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Analysis of Greek Construction Design - Engineers' Cognitive Abilities, Personality and Knowledge

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Abstract
The role of a project Designer – Engineer is of special importance to the well being, economic prosperity and viability of construction enterprises. This research is aiming at identifying the Greek project Engineers' - Designers' cognitive abilities, personality characteristics, skills and knowledge. An effort is made to identify key attributes associated with successful designer performance and career development. The survey was conducted based on a structured questionnaire. The ongoing research effort led to 145 responses, originating from engineers and construction professionals, throughout the Greek Construction Industry. The questionnaire was based on international literature and extensive interviews with Greek project engineers. The outcome of the study forms a profile of the competent designer – engineer, and would be important for career orientation providing at the same time insight for academic study courses.

Keywords
Project Engineers - Designers, Cognitive Abilities, Personality Characteristics, Knowledge, Statistical Analysis.

1. Project Design Engineers' Profile

Design is widely considered to be the central activity of engineering (Dym et al. 2005). At the conceptual and design phases, the architect / engineer (A/E) work in close contact with the owner to translate the facility requirements into a viable design. During the bidding phase, the A/E firm transitions to the role of "implementation advisor" and then "inspector" during the construction (Moylan, 2008). The problems affecting the design phase can be divided into five categories: fast-tracking pressures on design, increasing organizational complexity of the client or employer, increasing building complexity in terms of fabric and content, difficulty in planning the design phase and difficulty in managing information (Austin, 1994). Carr (2010) suggests that the need to ensure the creation of high performing design teams will be critical to successful projects. It is the design effort that has the greatest impact on the success of a project.

According to Cheung et al. (2001) the design of construction projects is a collective effort, which brings together specialists from different organizations. The leadership of the design team head could affect the productivity of the design team and as a consequence the project success. Successful completion of a construction project involves the efficient execution of two major processes: design and construction (Manavazhi & Xunzhi 2001) so it was considered important to focus on the Engineers' – Designers' attributes and knowledge.

Gautam and Singh (2010) suggest that design engineers had predominant traits of introversion, sensing, feeling and judging. Their research suggests that 'Thinking' was the weakest trait, there are no "mechanically oriented" personalities interested in finding causes and effects. Also a lack of individuals good at solving problems, who strive for originality, defend their design principles, and deal with others tactfully, was observed. Xia et al. (2009) identified six ranked key competences of design-builders, namely: experience with similar DB projects, capability of corporate management, combination of building techniques and design expertise, financial capability for DB projects, enterprise qualification and scale, and credit records and reputation in the industry.

Moylan (2007) suggests that the most prevalent values among the major stakeholders in the construction industry are the requirements of trustworthiness in developing harmonious business relationships, the opportunity to earn a just profit for the associated risks and the need for integrity and trust in collaborating. Moreover, Molen et al. (2007) measured the Big Five personality factors. The research results seem to imply that, assuming that age is related to experience, growing experience with the profession encourages engineers to become more thorough and precise. Alternatively, it may imply that those less thorough and precise leave the profession and only the more conscientious engineers survive. The same type of reasoning may apply to the trait of autonomy. Level of education is negatively related to conscientiousness. He concluded that engineers are more conscientious, but they are also more extraverted, emotionally stable, and autonomous than the general population.

Like other crucial organizational outcomes, the creativity of engineering design teams stems not only from overall firm strategy and access to resources but, more fundamentally, from the minds of the individual employees (Amabile et al., 2004) cited in Kratzer et al (2008). Newport and Elms (1997) focused on effective engineer qualities. Qualities associated with mental agility, enterprise and interpersonal capability correlated most significantly with effectiveness. Some years later, Maillardet (1981) distinguishes six necessary skills for the graduate design engineers: graphical, practical, communication, application, methodological, team.

2. Research aim and methodology

A structured questionnaire was used in order to evaluate the importance of various cognitive abilities, personality characteristics and body of knowledge of PDEs. Frequency analysis took place and identified the most dominant characteristics and knowledge. This paper examines the perception of cognitive skills, characteristics and knowledge that are considered necessary and important for the success of the construction project designers. For this purpose, questionnaires were handed to professional engineers of all disciplines. The content of this research questionnaire was based on synthesis of the international literature and an open-ended questionnaire which was dispatched three years prior to this paper. The survey firstly records the personal and professional profile of the participating engineers. The collected data included but was not limited to: age, gender, engineering discipline, specialty and years of experience. Respondents attributed scores, ranging from 1 (less significant) to 5 (most significant) on a Likert scale, to the personality characteristics and cognitive skills, so as to make evident which characteristics are significant for the construction designer's career. The required knowledge was also ranked using the same approach. The data was collected and processed with the SPSS software and frequency analysis was used in order to draw conclusions.

The results of the research are based on a sample of 145 Greek Project Engineers. The survey participants are 64% males, whereas 36% are females. The ages vary from 24 to 65, with the 41% of them to be among the ages of 27 and 38. Over 7% of the respondents have worked in construction projects outside Greece. The questionnaire consists of the following three main parts: Profile of the survey's participant – respondent, Personality characteristics and cognitive abilities of project designer – engineers, Essential or required knowledge of project designer – engineers. The first part of the questionnaire is devoted to the participants, which have to respond to 13 personal questions, ranging from age to academic and professional background. The total characteristics regarding cognitive abilities and personality of designers sum up to 34 elements. The "Knowledge" section includes 7 elements. The majority of the answers are collected through check boxes. The Cronbach's Alpha computation which equals to 0,859 reveals that the results of the survey are reliable. According to the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy the value of 0,790 is adequate enough.

3. Descriptive Statistics

Descriptive statistics are estimated using SPSS v.22. The answers of the questionnaires were parameterized and a database was created. Every row represented a participant and every column represented a variable, such as Designers' attributes and participants' profile data. The results based on the whole sample, concerning the cognitive abilities and personality characteristics of project designers are presented in table (1) and the body of knowledge of project designers is presented in table (4). Another analysis has taken place based only on the part of the participants that consider themselves as
"Designers" (Tables 2, 3). The frequency analysis of the responses concerning the cognitive skills and personality characteristics led to the following results shown in the tables below, where each value represents a percentage:

Table 1. Descriptive statistics concerning PDEs' attributes (All Participants)

Cognitive Skills and Personality Characteristics	1	2	3	4	5
Responsibility	0,0	0,7	6,9	35,9	56,6
Reliability	0,0	2,8	7,6	40,0	49,7
Diligent	0,7	0,7	13,8	36,6	48,3
Capability of Identifying Critical Project Activities	1,4	6,2	12,4	33,1	46,9
Obedience to Rules	1,4	4,1	17,2	30,3	46,9
Justified Opinion	0,7	0,7	12,4	40,0	46,2
Combinatorial Thinking	0,0	1,4	15,2	39,3	44,1
Promptness on Solution Provision	0,7	5,5	15,2	34,5	44,1
Hardworking	0,7	0,7	14,5	40,7	43,4
Accuracy	0,0	0,7	17,9	39,3	42,1
Collaborative, Team Spirit	0,7	2,8	11,7	44,1	40,7
Integrated Perception of the Projects' Process and Schedule	0,7	4,1	22,1	37,9	35,2
Capability of Predicting	0,0	4,8	24,8	35,2	35,2
Creativity	0,7	7,6	19,3	37,9	34,5
Clarity of Design Solutions	0,0	4,1	29,0	35,2	31,7
Patience	2,8	12,4	25,5	29,7	29,7
Methodicalness	0,0	4,8	24,1	42,8	28,3
Cleverness	0,7	5,5	20,7	45,5	27,6
Perception of the Projects' Social Consequences	0,7	3,4	22,1	46,9	26,9
Analytical Thinking	0,0	5,5	28,3	39,3	26,9
Communication Skills	3,4	11,0	20,0	39,3	26,2
Scheduling Capability	2,8	11,0	27,6	33,8	24,8
Decisiveness	2,8	13,8	26,9	35,2	21,4
Fantasy / Imagination	2,8	12,4	29,7	35,2	20,0
Typicality	0,7	8,3	34,5	40,0	16,6
Public Relations	13,9	17,4	28,5	24,3	16,0
Proper Acquaintances	13,8	19,3	31,0	20,0	15,9
Conflict Resolution	8,3	16,6	27,6	33,1	14,5
Increased Esthetic	3,4	15,2	35,2	31,7	14,5

Table 1. Descriptive statistics concerning PDEs' attributes (All Participants - continued)

Cognitive Skills and Personality Characteristics	1	2	3	4	5
Originality	3,4	14,5	35,2	33,1	13,8
Instructiveness	3,4	22,8	26,9	33,8	13,1
Politeness	6,2	15,2	31,7	35,2	11,7
Capability of Dominating	11,8	21,5	33,3	25,0	8,3
Understanding	4,1	18,6	33,1	37,9	6,2

Table 2. Descriptive statistics concerning PDEs' attributes (Designers)

Cognitive Skills and Personality Characteristics	1	2	3	4	5
Responsibility			3,8	32,1	64,1
Reliability		1,3	7,7	37,2	53,8
Capability of Identifying Critical Project Activities		5,1	5,1	37,2	52,6
Justified Opinion			17,9	29,5	52,6
Combinatorial Thinking			12,8	37,2	50,0
Diligent			14,1	35,9	50,0
Promptness on Solution Provision		5,1	14,1	32,1	48,7
Hardworking		1,3	9,0	42,3	47,4
Accuracy			15,4	39,7	44,9
Integrated Perception of the Projects' Process and Schedule		2,6	23,1	32,1	42,3
Collaborative, Team Spirit		2,6	9,0	47,4	41,0
Obedience to Rules	1,3	3,8	20,5	33,3	41,0
Capability of Predicting			24,4	42,3	33,3
Clarity of Design Solutions		3,8	33,3	29,5	33,3
Methodicalness		3,8	23,1	39,7	33,3
Patience	1,3	6,4	25,6	34,6	32,1
Creativity		9,0	16,7	43,6	30,8
Communication Skills	1,3	10,3	24,4	34,6	29,5
Scheduling Capability		6,4	24,4	39,7	29,5
Cleverness		2,6	20,5	47,4	29,5
Perception of the Projects' Social Consequences		5,1	17,9	50,0	26,9
Analytical Thinking		2,6	29,5	42,3	25,6
Decisiveness		9,0	24,4	42,3	24,4
Fantasy / Imagination	1,3	15,4	26,9	41,0	15,4
Proper Acquaintances	14,1	19,2	28,2	23,1	15,4
Public Relations	15,4	20,5	24,4	24,4	15,4
Increased Esthetic	3,8	11,5	38,5	32,1	14,1
Instructiveness	1,3	19,2	24,4	41,0	14,1
Typicality	1,3	6,4	35,9	42,3	14,1
Originality	2,6	10,3	43,6	30,8	12,8
Conflict Resolution	6,4	11,5	30,8	39,7	11,5
Politeness	5,1	16,7	32,1	35,9	10,3
Capability of Dominating	7,7	16,7	39,7	25,6	10,3
Understanding	3,8	16,7	29,5	44,9	5,1

According to the frequencies as estimated, from the whole sample, it is observed that the majority of the engineers surveyed assume that construction designers should be responsible, reliable and diligent. Apparently, those results can be reasoned by the fact that designers have to face many risks, deadlines and responsibilities while working and at the same time perform calculations and apply rules to the letter. It is significant that "Responsibility" was graded by almost ninety-three percent (92,5%) of the respondents with four and five. This percentage is equivalent to that of "Reliability", which is as high as almost ninety percent (89,7%).

Other cognitive skills and personality characteristics which are considered to be suitable for the construction designers are: "Capability of Identifying Critical Project Activities", "Obedience to Rules", "Justified Opinion", "Combinatorial Thinking" and "Promptness on Solution Provision". On the other hand, it is obvious from the results that "Collaboration" is a key element, but "Domination" is not, as one third of those participating in the survey rated "Domination" with one or two points. In addition, "Proper Acquaintances" and "Public Relationships" are not considered to be necessary for the effectiveness of the

designer, though 65% of the respondents consider "Sociability" to be essential. These scores, if combined, can lead to the assumption that "Team Work" is a basic element. Other skills which are placed last on the list are: "Understanding", "Politeness" and "Instructiveness". Table (2) presents the frequency analysis' results as derived from the Designers' point of view. A brief comparison among Tables (1) and (2), reveals that the differences are very small. Focusing on the top 10 characteristics, it can be noted that "Diligence" and "Obedience to Rules" are receiving lower scores from Designers in comparison to the whole sample. Even the attributes at the end of the lists are ordered in almost the same way in the two samples. The following tables indicate the frequencies' analysis of the designers' required knowledge. The resulting values represent percentages:

Table 3. Descriptive statistics concerning PDEs' body of knowledge (Designers)

Knowledge of	1	2	3	4	5
Regulations		1,3	6,4	10,3	82,1
Legislation	1,3	2,6	6,4	28,2	61,5
Construction Procedures		2,6	19,2	35,9	42,3
Scheduling	1,3	10,3	33,3	29,5	25,6
Materials	2,6	11,7	24,7	39,0	22,1
Mechanical Equipment	7,7	17,9	26,9	32,1	15,4
Economics	1,3	10,3	35,9	38,5	14,1

Table 4. Descriptive statistics concerning PDEs' body of knowledge (All Participants)

Knowledge of	1	2	3	4	5
Regulations	0,0	0,7	4,2	15,3	79,9
Legislation	0,7	1,4	4,9	27,1	66,0
Construction Procedures	0,0	2,1	16,0	38,9	43,1
Materials	2,1	7,7	26,6	36,4	27,3
Scheduling	1,4	10,4	33,3	31,9	22,9
Economics	1,4	9,7	31,9	41,0	16,0
Mechanical Equipment	8,3	20,8	33,3	25,7	11,8

The scores below two attract low percentages, leading to the assumption that all the rated elements are significant. Nevertheless, knowledge of "Regulations" and "Legislation" are acknowledged as the most important assets for the designers, while scores equal or above four represent more than 90% of the given answers. On the contrary, knowledge of "Mechanical Equipment" and "Economics" are placed last on the list. It can be assumed by the results that designing has to follow specific rules and procedures that are defined by the science of engineering and the legislation, but aspects of knowledge dealing with the implementation of the design are not considered to be such an important part of the designer's role. Comparing the whole sample with the "Designers" sample, it can be observed that in the last places there is a switch among "Economics" and "Mechanical Equipment". Designers consider the Knowledge of "Mechanical Equipment" more useful than "Economics" in comparison with the whole participants' sample.

4. Conclusions and future work

This study identified the perceptions of the Greek Engineers regarding the attributes of PDEs. The attributes with the highest scores are: "Responsibility", "Reliability", "Diligent", "Capability of Identifying Critical Project Activities", "Obedience to Rules" and "Justified Opinion". On the other hand the attributes that receive the poorest scores include: "Originality", "Instructiveness", "Politeness", "Capability of Dominating" and "Understanding". The contribution of this research as far as the knowledge is concerned could be to provide guidelines for academic program courses. The findings show

that the training of project designers could be conducted with greater efficiency and at the same time selection of the most competent project designer could be made with greater reliability.

One other point of interest is that the knowledge subjects dealing with the design implementation, in other words the project construction, are placed last on the list. The future work could focus on measuring the presence of dominant cognitive abilities and personality characteristics in designer – engineers, by applying psychometric tests. These results could be used as a base for career orientation. Even in the case of promotions or assignments in the construction industry, the dominant attributes and their presence in an engineer could act as the criterion for his promotion and predict his future performance in designing a project. It is a fact that cognitive abilities and personality characteristics could not be altered. Social skills and especially communication skills could be improved by adopting various techniques. On the other hand the area which also leaves room for improvement is the required knowledge. This could be planned and organized in such a manner that creates efficient designers.

It would be useful to examine how each group belonging to "Basic Experience" namely: "Constructors – Engineers", "Project Managers" and "Contractors" consider and assess the characteristics, attributes and knowledge of the current research. The next step of the research apart from the incorporation of psychometric tests will focus on a variety of statistical analyses, which include: correlation analysis, principal component analysis and regression analysis. The effort will be partly focused on grouping the attributes. Furthermore, based on the notion that the conception of the PDEs' attributes is correlated with the profile of the participant in the survey, prediction models will be produced. The role of the models will be to "predict" the desired profile of the PDE, based on the profile of the person responsible for "human resource management". Immediate plans for the future work include an increase in the sample. The survey would produce representative samples of participants, based on their profile. The goal would be to identify the different viewpoints on the skills, abilities and knowledge from different groups of participants. Investigation would compare responses from groups based on Gender, Discipline, Experience and Job Profile. Finally, a multi-criteria analysis will be conducted to provide a model for PDE screening and selection.

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