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Application of Knowledge Management in Construction Production Management

Hamzah Abdul Rahman
Civil Engineering Department, University of Malaya, Malaysia

M.A. Berawi
Civil Engineering & Construction Management Department,
Oxford Brookes University, United Kingdom

Abstract
Knowledge Management (KM) addresses the critical issues of organizational adoption, survival and competence in the face of an increasingly changing environment. Knowledge is rapidly becoming the most important asset of every organization. Construction is no exception. The ability to manage and exploit knowledge will be the main source of competitive advantage for the construction industry of the future. In that role, knowledge management will improve production management and avoid or minimize losses and weakness that usually come from poor performance, and will increase the competitive level of a company and its ability to survive in the global marketplace. This paper is concerned with the improvement of production management theory through the application of some core principles in the construction context. The best production practices world-wide have a common core. The cores principles investigate are the "reduction of cycle time", "reduction of variability", "increased transparency" and "development of continuous improvement into the process". The fundamental rational underlying these principles is the concept of flow where production is seen as composed of waiting, transporting, inspecting and transformation (processing) activities. According to this concept, transformation activities are the only ones that actually add value. Hence, all other activities should be reduced or eliminated from the flow whilst increasing the efficiency of transformation activities. The paper suggests the development of a knowledge management model in production management appropriate for the construction industry. It is anticipated to serve as a foundation for wider applications of knowledge management in other sectors of the construction industry. The paper also aims at gathering data on the philosophy and practice of construction firms pertaining to the utilization and management of tacit and explicit knowledge. Of priority the paper is set to identify and develop a service and production system based on knowledge management.

Keywords
Knowledge Management, Production Management, Construction Project, Technology Process.

1. Introduction
The powerful combination of intelligence and knowledge is a key factor towards globalization (Abdul Rahman & Berawi, 2002a). The pace is accelerating, territories are widening and contacts are multiplying on a worldwide scale. There are many drivers for knowledge management, including the need to learn from past experience, the need to retain key staff and their skills and the need to become more efficient at delivery value to the client or end-user. Failure to adapt and adjust to systems that would increase efficiency in management may result in project delays and monetary losses. Another consequence of a faulty management system is unsatisfactory quality of services and products. Over

time companies will find themselves losing their competitive advantage. There are abundant examples in construction industry where delays are causing substantial financial losses to the contractors and at the same time much inconvenience to their clients. A closer scrutiny of the situation reveal factors associated primarily with the management system. Of major importance are (i) unspecific work description (ii) non-compliance to standards (iii) low quality services and products, and (iv) ethical issues. These are not isolated factors but are linked to the larger environmental factors – social, economic, administrative and physical. Apart from the conditions that affect the demand and supply forces in the construction industry, a significant contributing factor has to do with the human factor, namely, with how the firms manage the tacit and explicit knowledge at their disposal. A case in point is the use of the Standard Forms of Contract by the parties involved - protocols that require contractors to indicate the flow of both implicit and explicit information, but which they failed to do right (Abdul Rahman & Berawi, 2001). If such practices continue, the construction industry will not be able to sustain their activities. In the face of globalization and the information technology, construction firms can no longer afford to loose their business. Gone are the days where physical assets are the key to competitive advantage. The key factors in the present age lie in the firms' ability '… to create, transfer, utilize and protect difficult to imitate knowledge assets' (Teece, 2000). Within the context of the construction industry, the challenge now is not to manage the problem of production, as in the old economy, but in the knowledge economy it is 'to build, combine and integrate the knowledge assets of many thousands of individuals – a much more formidable task (Nonaka & Teece 2001). Knowledge management involves the identification and analysis of available and required knowledge, and the subsequent planning and control of actions to develop knowledge assets so as to fulfill the organizational objective. Knowledge assets are the knowledge regarding markets, products, technologies and organizations that a business owns or needs to own and that enable the business to generate profits. Managing money is the focus of most project management "how to" books and management software. A good job cost system monitors the "projected" cost at completion throughout the course of construction. This is different from an after-the-fact accounting of the cost that does not use all of the knowledge available. The to-date costs, cost to complete, and projected costs at completion are, all three, important indicators of the financial status of a project that reflect quality.

In production management, a combination of past theories and newer theories has produced a complex portfolio of different strategies for action. The principal group of theories comes as a combination of Just-in-Time (JIT) and Total Quality Control (TQC) with other theories such as Visual Management, Total Productive Maintenance, Re-engineering and Value Based Management. However, the boundaries of these theories are not always clear and, quite often, there is an overlap among the main ideas underlying them. In many cases, this situation results in unproductive semantic disputes, leading to confusion and conflict among researchers, consultants and practitioners. Those trying to get agreement and, thus, consensus between these theories often waste precious resource and brainpower trying to resolve these conflicts. Furthermore, the miscellany of terms and definitions used in current production management theories worsens this situation. Indeed, truly new ideas may be misunderstood, and not applied, due to the difficulties in communicating their actual meaning (Santos, A., 1999). Sadly, this situation is not confined to production management field alone. Construction industry is under heavy pressure to improve its present practices since it now has to compete for investments with other, increasingly sophisticated and competitive, industries. Some of the most important sources of this pressure as follows: low productivity (Hill, 1992; Egan, 1998), economic and social demands (VTT, 1997), high levels of environmental excess (Browne, et.al., 1995) and construction performances and value (Barrie & Paulson, 1992).

2. Knowledge Demand and Supply

According to Lillrank (1995), knowledge is more effectively transferred when people demand it (demand driven knowledge) as opposed to situations when knowledge is pushed at them, or simply supplied without being wanted (supply driven knowledge), as illustrated on Figure 1. In the present context, to understand the multi-purpose ideas that constitute best production practices is a necessary step for enabling effective learning. Fortunately, many theories have already translated a great number of effective production practices into multi-purpose ideas that can be the basis for better knowledge transfer. Nevertheless, there is a clear lack of integration, appropriate structuring and clear definition of existing ideas within a common theoretical framework.

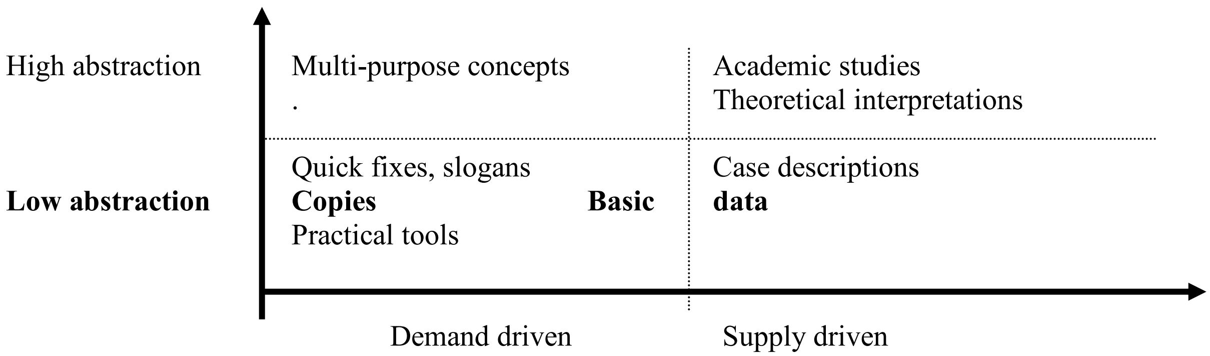

Figure 1: Model of Transfer Channels (Lillrank, 1995)

Deploying technology to successfully organise and share knowledge will remain important. Organisational knowledge is distinct from individual knowledge. A knowledge development cycle in an organisation consists of knowledge creation, knowledge adoption, knowledge distribution, and knowledge review and revision phases (Ganesh, 2000). The challenge for a company is to create an environment that demands and allows generation and processing of information continually. The importance of knowledge sharing, and the integration between individuals in a company can increase not only the company's learning capability but also its knowledge. "Value added" in most construction industries today is in the form of knowledge, not stuff. The extended human innovation-creation and CIT has been quick to promote the notion that knowledge management not only lowers cost structures and increases strategic flexibility but also facilitates knowledge creation and utilization, especially for firms competing in dynamic environments (Nonaka and Takeuchi, 1995; Malhotra, 2001). The ability and performance of a company to adapt to changes at the right time is important for a company to survive and to maintain a competitive advantage (Figure 2). The interaction between these three factors influences each other. Forecasting, planning, organising, commanding, coordinating and controlling these factors is key to successful management of the project and the continuing existence of the construction company in global market place (Abdul Rahman & Berawi, 2002b). The three factors lead to the value added core competencies and improve technology and innovation to set the mission and vision of company to survive and face globalization and begin the gradual revolution – adopting to the market and stakeholders – and continual improvement (Abdul Rahman & Berawi, 2002c). The nature of the work in construction drives the design of the production control system. It will include the management of human resources, material and supply chain, plant, equipment and tools, finance and how to drive high technology into companies. The success of a construction project can be evaluated by the degree to which it meets the performance and client/end user's requirements (Abdul Rahman & Berawi, 2002d). Achieving this requires not only the resources of a number of organizations and individuals, but also the successful interaction amongst these parties. The concept of KM to improve production management system in construction will arise to ensure that market demands, and a level of performance and conformance are achieved as shown in Figure 3 (Abdul Rahman & Berawi, 2002e).

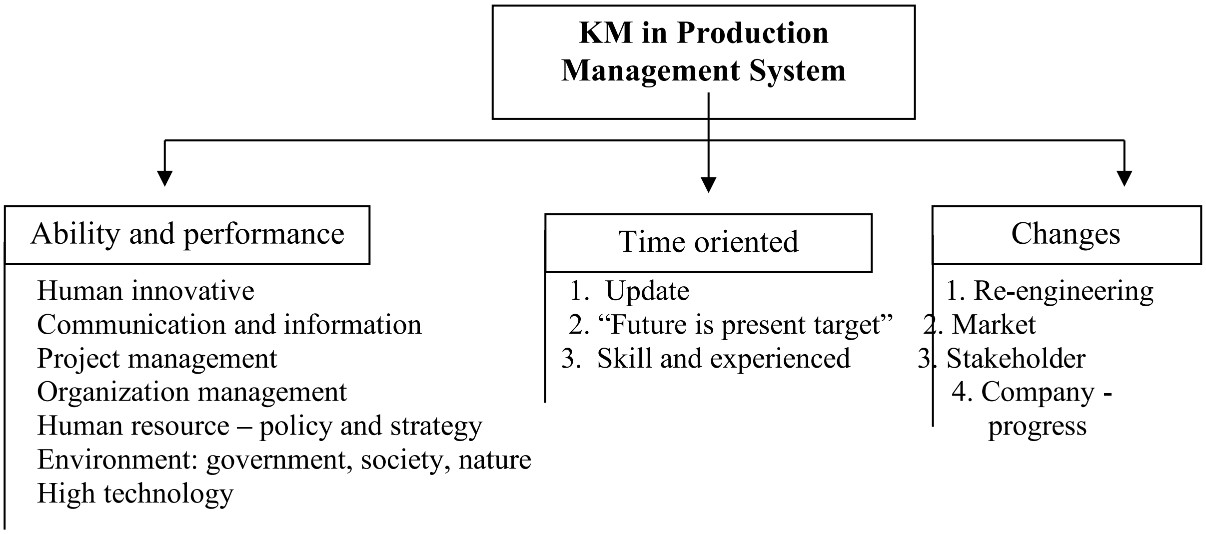

Figure 2: Knowledge Management in Production Management

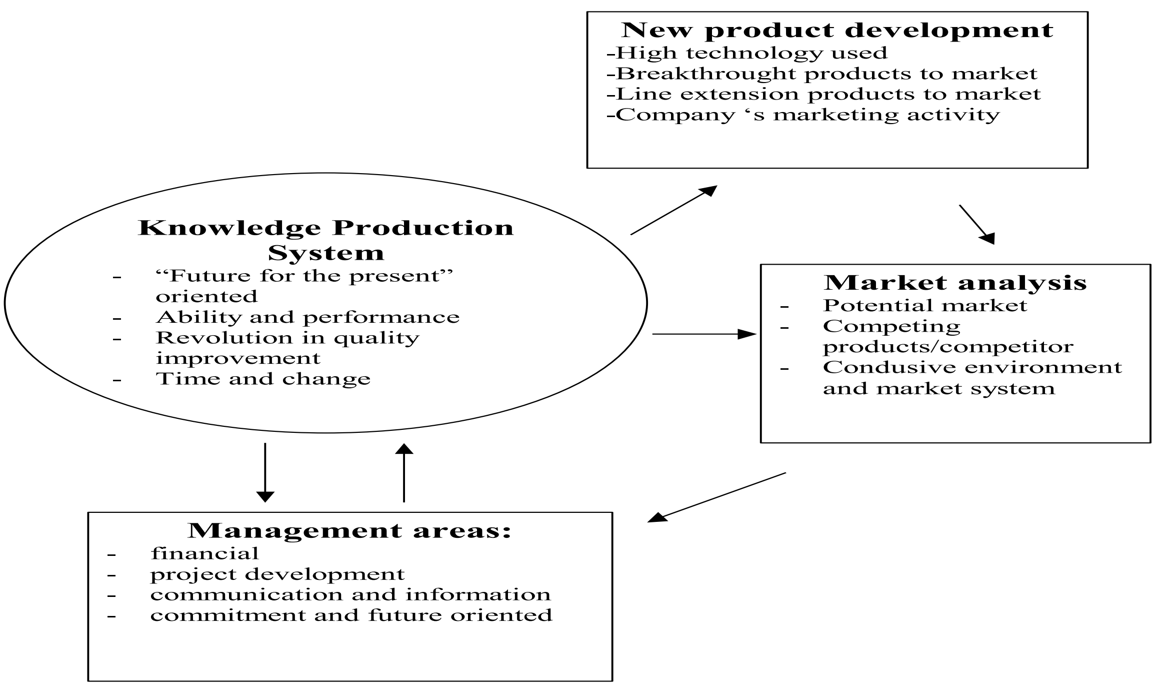

Figure 3: Overview of Model Structure

As noted in literatures (Nonaka & Takeuchi, 1995; Van Engers, et. al., 1995), the knowledge chain consists of seven links: listing the existing knowledge, determining the required knowledge, developing new knowledge, allocating new and existing knowledge, applying knowledge, maintaining knowledge, disposing of knowledge. The building of CM relies on the following steps (Rose et. al., 1998):

(1) *Detection of needs in corporate memory,*
(2) *Construction of the corporate memory,*

(3) *Diffusion of the corporate memory,*
(4) *Use of the corporate memory,*
(5) *Evaluation of the corporate memory,*
(6) *Maintenance and evolution of the corporate memory.*

3. A Mathematical Model for Production System

The construction industry covers a spectrum ranging from slow, certain, and simple (stodgy) projects on one end to quick, uncertain, and complex (dynamic) projects on the other. The basic idea for a mathematical approach as techniques to achieve an optimal production design is to increase all of the strength factors of a project and minimize all the weak factors. The concept can apply for all kind of product and business process innovation whereas construction industry as a sample. The product needs an optimal design and application (Ilyas et.al., 2001). The quality of a product or process is measured in terms of these characteristics.

$$Q = \{q_1, q_2, q_3, ..., q_n, ...q_N\} \quad (1)$$

Where ; q_n = n_{th} quality characteristic
N = number of quality characteristics

Control factors under investigation is :

$$X = \{x_1, x_2, x_3, ..., x_n, ...x_N\} \quad (2)$$

Where; x_n = i_{th} control factor
N = number of control factor
$X_{i\_min} < X_i < X_{i\_max}$

Damage is represented by factors such as ambient temperature, pressure, nature damage/earthquake, people or lack of product.

$$V = \{v_1, v_2, v_3, ..., v_n, ...v_N\} \quad (3)$$

Where ; v_n = n_{th} damage factor
N = number of damage factor
$V_{i\_min} < V_i < V_{i\_max}$

A quality engineering target function may be written as;

$$Q^* = Opt (X,V) \quad (4)$$

The orthogonal experiment is used to determine which factors are influential to the performance characteristic of interest.

$$X_{inf} \leq X \text{ and } V_{inf} \leq V \quad (5)$$

Where;
X_{inf} = number of influential control factors
V_{inf} = number of influential noises factors

Then formula (4) may be rewritten as ;

$$Q^* = Opt (X_{inf}, V_{inf}) \quad (6)$$

Where ; X_{inf} = influential control factors
V_{inf} = influential damage factors

The mathematical model for one quality characteristic and three influential control factors may be written as:

$$q = \{ \; a_0 + \; a_1 x_1^{\inf} + \; a_2 x_2^{\inf} + \; a_3 x_3^{\inf} + \; a_4 x_1^{\inf} x_2^{\inf} + \; a_5 x_1^{\inf} x_3^{\inf} + \; a_6 x_2^{\inf} x_3^{\inf} + \; a_7 x_1^{\inf} x_2^{\inf} x_3^{\inf} \; \} \quad (7)$$

Pareto's area (AB) for two quality characteristics is shown in figure 4.

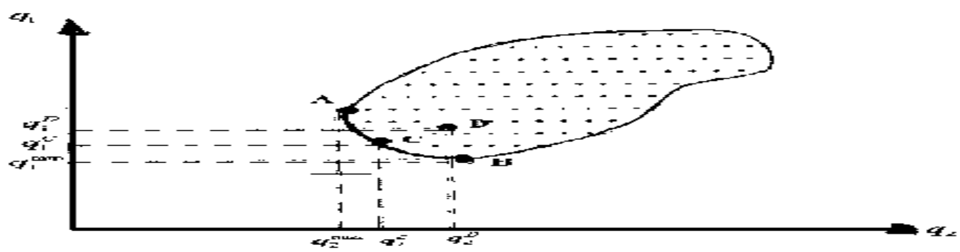

Figure 4: Pareto's area (AB) for two qualities characteristics, q_1 and q_2

The design version C is better than the design version D because point C $(q_1^C, q_2^C) <$ D (q_1^D, q_2^D) i.e., $q_1^C < q_1^D$ and $q_2^C < q_2^D$.

The mathematical model uses the effects of the factors and allows a person to calculate optimal value of the system performance when the values of the factors are between low and high levels. The predicted amount of response is:

Where; e_0 = Sum of all Responses

$$Y_{opt} = (e_0 + e_1 x_1 + e_2 x_2 + e_3 x_3 + \ldots\ldots e_n x_n) / N$$

e_n = Effect of n_{th} factor.
x_n = Coded level of n_{th} factor.
N = Number of test.
n = Number of factor.

Equation to calculate the change in the response value, is given by :

$$X_{n\_new} = \left[r - (r_+ + r_-)/2 \right] / \left[(r_+ - r_-)/2 \right]$$

Where; X_{n_new} = New n_{th} factor coded level.
R = New level factor natural value.
r_+ = New high level factor value.
r_- = New low level factor value.

4. Methodology and Implementation to Improve Production

Construction companies need techniques that will enable them to quickly identify the specific needs of each market and project. Responsibility charts for all of the companies' management to a particular project will be compiled and cross-compared to build up a detailed picture of real control systems. A predictable political and social environment and knowledge of the market (in terms of change and structure) are further important elements of success. To meet the production system performance and objectives, the authors define an approach to the system that combines knowledge management, process review, vision and mission determinants, and production process management (managerial and technical aspect) (see Figure 5). The main point is to understand that problems and changes occur in achieving production target. Finding the causes and assisting in developing solutions is a strategy to manage the uncertainty in the production process. Improvements that lead to cooperation are specific to the work and require a detailed knowledge of the process. It is a dynamic process and requires some flexibility in its application. This will provide the company with the critical success factors to enable it to compete more effectively in the future when managing change and risk in production management system.

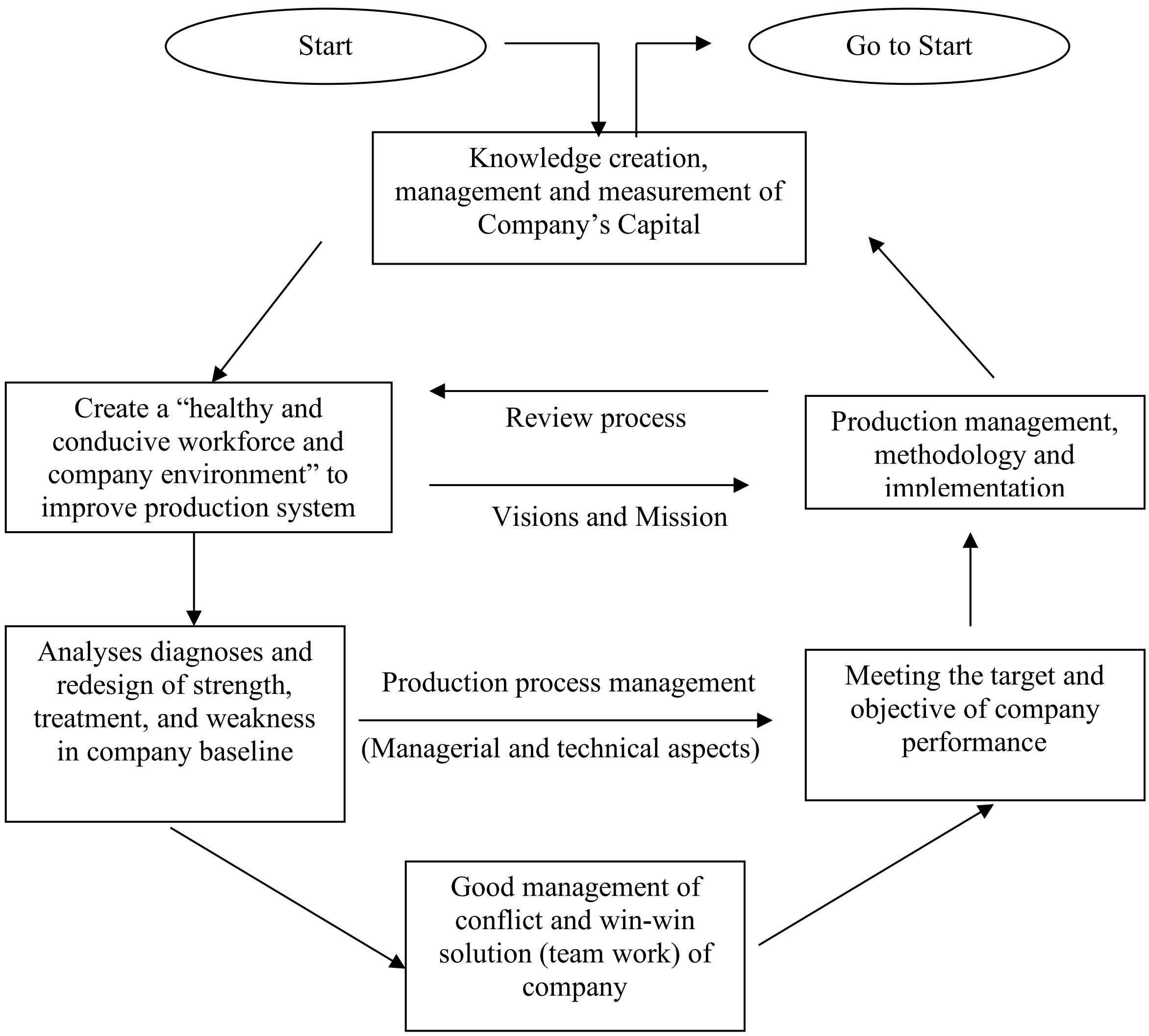

Figure 5: A Loop Schematic of an Approach to Power Quality Management System

5. Conclusion

Construction industry need to develop a systematic approach and implement efficiency improvements in production processes to gain efficiencies and value added. Construction industry repeatedly points to a lack of knowledge, poor organisational support or motivation among managers and workforce to implement the production principles. Knowledge management in production systems produces a synergy between technology and behavioral issues and human innovation that is necessary to compete and survive in the challenging global construction marketplace. High quality and efficiency of excellence in production management achievement aligned with a good schedule, tracking and projecting of costs forms the powerhouse needed to manage the job, the client, and the profits. The natural by-products of applying knowledge management system in production process are completed on time and within budget, important parameters of efficiency and quality.

6. References

Abdul-Rahman, H. & M.A. Berawi (2001), *Developing Knowledge Management for Construction Contract Management*, pp. 358-378, Prolog Association of Japan, ISSN 1345-0980.

Abdul-Rahman, H. & M.A.Berawi, (2002a). *Developing A Knowledge System*, 20th Conference Association of Management/International Association of Management (Aom/IAom), Canada.

Abdul-Rahman, H & M.A.Berawi (2002b), *Towards Innovation and Competitive Advantages Using A New Quality Management System,* The European Conference of Product and Process Modeling (ECPPM) '2002, Slovenia.

Abdul-Rahman, H & M.A. Berawi (2002c), *Power Quality System, A new System for Quality Management in Globalization-Towards Innovation and Competitive Advantages,* Volume 9, Issue 1, pp. 5 – 30, Quality Assurance: Best practice, Regulation, and Law- Taylor & Francis Journal.

Abdul-Rahman, H. & M.A.Berawi (2002d), *Managing Change in Construction Contracting*, Contract Management, pp. 10-16, Vol. 42, NCMA Press, USA.

Abdul-Rahman, H. & M.A.Berawi (2002e), "A New System for Quality Management in Construction", The 3rd International Conference on Decision Making in Urban and Civil Engineering, London.

Barrie, D. S. & Paulson, B. C. (1992), *Professional Construction Management,* Third Edition, McGraw-Hill.

Browne, J., Sackett, P. J., Wortmann, J. C. (1995), *Future manufacturing systems- toward the extended enterprise,* Computers in Industry, Vol.25, Issue 3, pp. 235-254.

Colin G. (1996), *Value for money: Helping the UK afford the buildings it likes*, London.

Hill, T. J. (1992), *Incorporating manufacturing perspectives in corporate strategy*, in [Voss, C. A. Manufacturing Strategy, Chapman & Hall].

Ilyas, T., Tamjis, M.R., and M.A.Berawi, 2001. *Optimizer,* Applied Science Fair, Kuala Lumpur.

Lillrank, P. (1995), *The transfer of management innovations from Japan*, Organization studies, Vol.16/6, pp. 971-989.

Malhotra, Y. (Ed.). (2001), *Knowledge Management and Business Model Innovation,* Idea Group Publishing.

Nonaka, I. and Takeuchi, H. (1995), *The Knowledge-Creating Company How Japanese Companies Create the Dynamics of innovation.* New York: The Oxford University Press.

Nonaka, I. and Tecee, DJ (2001), *Managing Industrial Knowledge creation, transfer and utilization*, Sage, London.

Rose D, Olivier C, Alain G, Myriam R, France (1988), *Methods and Tools for Corporate Knowledge Management,* Proceedings of KAW'98 , Eleventh Workshop on Knowledge Acquisition, Modeling and Management, Canada

Santos, A., dos (1999), *Application of flow principles in the production management of construction sites,* Unpublished PhD Thesis, School of Construction and Property Management, University of Salford, England.

Teece, D. J. (2000), *Managing Intellectual Capital,* Oxford University Press.

Tinnirello PC. (1999), *Project management Best practice series*, Auerbach Publications.

Van Engers, T. V., Mathies H., Leget J., and Dekker, C.C.C. (1995), *Knowledge Management in the Dutch Tax and Customs Administration: Professionalisation within a Knowledge Intensive Organization,* ISMICK'95, France.
VTT (1997), *Well-being through construction in Finland,* The Technical Research Centre of Finland.