UTILISATION OF KNOWLEDGE MANAGEMENT IN DECREASING WASTE OF STEEL STRUCTURE CONSTRUCTION VIA INCREASING EFFECTIVENESS OF WELDING PROCESS

Mohammad Hossein Hajikarimi[1], Abbas Ali Hajikarimi[2] and Mohammad Amin Ghalambor[3]

[1] *Concrete and Advanced Materials Institute, Pooyesh Advanced Technologies Research Center, Sharif University of Technology, Tehran, Iran*

[2] *Department of Management, University of Shahid Beheshti, Tehran, Iran*

[3] *Faculty of Management, University of Shahid Beheshti, Tehran, Iran*

As firms are facing with a new competitive environment which knowledge has a unique position, they should give more consideration to their employer's knowledge, and construction firms are not an exception. Employers are creating values for companies, and nowadays they are counted as strategic resources. In construction firms, due to their project based nature, workers are more important in creating values. One of the most essential elements of a construction firm is its ability to cope with social and environmental pressures to reduce waste and minimise the use of raw materials. To decrease wastes of Steel structure Construction, it is necessary to enhance the weld quality. Weld quality depends on many factors, and one of the most important of them is welder's effectiveness. From another point, it takes a long period of time and experience for an amateur welder to become a professional one. By using KM competences, workers' knowledge increases and tacit knowledge retains in the firm, and consequently quality of welding promotes, so waste of construction process such as wastes of materials, time, and project's cost mitigate. To determine how managers could use KM. According to APQC maturity road map, a survey study was done, also Delphi technique was used to understand experts' opinion, and exploratory research method was used to identify the principal components that explain influencing factors related to wastes welding. Principal component analysis (PCA) was used as a statistical method for data reduction. Finally 5 main categories (Welding Properties, Environment Condition, Educational Condition, welding Apparatus Condition, and Effect of Management) including 14 independent factors were obtained. It is recommended that steel structure firms' managers develop firms' KM strategy in accordance with these 14 factors to retain, develop, and share tacit knowledge of welders to reduce wastes of construction.

Keywords: knowledge management, waste reduction, welding process and quality, principal component analysis.

[1] Mh.hajikarimi@civil.sharif.com
[2] A-Hajikarimi@sbu.ac.ir
[3] Aminghalambor@gmail.com

Hajikarimi, M.H., Hajikarimi, A.A. and Ghalambor, M.A. (2009) Utilisation of knowledge management in decreasing waste of steel structure construction via increasing effectiveness of welding process. *In:* Dainty, A. (Ed) *Procs 25th Annual ARCOM Conference,* 7-9 September 2009, Nottingham, UK, Association of Researchers in Construction Management, 759-768.

INTRODUCTION

The construction industry is recognised as being poor in learning a consistent basis and improving performance and is notoriously slow in adapting to a progressive change (Brian and Ken 2006). In today's business environment, knowledge is considered to be the most important driver behind sustained competitive advantage (Grant 1996). Generation of solid and industrial wastes, destruction of the ecosystem, and other problems related to land, water, and air and become one of the most endangered urban and rural environments in the world. Sources of pollution and hazards from construction activities can be divided into seven major types: dust, harmful gases, noises, solid and liquid wastes, fallen objects, ground movements, and others. The causes of pollution and wastes of welding process play a great role in this area. Organisations have high expectations for KM to play a significant role in improving their competitive advantage. Despite the recognised need to adopt KM, it is considered to be in its infancy in the construction industry and is seen as a recent and evolving practice for construction organisations (Brian and Ken 2006). The most valuable form of knowledge to construction organisations is tacit, accumulated experience of construction professionals, which manifests itself through social interaction (Brian and Ken 2006). Due to the nature of construction industry, and being project based, it is extremely dependant on workers and its cost, Materials using, project time, and quality of processes is deeply related to workers ability, experience, and knowledge. There is a deep dependence between success of Construction organisations and knowledge, experience, and skills of their employees to execute construction projects as efficiently as possible. There is also a strong relationship between project costs, Materials using, project time and quality of processes, workers ability, experience, and knowledge. The capability of an organisation to innovate and continuously improve depends upon the effective sharing and exploitation of its intellectual capital (Egbu 2004). Knowledge management (KM) is now recognised for its potential to bring considerable gains to construction organisations, their projects and individual workers through social and technological interventions. If the construction industry wishes to improve profitability, reduce waste especially wastes of welding faults and inefficiency and offer better value to clients, the industry must fully embrace KM. Largely project-based, the construction sector is a complex, dynamic and changing environment (Raiden and Dainty 2006). The uniqueness of projects, fragmentation within the construction process, mobile staff and changing teams, the increasing need to become more customer-oriented and the high level of external knowledge required by construction companies all make the case for KM more compelling. Essentially, there are two types of knowledge: explicit knowledge which can be readily codified into documented form and can be managed as information; and tacit knowledge which is not easily visible or expressible, highly individualised, and context specific, difficult to share and manage (Nonaka and Takeuchi 1995). The most valuable form of knowledge to construction organisations is tacit, accumulated experience of construction professionals, which manifests itself through social interaction. In this context, the loss of important insights and knowledge due to professional welding tasks and unwillingness to share knowledge are persistent problems which need to be addressed.

KNOWLEDGE MANAGEMENT DEFINITION

In general, knowledge can be divided into two divisions. One is explicit knowledge; the other is tacit knowledge. According to Carlson W. Floyd (1999), Knowledge management is a formal process of determining what information a company has that can benefit others in the organisation and making the information easily available for use by those who need it. Once the process captures the organisation's knowledge, the real power occurs when the users utilising the information use it by putting the shared into action (Rieple and Haberberg 2009). In this study, we used APQC's KM maturity model which provides a road map for moving from immature, inconsistent knowledge management activities to mature, disciplined approaches aligned to strategic business imperatives. The KM is integrated with APQC's Stages of Implementation™ so that implementation at each stage provides a foundation of success and a launching pad to the next stage (Hubert and Lemons 2008).

Level 1: Initiate

This is the most basic stage of maturity at which most organisations begin their knowledge management journey. The key characteristic of a Level 1 organisation is random and informal knowledge sharing and transfer that, in turn, yields no impact to the business.

Level 2: Develop

The primary focus during this second stage is to establish the first iteration of a KM strategy. The strategy for KM should link tightly to the enterprise's business strategies and objectives and should identify business opportunities to apply knowledge sharing and transfer approaches. The business case should provide the calculation of a return on investment (ROI) that includes investments and valuation of assumed benefits that can be measured by undertaking KM projects focused on the work of the business.

Level 3: Standardise

The primary focus at Level 3 is to manage the KM strategy and processes and approaches identified and defined in Level 2. Oversight includes identifying opportunities to apply select KM approaches and processes, securing funding and resources for the pilots, marketing and communicating the strategy, implementing a change management strategy, and refining the KM approaches and processes into standard, replicable methodologies.

Level 4: Optimise

By Level 4, the foundations for KM have been established and standardised. Level 4 involves expanding KM initiatives throughout the organisation by leveraging the standardised KM approaches and processes (aligned with the KM strategy).The primary objective at this stage is to develop and market an expansion strategy leveraging the standardised KM processes and approaches. Tangentially, the organisation will also need to manage the growth resulting from that expansion.

Level 5: Innovate

When an organisation reaches Level 5, leaders are beginning to count on KM capabilities to support the business strategy and business model. The primary objective at this stage of maturity is to improve core business processes by optimising standard KM approaches and processes and embedding them, end-to-end, within those business processes in order to achieve desired business outcomes and breakthrough innovation. Continuous improvement should be institutionalised so that it occurs at the individual, department/functional and organisational levels. At the same time, it should also realign performance assessments with the KM strategy.

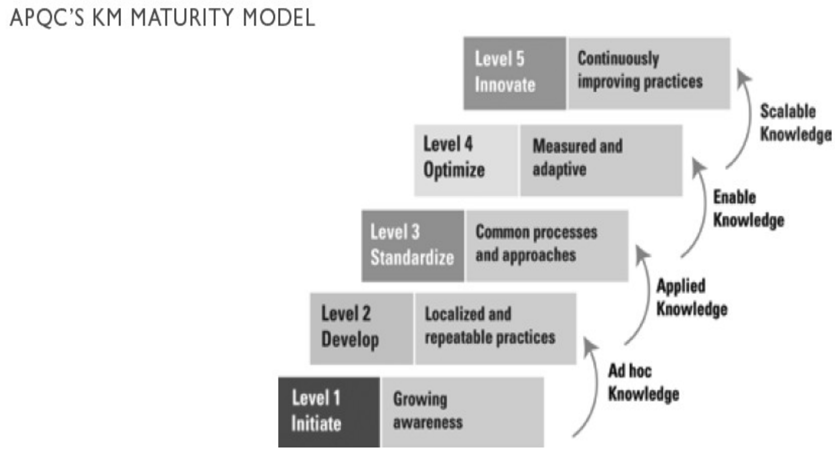

Figure 1:APQC maturity road map

RESEARCH METHODOLOGY

To satisfy research aims, a survey study was done, also a Delphi technique was used to understand experts' opinion, and exploratory research method was used to identify the principal components that explain weld's quality. The statistical method used for data reduction is principal component analysis (PCA). To use of KM appropriately, according to APQC maturity road map, 2 levels of road map has been expanded to satisfy the aims of research, and it is notable that the kind of knowledge which is surveyed was tacit knowledge. At the first level ("Initiate"), problem statement, project objective, and research question has been discussed, and consecutively welding process in Iranian construction firms and firms' stakeholders has been determined. At the second level ("Develop"), requirement specification and priority analysis have been done to show which factors are most important to increase welders' knowledge and continuously weld's quality. It is noticeable that steel construction firms' managers should develop their strategies according to the obtained factors to upgrade their welding quality and reduce wastes. The remained levels need another research and further work is in progress by this paper researchers.

INITIATE

A process is developed to cover project initiation. At first by making use of preliminary study and literature review, general plan of welding process in Iran Construction Industry is designed and problem statement, research questions, project objective, and adjusting stockholder are obtained.

Problem Statement and Project Objective

As knowledge is a strategic resource for firms and in welding process, proficiency is on the hand of professional welders, firms should give more consideration to welder's abilities, proficiencies, and capabilities (Rieple and Haberberg 2009). The construction industry is vital to the success of the nation. It is responsible for building physical infrastructure and provides shelter for its citizens, businesses, industries and institutions. An efficient and profitable construction firm is a fundamental key for national success. It has a major influence on the economic wealth, the societal well-being, and sustainability of the built environment. To remain competitive in today's global markets, the construction firm has to cope with social and environmental pressures to reduce waste and minimise the use of raw materials (Hubert and Lemons 2008). A written Welding Procedure Specification is required to provide specific instruction to the welder and inspector for each weld condition encountered (Mahin

1998). In spite of existing codes and regulations, most of structures do not have suitable detailed execution process in both design and construction. Steel structure is a considerable part of the construction and most of its problems relate to different kinds of faults and weaknesses in connections (Hajikarimi *et al.* 2009). Structural modification (upgrading) can be used both to improve building safety and reduce seismic risk. Connections which have been damaged can be economically modified at the same time repairs are made. Modification of connections throughout the structure, or provision of an alternative lateral force resisting system, will likely substantially improve building performance; however, this will entail a significant cost premium. Modification of only some connections, and not others, may cause an increase in vulnerability, due to unbalanced concentrations of stiffness and strength. It appears that poor workmanship and inadequate structural details can produce poor performance regardless of the welding procedure (Mahin 1998).

Welder has an enormous effect on welding quality,From one point, control processes and tests could be destructive and costly for a construction firm. After faults determination, during the reparation process, many materials such as steel profiles and electrodes are wasted and so much time, like reparation time, delay of project's time, long period of time to make an amateur welder to a professional one, and workers' valuable time are spent. From another angle, by low quality welding, steel structure's safety is threatened, and consequently after finishing the structure, building's residents and customers is menaced by natural disaster like earthquake and it makes such a catastrophe and irrecoverable tragedy that makes a huge waste, and it overhangs firm's brand. Meanwhile, without suitable execution, workers safety especially welders' safety is threatened, and it has a lot of cost for firm. The research follows KM competences to increase workers' skill and knowledge, and consequently quality of welding to reduce the waste of construction process such as wastes of materials, and time, and project's cost.

Research Question

There are several questions that should be answered.

1. Where is the Critical Path in Welding Process and where the Knowledge/Skill is concentrated?
2. Who have this Knowledge/Skill in Welding Process?
3. What kind of Knowledge/Skill is needed to muster?
4. How KM should be used to decrease waste of construction?

Welding Process in Iranian Construction Firms

In Welding Process, Contactor or Workshop Dean or Purchasing Officer uses an External source like forum or factories to provide Materials including Weld, Steel Profiles, and Weld Slag for welding operation. After that Transportation, units convey these materials for stock piling. Welders use these materials to weld and manufacture the last products (Figure2) (Hajikarimi *et al.* 2009).

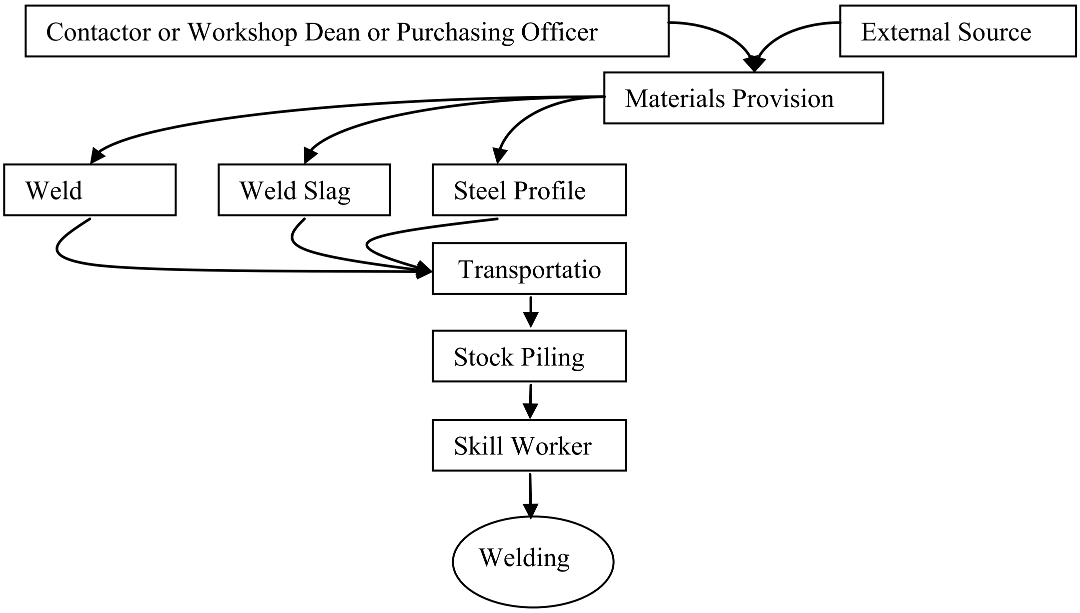

Figure 2: Welding process in Iranian construction firms

Stakeholders of Iranian Construction Firms

There are many stakeholders in Iran Construction Firms. Each stakeholder plays a different role to ensure the successful implementation of the construction process. The main stakeholders are Customer, Principal Contractor, Main Contractor, Sub Contactor, Consultant Eng, Supervisor Eng, Financial Supplier, and Planning and Management Organisation which generally have most effects on wastes of construction process. There are also sub stakeholders who play important roles, who are Welder, Workshop Dean, Storekeeper, Building Material Dealer, and Transporting Unit (Figure3) (Hajikarimi *et al.* 2009).

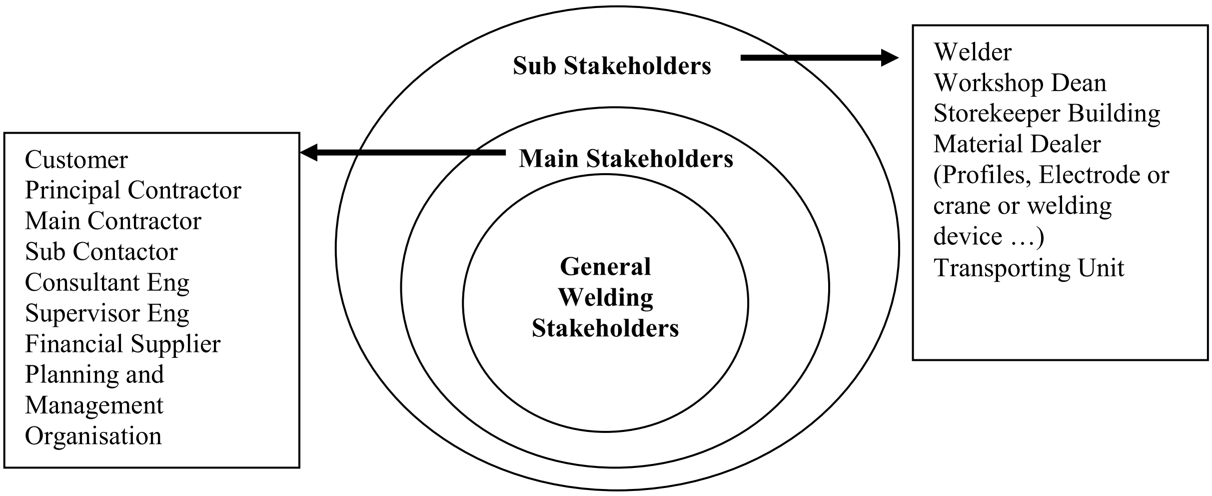

Figure 3:General welding stakeholders

DEVELOP

Developing is the second level after "Initiate" level and it Identifies Requirements and Analyses Priority.

Requirement specification

It is necessary to identify requirements to increase the weld quality, and since this study surveys welder Skill and his Tacit Knowledge, the influencing factors on welder skills and welds quality have been appraised. To identify influencing factors, by Delphi technique an open questionnaire was designed to gather expert's opinion about phenomena. Questionnaires were sent to 5 Professional Welders, 4 Weld Supervisors, 3 Supervisor Engineers and 3 Consultant Engineers (in all 15 persons). The initial components were discovered by Preliminary Study, Literature Review, and Logical Analysis, and finally 5 main categories and 20 factors were designed.

Priority analysis

Sampling design was stratified sampling method, and a close questionnaire was referred again to gather opinion of a broader sample (survey). Questionnaires were sent to 150 experts and 117 of them responded, and consequently 20 factors were rated. To reduce and extract the data, according to 5 main categories including Welding Properties, Environment Condition, Educational Condition, welding Apparatus Condition, and Effect of Management. The 20 factors were extracted by PCA exam via SPSS program to 14 independent factors (this exam separates and extracts the factors that have the same effect and content on the result, but the factors should be in a same category). For example in Environment category, 3 factors were identified, and at the first step via KMO and Bartlett's test the significant level was determined which was lesser than 0.05 and it means the PCA exam could have done correctly. (See Table 1)

Table 1: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.138
Bartlett's Test of Sphericity	Approx. Chi-Square	29.397
	Df	12
	Sig.	.044

At the next step, PCA exam was done, and 2 components explain 90.734% of all total variance related to Environment category (See Table 2 and Figure 4).

The 14 factors were composed of 3 factors which explain 84.35% of all total variance related to "Effect of Management", 2 factors that explain 90.734% of all total variance for Environment, 3 factors which explain 78.72% of all total variance related to "Welding Properties", 3 factors that explain 74.94 of all total variance for Welding Apparatus, and 3 factors which explain 87.31% of all total variance related to "Educational Condition".

For Reliability Analysis the Cronbach's α test was used to indicate the confidence level of questionnaire and it was 0.719 which shows a great Confidence Level for questionnaire (Cronbach's α indicates Confidence level and varies between 0-1 which 0 shows there is no Confidence Level for results in another same conditions and 1 shows there is a complete relation and confidence level for results in other same conditions).

Table 2: Environment's Total Cumulative Variance Explained. Extraction Method: Principal Component Analysis (PCA)

Factors	Initial Eigenvalues			Extraction Sums of Squared Loadings	
	Total	% of Variance	Cumulative %	Total	Cumulative %
1	2.45	57.401	57.401	1.722	57.401
2	1.13	33.333	90.734	1.000	90.734
3	.278	9.266	100.000		

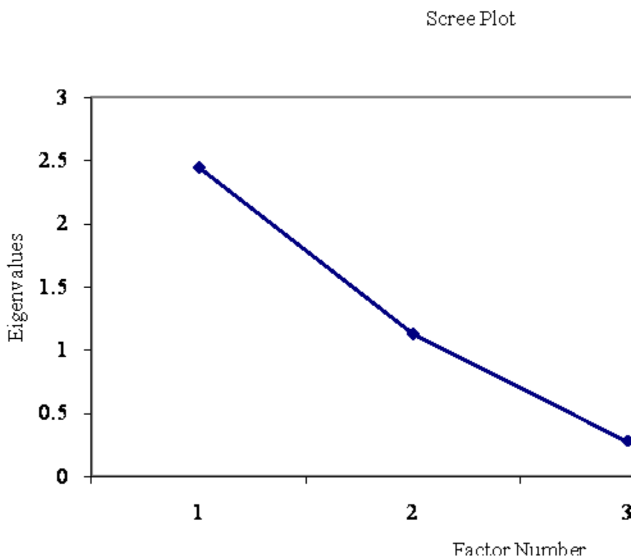

Figure 4: Eigenvalue's Scree Plot according to Environment's factors

To study Validity of the questionnaire, the questionnaire was surveyed according to Preliminary Study and Literature Review. At last, the final Influencing Factors have been depicted in Table 3. To find which factor is more important, Friedman's Test was used (this exam ranks the factors according to their importance) and the result is shown in Table 3. Managers should develop KM strategy according to priority of influencing factor with regard to its category. For example in "managing effect" category, "Accurate supervision and welding quality control" influencing factor, managers could hold teaching workshop for supervisors and show their effectiveness during a welding process to use their knowledge appropriately. " Compatibility of designer's design with executed details during the welding process" in "welding properties" category is another example that could be solved via continuous meeting and relating between designers and welders.

CONCLUSION

Despite International regulations like AISC, AWS, etc for designing and implementing steel structure, there are many faults in steel structures and especially in weld connections. From another angle, the welder effectiveness has a great effect on weld quality, so by increasing the welder skills and knowledge, the faults in weld connections and consequent hazards and wastes can be reduced. The article appraised knowledge management competences to mitigate waste of steel structures regarding the welders' effectiveness and skill. Five categories of "Effect of Management"," Welding Properties", "Apparatus Condition", "Educational Condition", and

"Environment" were discovered to fulfill knowledge management concept in welder's construction segment. It is recommended that firms develop their strategies but not limited to lesson learned, continuing personal development, strict work flow and loose work flow based on these 14 factors, to capture essential knowledge in order to mitigate 4 kinds of waste during the welding process. Additionally, to support organisations' knowledge management strategy, it is important to have foundational agreements of top management support and support of the IT department. The following conclusions can be concluded about benefits of using KM in construction firms with an eye to waste reduction (4 kinds of waste reduction):

Table 3: Influencing Factors on waste reduction related to KM, and steel structure

Importance Priority	Influencing Factor	Category
1	Accurate supervision and welding quality control	Effect of Management
2	Compatibility of designer's design with executed details during the welding process	Welding Properties
3	The use of professional welder in projects	Effect of Management
4	Weld' accuracy	Welding Properties
5	Annihilate noises caused by alternative currency during the welding	Apparatus Condition
6	The importance of teaching course to inbreed skilled workers and welders in construction industry	Educational Condition
7	Effect of welding time delay on project's delay and consequently increasing cost and times of project	Welding Properties
8	Welder 's utilisation of safety equipments	Effect of Management
9	Teaching welders for using safety equipments during the welding	Educational Condition
10	Efficient and practical education for supervisor engineer and spectator to get proper controlling	Educational Condition
11	Using SWAW method in open area workshop	Environment
12	Using new and advanced welding apparatus	Apparatus condition
13	Attention to weather condition in open area workshop	Environment
14	Accurate adjustment for old welding devices (because they usually do not have Ammeter, and just a few experienced welders can work with them)	Apparatus condition

- Financial Cost: Cost of additional control processes, additional tests especially destructive and expensive tests, reparation, material over using, building's retention, and possible hazards that may happen at the future is diminished.
- Time wastage: Reparation time, project's delay, long period of time which takes to make an amateur welder to a professional one and required time to recruit new professional welders is decreased and workers' valuable time is increased.
- Human life: Workers' safety during work, and Resident safety and health after finishing the structure is promoted, and consequently hazards related to the human is reduced.
- Firm's brand: Safer constructions and buildings boost firm's brand and make competitive advantage for firm in competitive market.

AKNOWLEDGEMENT

The authors are indebted to Mr.Abdolmaleki, BA in English Translation, and Dr.Ahmadi at Payamnoor University for their valuable assistance.

REFERENCES

Brian, G, and Ken, T (2006) Knowledge Management in Irish Construction: The Role of CPD Accreditation, *22nd Annual ARCOM Conference,* 4-6 September 2006, Birmingham of UK. Association of Researchers in Construction Management, Vol. 2, 1015-24.

Brian, G and Ken, T (2006) Managing Knowledge within the Leading Irish Construction Organisations: Current Practices and Future Directions, *22nd Annual ARCOM Conference,* 4-6 September 2006, Birmingham of UK. Association of Researchers in Construction Management, Vol. 2, 1015-24.

Brian, G and Ken, T (2006) The Development of an Integrated Knowledge Management Model for Construction, *22nd Annual ARCOM Conference,* 4-6 September 2006, Birmingham of UK. Association of Researchers in Construction Management, Vol. 2, 1015-24.

Carlson, W (1999) *A Guide to Planning a Knowledge Management System*, PhD, Department of Management, University of Maryland Bowie.

Egbu, C (2004) Managing knowledge and intellectual capital for improved organisational innovations in the construction industry: an examination of critical success factors, *Engineering, Construction and Architectural Management*, **11**(5), 301-315.

Grant, R M (1996) Toward a Knowledge-Based Theory of the Firm. *Strategic Management Journal*, **17**, 109-122.

Hajikarimi, M H, Hajikarimi, A, Ghalambor, M A, Bahaddin B and Hosseini, P (2009) Appraisal of KM Competencies to increase the Steel Structures Safety via mitigation of faults of welding due to amplification of technical knowledge, *5th Conference Information and knowledge In Building-Sharing Global Construction Knowledge*, CIB-W102, Rio De Janeiro, Brazil, June 2009. Vol.8.

Hubert, C and Lemons, D (2008) A Knowledge Management Maturity Model APQC's Stages of Implementation, *APQC*, 2-3.

Mahin, S A (1998) Lessons from damage to steel buildings during the Northridge earthquake, Engineering Structures, *Department of Civil and Environmental Engineering*, University of California, Berkeley, Vol. 20, 261-270.

Mohamed, A (2005) A portal based knowledge management solution for an editorial department, PhD, Department of Technology, University Malaysia.

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

NRC-IRC (2004) Strategic plan, *Institute for research in construction*, National Research Council Canada, NRCC-46892, 5-6.

Raiden, A and Dainty, A R J (2006) Human Resource Development in Construction Organisations, *The Learning Organisation*, **13**(1), 63-79.

Rieple, A and Haberberg, A (209) Strategy formulation, *Strategic Management*, Oxford: University Press.