cost/time scheduling optimization	0	2	2
Time scheduling and control techniques	3	1	4
Total	6	3	9
2. Project management			
Design and construction integration	1	2	3
Design management, Value engineering and management, Pre-design and design estimates	7	8	15
Marketing of professional services	1	2	3
Partnering and cooperation, leadership and negotiation	6	16	22
Project performance and feedback	0	2	2
Project MIS and IT applications, Databases and communication systems	4	5	9
Project planning and organization, Project models, Project scope definition	7	2	9
Project quality planning and control	4	7	11
Project risk analysis and management	5	3	8
Total	35	47	82
3. Construction contracts development and administration, Contract formulation and documentation			
Claims and disputes, negotiation and resolution, Construction delays	7	9	16
Construction contracts development and administration, Contract formulation and documentation	1	0	1
Contract performance	1	0	1
Contractual clauses and risk allocation, Incentives and disincentives, Insurance issues	2	3	5
Liability issues	5	0	5
Management of contractual clauses and contingencies	1	1	2
Responsibilities of project team members	0	1	1
Staffing for contract administration, Inspection and testing	1	0	1
Total	18	14	32
4. Management and organization of firm			
Accounting and financial management	6	5	11
Adoption of innovation	9	3	12
Bidding activities and strategies, Tendering practices	1	0	1
Bonding issues (contractor's risk), Insurance and Worker compensation	1	0	1
Business strategy, competitive factors and performance	0	11	11
Corporate programs, eg. TQM	13	7	20
Firm organization and culture	5	8	13
Inter-firm relationships, Partnerships, joint ventures, subcontracts	7	4	11
Management of Information Systems, IT applications	4	4	8
Management of the firm	2	2	4
Marketing of services, CM services, as business line	6	1	7
Planning of the firm's operations	18	6	24

Reengineering and change of firm	1	7	8
Risk evaluation and management, Project selection, selection of new projects	5	2	7
Total	78	60	138
5. Human Factors, Management of safety and labor relationships			
Injury analysis and cost	0	1	1
Labor related issues (project level)	1	0	1
Safety issues and programs, Project environment issues (if related to safety)	0	2	2
Total	1	3	4
6. Construction operations, methods and materials			
Construction failures	0	1	1
Total	0	1	1
7. Management of personnel			
Communication, Learning and training	9	0	9
Communication, personnel evaluation	4	1	5
Engineering managers characteristics and recruitment issues	11	3	14
Factors influencing human performance, Motivation, teamwork, leadership	13	6	19
Incentives, retirement and benefits	2	1	3
Performance improvement, Quality circles	12	2	14
Performance analysis and measurement, Work sampling	4	1	5
Total	55	14	69
8. Trends in R & D			
Construction automation and robotics, trends	1	0	1
Evaluation of new technology (industry level)	4	1	5
Innovation and technology transfer, analysis and mechanisms	2	2	4
IT based integration and communication + GPS	1	0	1
Overviews of AI applications	1	0	1
Research and development issues, research needs	3	1	4
Total	12	4	16
9. Construction costing and control			
Cost control, project cash flow, cost performance	5	1	6
Deterministic Estimating techniques, procedures	1	0	1
Life cycle costing	1	4	5
Total	7	5	12
10. Project delivery systems and purchasing of construction services			
Bonding issues	2	0	2
Design/Build	1	10	11
Evaluation of capital investments, project financing issues	2	1	3
Financial evaluation, failures	1	0	1
Project delivery systems and contracts: Analysis and selection criteria	2	7	9
Project delivery systems with private financing, e.g., BOT	4	4	8
Selection and evaluation of bids and proposals	1	2	3
Selection and evaluation of contractors	3	5	8

Total	16	29	45
11. Site, material and equipment management, Mobilization and logistics			
Demolition and decommissioning	0	1	1
Environmental contamination issues and management, Waste disposal and management, Noise & pollution	3	1	4
Equipment maintenance & replacement	0	1	1
Material and component management and handling, Bar coding, Field data collection	0	1	1
Total	3	4	7
12. Industry structure and environment			
Codes, standards and information systems	2	4	6
Domestic construction issues and practices	2	6	8
Domestic industry structure and performance, Economic issues and impacts	7	4	11
Education and professional development	17	18	35
Foreign construction issues and practices (other than R&D)	4	4	8
Roles and cooperation in the industry (owners, contractors, subcontractors and professionals	4	2	6
Total	36	38	74
13. Construction planning and control			
Constructability analysis	0	1	1
Evaluation of established construction technologies	1	2	3
Planning of construction process, Selection of procedures and methods, WBS, Factors affecting construction	4	1	5
Process modeling (static)	0	1	1
Quality programs and control, TQM, Inspections	7	7	14
Resources planning and allocation, IT applications, simulation	1	2	3
Total	13	14	27