Modelling the Construction Technology Implementation Framework: An Empirical Study

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ABSTRACT

Implementation of new technology is often required when a company wants to improve productivity and enhance safety in construction. Many studies in the literature have focused on new technology applications in the construction industry and how it can improve productivity or solve a complex problem. However, the literature has overlooked how a construction company introduces new technology and especially what attributes and other considerations (e.g. spare parts and down time) affect the adoption decision.

This paper presents a multi-stage framework for the implementation process following the construction company's adoption decision. The aim of this paper is to understand how a company proceeds after the adoption decision in order to implement new technology. 35 participants from Australia and 63 participants from North America (i.e. the US, and Canada) were interviewed to investigate the process. Participants from both sides of the process (i.e. customers and vendors) were chosen in order to cross-validate the findings of each group using data triangulation methods.

A systematic multi-stage framework consisting of three stages: "operation commence", "maintenance set up", and "assessment" was developed to describe the implementation processes of construction companies. Vendor activities that contribute to the process are also described.

Keywords –

Implementation; new technology; adoption; decision making; operation; maintenance

1 Introduction

Previous studies about innovation and technology adoption provides an abundance of theory and evidence regarding how information technology is adopted at the macro level, and how the decision to adopt proceeds at a micro-level. However, very little is known about how the construction technology itself is implemented and how the anticipated implementation or previous implementations affects the adoption decision [21-23]. Some of the best known studies about technology adoption remain vague about the implementation phase of the adoption process and take awareness of the technology and its perceived value as a given [12]. Rogers' quintessential model of stages in the innovation-decision process [17] explains that "Implementation" follows "Decision". However, his volumes remain vague about how the implementation occurs in the first place, and how implementation gives knowledge to other decision makers who are contemplating buying the same technology. Most of his work focuses on interpersonal communication between mass media and consumers, which works relatively well for consumer products, but has limited applicability to industrial technologies such as those in the construction industry. In response to this gap in the literature, we present our inductive analysis of how customers and vendors in the construction industry interact and follow a pathway after their decision to adopt a technology. Our findings provide the empirical foundation upon which we develop an improved Construction Technology Adoption Framework (CTAF) [21-23].

While the technologies themselves have been studied in the literature, the process of how a construction company makes the decision to adopt these technologies is largely unexplored. Several studies have focused on technology selection or prediction of performance for a particular technology such as cranes [29], earthmoving machinery [13,19], or concreting equipment [28] utilizing quantitative analysis, such as the analytical hierarchy process approach [24]. For example, Ulubeyli [27] suggests that the selection of a new concrete pump is mainly based on distance pumped. In addition, they suggest a selection method considering five different criteria (e.g. selling price, operating cost per day, technical services). However, the result of each of these studies is an algorithm for technology choice based on limited factors or technology features. The unfamiliarity of the technology for a construction company, vendor issues, or dynamic factors such as previous performance of both vendor and technology are often ignored. In addition, such studies assume that the technology selection occurs in a single stage, akin to an impulse purchase [27], rather than a multi-stage decision making process, which sometimes takes more than a year in the construction industry, particularly for heavy equipment. Furthermore, they assume that only a certain group of individuals such as the engineer is going to make the selection whereas usually the decision is driven by more than one person with more than one objective.

This study presents a model that can be used to systematically analyse the implementation stages of the adoption process from the perspective of vendors and customers. The model appeals to innovation researchers by providing a more accurate and detailed summary of the stages of the implementation process. It also appeals to innovators, entrepreneurs, and vendors who are interested in facilitating the adoption process and developing their business.

The originality of this paper lies in the examination of the interactions between the customer and the vendor during the implementation process after a construction company has decided to use a new technology. The literature shows that most studies in this area focus on the introduction of an innovation and its applicability. However, the process that occurs after the purchase decision has not been investigated. This paper helps to fill a gap in the literature of construction technology by considering the process a customer passes though, after committing to use a particular technology on a construction project. The findings of the paper will assist innovators to understand the new technology adoption process, and facilitate adoption of their technology.

The paper proceeds as follows. First, we present our inductive method by which we explore how the implementation process occurs in the construction industry. Second, we present our analysis of interview data, from which we isolate mechanisms by which the process is implemented by customers and vendors. Third, the adoption process is presented as the last part of the Construction Technology Adoption Framework (CTAF). Finally this is followed by our conclusions.

2 Research Methodology

In order to explore the implementation phase of technology adoption in construction, we employed semi-structured interviews, because of their flexibility in obtaining deep understanding [5]. This research strategy enables description of the implementation process itself, and production of new insight [7]. By interviewing both customer and vendor, we can integrate their perspectives into a larger picture and recognise commonalities [31]. We analysed the data using thematic analysis and open coding techniques, as reflected in grounded theory methods [11] and the Gioia method [10].

We collect first-hand data by attending five Australian technology exhibitions or industry gatherings in Sydney, Adelaide, Melbourne, Brisbane and Perth, and cross-validated by attending similar events in the USA. A sample of 98 participants was purposefully selected based on their relevant experience and involvement in the implementation process. In order to generalise the technology adoption process across countries and cross-validate the findings, participants were recruited from both Australia and North America, applying the comparative sampling approach [14,16,25]. Comparative sampling involves selecting participants so that there are major differences between interviewees on various scales so that comparisons can be made between each end of these scales. The participants were chosen from five technology exhibitions in Australia and from the largest construction technology exhibition in North America. A summary of the participants' profiles are provided in Table 1.

Table 1 A summary of technology exhibition participants' profiles

Item	Description	Vendors	Customers	Total
Region (Interviewees' business base)	Australia	9	26	35
	North America	30	33	63
Size (based on the number of employees)	Small (4-19)	4	20	23
	Medium (20-199)	14	22	39
	Large (>200)	14	24	27
Interviewees' experience (years)	<5	3	0	3
	6-10	8	5	13
	11-30	18	32	50
	>30	8	24	32
Total		39	59	98

The fundamental premise of any technology exhibition (TE) is to provide customers access to a wide range of vendors and technologies. Based on the chain sampling scheme of Abowitz and Toole [1] sixteen participants were sequentially chosen outside the TE based on the recommendations of some of the interviewees to cover gaps in the sample. These sampling methods are acceptable because the purpose of the interview was to elicit facts rather than to determine representative behaviour [20]. Based on the recommendations of Denzin [8] and Mathison [15], data triangulation is used to cross-validate findings by recruiting both customer and vendor representatives as participants.

All of the data collected from the interviews was entered into NVivo, a software package that facilitates thematic analysis. The collected data includes 260 pages of transcriptions from 120 hours of voice records, initial background forms, and the interviewer's notes taken during the interviews. In addition, supplementary information such as 7,877 photos of technology examples, vendors' booths and activities, company online information and supplementary brochures of specific technologies were collected and used to help in in the interpretation of respondents' views.

3 Exploring the Process

This section describes the process used for applying thematic analysis techniques to the transcriptions of the interviews [3,18] in order to identify themes representing the stages a customer passes in implementing a new technology. The themes are identified based on customer and vendor activities and are used to structure the implementation framework.

3.1.1 Micro analysis and coding data

The 260 pages of transcripts are broken down into smaller parts called passages in order to classify and create meaningful concepts [9] from which appropriate themes are extracted. In order to analyse the data without missing useful material [26,30], different criteria are used to choose passages. For example, one criterion might be to identify any incidents describing the process, and another one might be any new ideas and sentences related to the adoption decision process are selected as a new node to categorize the data [6].

3.1.2 Create activity nodes

At this point 565 passages that indicate a part of the implementation process or a related activity (e.g. training, delivery and commissioning) had been identified by applying the criteria from the previous section.

In the next step, these passages were assigned into relevant child nodes. Each of these child nodes represented one activity related to implementation. In order to increase consistency of analysis, active words such as "we have", "we do", "we go", and "we ask" are considered as signal words for coding the passage. If a node relevant to the passage did not exist, a new node was created. This process resulted in a total of 11 nodes related to customer activities being created. Table 2 lists examples of these nodes and also gives an example comment extracted from an interview illustrating each one.

Table 2 Customer quotes assigned to appropriate nodes

Child node	Selected comments
Installation	*We are looking at how we can handle the crane, how we install it [..].* (#cn45)
	[Sub-contractors] choose the piling rig they need to install [..]. (39.0#cn39)
Installation training	*..learning how the new technology should be installed, started up and operated [..].* (10.00 #cn35)
Assembly	*[..in] assembly time we put the crane together [and ..] have the boom together.* (#cx17)

A further 20 nodes were created related to vendor activities. Three example nodes are listed in Table 3 together with illustrative examples.

Table 3 Vendor quotes assigned to appropriate nodes

Child node	Selected comments
Transportation	*We transport [the machine] to [the] site..* (30.10 #cn55)
Delivery	*Design and manufacture take 12 to 14 months..* (29.10 #cn55)
	If we are going to give this large crane, delivery time is one year, to deliver to Australia. (36.21 #cn21)
Assembly supervision	*The customer starts assembling the equipment. We do supervision. He needs a fitter and an engineer, because he did not know how to connect hydraulic and electric [parts].."* (36.42 #cn1)

3.1.3 Identify basic themes and relationships

The next step to analyse the data is to identify basic themes and relationships that link the various child nodes. Basic themes are the lowest-order premises evident in the data [2]. In this case the themes are coherent steps in the overall implementation phase. This step involves allocating child nodes to parent nodes and sorting them into identifiable basic themes. Each parent node represents a family of activities with some basic similarity of sequential connection. These parent nodes are connected to each other using the function of "create relationship" in NVivo.

The relationships between nodes are analysed. A preceding relationship occurs when one activity must be completed before the other starts. This was assigned to nodes based on one node's priority over another. A clear example is that operation occurs before maintenance and servicing.

Then, each basic theme is re-examined to identify if it refers to a specific event or some other meaningful entity. Table 4 shows that 4 new parent nodes are generated using data from 11 customer activity nodes. For example, one of the parent nodes is called "Training" indicating one of the customers' activities after the adoption decision. This node has several child nodes such as "Installation training", "Operator training", and "Factory training". The resulting basic themes will assist in developing overarching themes that will be used in structuring the implementation framework.

Table 4 Allocating child nodes to parent nodes using customers' comments

Child node	**Parent node**
Assembly	1. Start up and use
Installation	
Start up	
Installation training	2. Training
Operator training	
Factory training	
Refresh training	
Need for services	3. Service need
Need for spare parts	
Assessment	4. Assessment
Feed back	

Table 5 shows that 4 new parent nodes are generated using data from the 18 vendors' activity nodes.

Table 5 Allocating child nodes to parent nodes using vendors' comments

Child node	**Parent node**
Transportation	1. Supervision and test
Delivery	
Assembly supervision	
Installation support	
Start up support	
Performance test	
Cold start up	
Warm start up	
Start-up supervision	
Wet test	
Dry test	
Commissioning	
Assembly training	2. Training service
Technical training	
On-site support	3. Support
Spare parts support	
Assessment	4. Assessment

3.1.4 Develop Candidate themes to develop the implementation framework and cross validation

Comparison between the parent nodes generated from the customer interviews with the parent nodes generated from the vendor interviews shows that they are identical. Thus the two groups of interviews cross-validate each other. Each pair of associated parent nodes constitutes a candidate theme representing related activities in the implementation process. A summary of candidate themes and parent nodes is presented in Table 6.

In order to increase the accuracy of candidate themes, all relevant passages linked to nodes within the identified themes were reviewed in terms of integrity and criticality. This review is called re-focusing the analysis at the broader level of themes [4]. The result of the re-focus analysis shows that vendors support the machine start up and train customers concurrently. Whereas the two activities associated with maintenance and assessment tend to be quite separate. Therefore, theme I and II should be merged into one theme to cover all activities between the adoption decision and the start of maintenance. The three rationalized overarching themes that can be used for the framework are described in the following sections.

Table 6 Four candidate themes covering the implementation phase combining customer and vendor comments

Parent nodes	Candidate theme	Source	Reference
1. Start-up and use	I Delivery and use	40	183
1. Supervision and test			
2. Training (customer activity)	II Training	13	22
2. Training service (vendor activity)			
3. Service need	III Maintenance	25	48
3. Support			
4. Assessment (customer activity)	IV Assessment	19	63
4. Assessment (vendor activity)			

3.1.5 Develop the structure of the implementation process

In this section, the relationships of overarching themes are determined based on the connections between the basic themes and the thematic map. A new model is created in NVivo that includes the three overarching themes and the connections between them. Figure 1 shows the framework of the implementation process including Stages 7 to 9 as modelled in NVivo. (Stages 1 to 6 relate to the previously occurring investigation and decision phases). The framework shows that customers pass through three stages to consolidate the adoption decision: commencing operation, setting up maintenance procedures and assessing the technology performance.

Table 7 shows the number of sources (interviewees that mention the stage) and references (total number of times that the stage was mentioned) for each stage of the framework. This shows that customers and vendors tend to focus on operation and maintenance rather than formal assessment procedures. If a technology does not perform they will simply avoid it in future and use a different supplier.

Table 7. Stages 7 to 9 of the implementation process

Stage	Source	Reference	% of times ranked "high"
Stage 7. Operation commence	69	295	71
Stage 8. Maintenance set up	61	277	72
Stage 9. Assessment	33	93	67

To further cross validate the three steps involved in the framework interviewees were asked to check whether each stage reflected their experience of the technology adoption process. They were directly asked to evaluate each stage of the process by using a Likert scale of high, medium, low, and not applicable. Results are provided in the last column of Table 7. These results also cross-validate the findings of the qualitative analysis. Operation and maintenance feature more prominently in the minds of the interviewees than formal assessment procedure. However, they still tend to rate all three as important.

The two steps of operation and maintenance are critically important to customers, because that is why they buy the technology. In particular factors related to operations and maintenance will have a large impact on the original decision to purchase the technology.

3.2 Synthesis of Results for Framework Development

Figure 1 gives an overview of the implementation phase and the key factors that are considered by customers and vendors in each stage. This section describes each of these stages in detail. What happens after the sale is very important for customers and will be considered as a part of the adoption process. For example, a top manager of a customer states that "*you need to look first at their after sales service.*"

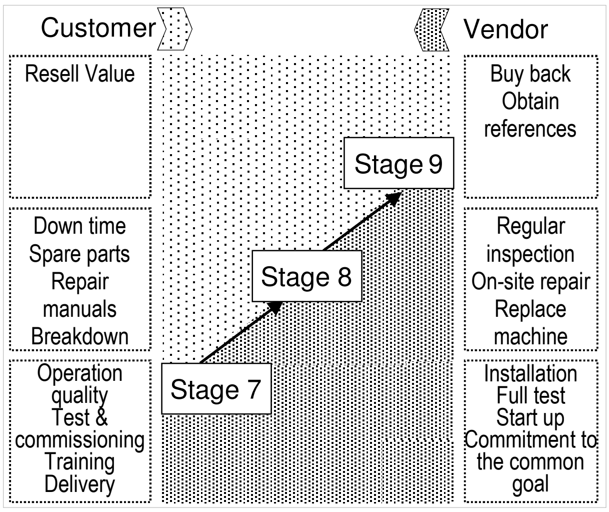

Figure 1. Schematic of the structure and key factors contributing the implementation

3.2.1 Stage 7 – Commencement of operation

Stage 7 in the framework is the commencement of operation. The main concern of customers during this stage is whether the technology actually does meet their project objectives (e.g. safety, quality, and productivity). The main activities during this stage are transportation, training, on-site assembly, testing and commissioning, and modification of other aspects of the project to be compatible with the technology. Actual operation and production can then begin.

Since operating the technology to solve a problem is the purpose of the purchase, operational considerations have a large impact on all of the other stages. New technology operation is often difficult at first because staff from the organisation have not used the technology before. Furthermore the organisation will often need to modify, or even establish, other systems to accommodate the new equipment and it may take a while before these systems function smoothly.

Therefore at all of the earlier stages questions will have been asked such as: Does the technology deliver the functionality? Does the vendor train our operators?

The decision maker has to consider how the decisions in each stage would affect the outcome of the adoption process and finally the implementation, and the probable impact of the delivery in terms of time and cost.

3.2.2 Stage 8 – Maintenance setup

Stage 8 in the framework is to setup a maintenance system for the technology. All technologies need spare parts and other maintenance activities to occur to keep them running. Technology maintenance attributes were at the core of most interviews and were found to be a major concern of the construction technology adoption process. The interviewees frequently discussed technology break down (e.g. components breaking, electronic malfunctions due to heat), downtime, availability of spare parts, repair support and services. For example, a director of a small contractor (customer) in Kalgoorlie (Western Australia) discussed their concerns:

"Can they [the vendor] service the product for us? Can they maintain the product for us in our region? Because if we have to drive 600 km to Perth to get a truck serviced then it becomes uneconomic for us. They wait for the parts [to arrive] from the Germany and then we wait [for them to get the parts to us]."

Smaller companies may be desirous of the supplier maintaining the equipment for them. Larger companies will usually want to perform their own preventative maintenance and so will be very interested in the availability of the information (eg manuals) required to do this.

Therefore during the earlier purchase decision stages questions will have been asked such as: How reliable will the machine performance be in terms of breaking down? How does the vendor service the machine (e.g. solve technical problems, repair break downs, provide spare parts)? The decision maker estimates the service outcome and value-in-use before any commitments towards purchasing the technology are made.

3.2.3 Stage 9 – Assessment

Stage 9 in the framework is assessment. The interviews show that technology adoption will be assessed based on issues such as frequency of technology break down, spare part availability and vendor supportiveness. These issues generally fit into three main criteria: downtime (D), interpersonal relationship (I), and technology operation quality (T). These issues and criteria are called the DIT framework and are schematically shown in Figure 2.

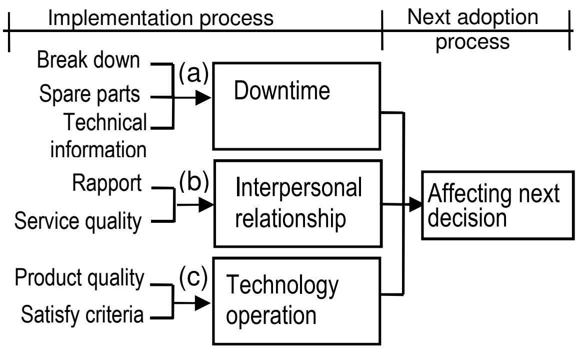

Figure 2 The DIT framework representing key assessment criteria affecting purchase decision. (a), (b) and (c) refer to the criteria discussed in the next section.

a) Downtime refers to periods when the technology is not working due to maintenance either scheduled or unscheduled (breakdowns). The length of time that the technology spends in maintenance will depend on the availability of spare parts and technical maintenance information.

b) Interpersonal relationship – The findings show that the interpersonal relationship with the vendor will affect the purchase decision for many customers. The relationship refers to rapport and customers' perception of being cared for by the vendor. For example one technology dealer described how she would organise social events (barbeques) for her customers and would seek to learn the names of the customer's spouses and children to create a more personal relationship. Showing that the vendor cares about the personal issues of the customer is intended to convey the message that they will care about their business issues also. Parsons (2002) and Song et al. (2012) suggest businesses are increasingly dependent on relationships between vendors and customers to stay ahead of competition.

c) Technology operation quality – It is unusual that the technology will not perform at all. Instead the operation quality issues that customers are normally concerned about are criteria such as production rate, load capacity, accuracy, and other related issues discussed in this paper. Customers will compare the technology against such criteria to technologies they have previously used or are available from competitors. Commonly these criteria will be the reason that customers will seek upgrades or customisation.

4 Conclusion

The purpose of this paper was to develop a deep understanding of how the technology adoption process consolidates the implementation phase, and how the assessment affects the adoption decision. This paper systematically tests the hypothesis that there are specific processes occurring in the implementation phase of technology adoption that affect both the adoption of the current technology as well as future technology adoption decisions.

Through the analysis of 98 semi-structured interviews with experts in Australia and North America, it was found that customers pass through three distinct stages. The outcome confirms the original hypothesis that the implementation process has well-defined stages starting with: a) commencement of operation, b) maintenance setup, and c) assessment. These three stages are mirrored by vendor activities which respond to potential adopters by offering: a) delivery and training; b) maintenance support; and c) feedback mechanisms. In addition, it is found that the criteria framework (DIT) considering downtime (D), interpersonal relationships (I), and technology operation quality (T) affects future adoption decisions. This finding was validated by data triangulation between the results of customer and vendor activities during the implementation process.

The study is innovative in that it examines the whole process rather than focusing on the customer's intention to use a specific technology at a particular stage as in previous studies. In addition, this study investigates vendors' activities that might contribute to the process, which have also been overlooked in previous research. The findings of this paper fill a gap insofar as it provides a deeper understanding of the technology installation and use process. The research also contributes to the body of knowledge in technology adoption by developing a systematic framework for predicting the post-adoption process.

The original contributions of the findings of this paper lie in its careful collection and analysis of two different samples (Australia and North America) from both customers and vendors to establish a scientifically sound understanding of the last stages of adopting new technology. The testing of the prepared hypotheses led to four key observations: (1) the last adoption phase consists of three stages; (2) each stage comprises unique activities; (3) the process stages of the decision makers (customers) are paralleled by clearly identifiable steps taken by vendors; and (4) the characteristics of the technology and the needs of the customer (e.g., start new project vs improve productivity of existing operation) result in discernible sub-patterns within the implementation phase.

References

[1] D. Abowitz, T. Toole, Mixed Method Research: Fundamental Issues of Design, Validity, and Reliability in Construction Research, Journal of construction engineering and management 136 (1) (2009) 108-116.

[2] J. Attride-Stirling, Thematic Networks: An Analytic Tool for Qualitative Research, Qualitative research 1 (3) (2001) 385-405.

[3] R.E. Boyatzis, Transforming Qualitative Information: Thematic Analysis and Code Development, Sage, Thousand Oaks, CA, US, 1998.

[4] V. Braun, V. Clarke, Using Thematic Analysis in Psychology, Qualitative research in psychology 3 (2) (2006) 77-101.

[5] A. Bryman, Social Research Methods, Oxford University Press, NY, US, 2012.

[6] K. Charmaz, Constructing Grounded Theory: A Practical Guide through Qualitative Analysis, Pine Forge Press, London, 2006.

[7] J. Corbin, A. Strauss, Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory, Sage Publications, Thousand Oaks, CA, 2008.

[8] N.K. Denzin, Interpretive biography, Sage, 1989.

[9] I. Dey, Qualitative Data Analysis: A User Friendly Guide for Social Scientists, Routledge, London, 1993.

[10] D.A. Gioia, K.G. Corley, A.L. Hamilton, Seeking qualitative rigor in inductive research notes on the gioia methodology, Organizational Research Methods 16 (1) (2013) 15-31.

[11] B. Glaser, A. Strauss, The Discovery of Grounded Theory, Weidenfield & Nicolson, London (1967).

[12] E. Karahanna, D.W. Straub, N.L. Chervany, Information Technology Adoption across Time: A Cross-sectional Comparison of Pre-adoption and Post-adoption Beliefs, MIS quarterly (1999) 183-213.

[13] S. Kim, Y. Bai, Y.-K. Jung, Determining Significant Factors for Earthmoving in the Bridge Construction, Transportation Research Board 92nd Annual Meeting, 2013.

[14] J. Mason, Qualitative Researching, Sage, London, 2002.

[15] S. Mathison, Why Triangulate?, Educational researcher 17 (2) (1988) 13-17.

[16] M.Q. Patton, Qualitative Evaluation and Research Methods, Sage, Thousand Oaks, 1990.
[17] E.M. Rogers, Diffusion of innovations, 4th ed ed., Free Press., New York, 1995.
[18] K. Roulston, Data analysis and 'theorizing as ideology', Qualitative research 1 (3) (2001) 279-302.
[19] K. Schabowicz, B. Hola, Mathematical Neural Model for Assessing Productivity of Earthmoving Machinery, Journal of Civil Engineering and Management 13 (1) (2007) 47-54.
[20] U. Schultze, M. Avital, Designing Interviews to Generate Rich Data for Information Systems Research, Information and Organization 21 (1) (2011) 1-16.
[21] S.M. Sepasgozar, S.R. Davis, A Decision Framework for Advanced Construction Technology Adoption, Transportation Research Board 94th Annual Meeting, 2015.
[22] S.M. Sepasgozar, S.R. Davis, Pioneers, Followers and Interaction Networks in New Technology Adoption, (2014).
[23] S.M.E. Sepasgozar, S. Davis, Diffusion Pattern Recognition of Technology Vendors in Construction, Construction Research Congress 2014, 2014, pp. 2106-2115.
[24] A. Shapira, M. Goldenberg, AHP-based Equipment Selection Model for Construction Projects, Journal of construction engineering and management 131 (12) (2005) 1263-1273.
[25] C. Teddlie, F. Yu, Mixed Methods Sampling: A Typology With Examples, Journal of Mixed Methods Research 1 (1) (2007) 77-100.
[26] A.G. Tuckett, Applying thematic analysis theory to practice: A researcher's experience, Contemporary Nurse 19 (1-2) (2005) 75-87.
[27] S. Ulubeyli, A. Kazaz, A Multiple Criteria Decision-Making Approach to the Selection of Concrete Pumps, Journal of Civil Engineering and Management 15 (4) (2009) 369-376.
[28] S. Ulubeyli, A. Kazaz, A Multiple Criteria Decision Making Approach to the Selection of Concrete Pumps, Journal of Civil Engineering and Management 15 (4) (2009) 369.
[29] P. Valli, C.A. Jeyasehar, R. Dhanaraj, Tower Crane Selection for an Industrial Project: Case Study, International Journal of Engineering Management and Economics 4 (1) (2013) 84-97.
[30] D. Wicks, Coding: Axial Coding. Encyclopedia of Case Study Research. SAGE Publications, Inc, Sage, Thousand Oaks, CA, 2010.
[31] R.K. Yin, Qualitative Research from Start to Finish, Guilford Press, New York, 2010.