Axiomatic and Measurement Theory based Framework for Selecting Success Factors in Software Project Management

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Summary
In this paper, the basis for selecting success factors in software project management based on axiomatic and measurement theory framework is proposed using five domains of interest including Customer-User-stakeholder domain, Software-Functional-Requirement domain, Physical-design-parameters domain, Process-Standard domain, and Constraints domain.

Key words:
Software project management, Success factors, Axioms, Axiomatic design theory, Measurement theory..

1. Introduction

Previous research has shown that successful execution of projects is dependent on decisions made at the inception and design stage of a project. This is particularly true for software development project whose measure of success is greatly influenced by the ability to meet all stakeholders' initial requirements and expectations. With many companies using software to manage daily business operations, failure of these projects can lead to adverse effects in terms of aspects including finance and reputation, crucial factors in an age where companies are struggling to exist in the era of rapidly growing global competition. While there are differing perspectives on what defines successful software development projects, a common theme in what are considered successes is that in addition to meeting users' requirements they were implemented within given constraints crucially budget and time. On the other hand evidence of poor management exists in many project failures. It is thus evident that as common to other fields, application of effective management skills is also essential in software development. However as with other projects the degree of success or failure is still a challenge to measure as success factors vary across the literature. In addition stakeholders depending on whether they are clients, managers or developers tend to use differing factors for evaluation [1]. Our interest and thus the aim of our paper is to study these factors and their effect on the management and hence outcome of software development projects using axiomatic and measurement theory principles. Our choice of approach is influenced by the fact that axiomatic design provides a systematic framework that enables decision making based on clearly identified functional requirements and design parameters, allowing us to make determination on the degree up to which some options are better than others. In addition, measurement theory principles are applied in the measurement of software project management success in order to ensure that any selected success factors and their degree of success truly represent a measure of the degree of success about the project.

The organization of this paper is as follows. In section 2, relevant literature are reviewed on factors affecting management of software development project success or failure, the axiomatic design theory and measurement theory. In section 3 we suggest a new framework based on axioms and measurement theory for selecting success factors essential in the management of projects. Section 4 is devoted to conclusions and future research directions.

2. Literature review

2.1 Managing successful projects

Project management is a complex process that requires proper identification and completion of a set of activities often referred to as critical success factors. These are in essence activities whose failure to implement could adversely affect the outcome of the project [2].

The challenge of measuring software project management success has been a topic of research for many years [2,3,4]. The result has been a compilation of various success factors by several authors[5,6] due to the different types of projects under study and the varying perspectives of success by stakeholders [7]. It is thus evident that any project being undertaken will have its own unique set of success factors. Therefore project managers should be equipped with tools to correctly select and prioritize factors specific to their project's needs [8,9]. Some models in the literature that attempt to do this include a conceptual model in [5] that identifies and categorizes success factors based on dimensions such as communication and environment. In an approach in [10] identifying the factors that may foster innovation and minimize the uncertainty effects in innovative projects was proposed. Other related approaches are proposed in [11, 12] . We thus aim to contribute to this body of literature by

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developing a framework that will optimize the identification and selection of critical success factors by applying mathematical principles in the form of axiomatic based theory [13], and measurement theory [14, 15, 16, 17]. The ultimate goal is to assist project managers in making the best decisions on activities that will influence the outcome of their projects.

2.2 Axiomatic Design Theory

Axiomatic Design (AD) theory [18] has been used successfully to support the management and development of complex systems across various disciplines. This is attributed to the theory's ability to provide a scientific basis for clearly defining a system objectives and finding suitable design solutions. Application in the literature include Chen [19] who used AD to integrate the software of existing design methods for concurrent engineering, and Jang [20] who investigated the possibility of applying design axioms in marine design, while Gonçalves-Coelho and Mourão [21] applied AD principles to the selection of the most appropriate manufacturing process and Arcidiacono et al, used the principles to develop a framework for optimizing patient flows in hospitals.

The axiomatic design approach as proposed in [18] is characterized by two design axioms. The first axiom is the Independence axiom which states that the independence of Functional Requirements (FRs) should always be maintained, where FRs are defined as the minimum set of independent requirements that characterize the design goals [22]. The second axiom is the Information axiom which states that the smallest information content among alternatives in the form of Design Parameters (DPs) used to satisfy FRs is the best design [23], 2000)

In AD any process can be represented by four design domains namely:

i) Customer Domain (CD). The customer needs vector, {CN} articulates a customer's expectations regarding the system in the Customer Domain.
ii) Functional Domain (FD). The Functional domain is characterized by the Functional Requirements {FR} which are a minimum set of target requirements of a system.
iii) Physical Domain (PD). The Physical domain identifies Design Parameters {DP} necessary for satisfying the functional requirements.
iv) Process Domain (PD). In the Process Domain exists the process variables vector {PV} which represents the design solutions specified by the design parameters vector {DP} [22].

The transition between two domains is accomplished through a top-down decomposition and mapping process referred to as zigzagging which also takes into account the system's constraints. The mappings between the domains can be represented as follows [22]:

$$\{CN\}=[A]\{FR\} \quad (1)$$
$$\{FR\}=[B]\{DP\} \quad (2)$$
$$\{DP\}=[C]\{PV\} \quad (3)$$

Where [A],[B], [C] are design matrices showing relationships between the domains. The mapping is a measurement approach.

$$\begin{bmatrix} FR_1 \\ FR_2 \\ . \\ . \\ . \\ FR_m \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} & \dots & B_{1n} \\ B_{21} & A_{22} & \dots & B_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ B_{m1} & B_{m2} & \dots & B_{mn} \end{bmatrix} \cdot \begin{bmatrix} DP_1 \\ DP_2 \\ \vdots \\ DP_n \end{bmatrix} \quad (4)$$

Independence requires that the Design Matrix should either be diagonal or triangular. A diagonal matrix supports an uncoupled design whereby exactly one DP can satisfy each of the FRs independently. In a triangular matrix the independence of FRs can be fulfilled only if the DPs are determined in a proper sequence. The design is referred to as decoupled.

2.3 Software Measurement and Measurement theory

Measurement is a mapping from the empirical world to the formal, relational world. Consequently, a measure is the number or symbol assigned to an entity by this mapping in order to characterize an attribute [24].

Furthermore, Measurement Theory (MT) species the rules for developing and reasoning about all kinds of measurement. Rule based approach is common in the sciences. For instance Mathematicians learned about the world by defining axioms for a geometry; by combining axioms and using their result to support or refute their observations, they expanded their understanding and the set of rules that govern the behaviour of objects. The obligation of any software measurement activity is to Identify the entities and attributes to be measured, and ensure that the approach used satisfies measurement theory requirements. The approach according to [13] include the following:

i) Determine the axioms that capture intuitive understanding and empirical observations about the attribute
ii) Use the representation theorem to show that the attributes can be represented in an appropriate number system by a mapping which preserves the axioms

iii) Use the uniqueness theorem to show that any two functions defined from the set of entities to the set of numbers faithfully represent the attributes, and are related.

Software measurement essentially involves measuring three software activities namely:

- Processes – collections of software related activities
- Products - artefacts, deliverables or documents resulting from process activities
- Resources – entities required by a process activity

Software artefacts have 2 essential types of attributes namely internal and external attributes. Internal attributes (figure 2) are measured in terms of the product itself. Internal attributes are code based measures of software quality attributes such as cohesion, coupling, control structures, algorithms, data structures, and nesting level [14].

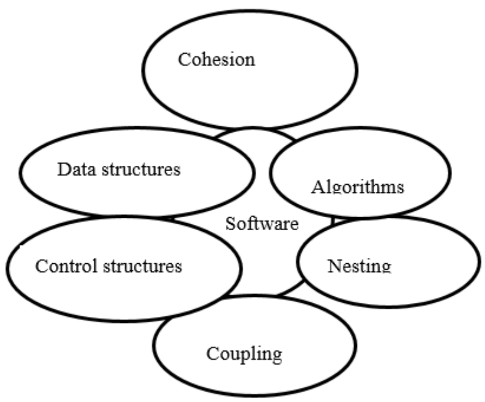

Fig. 2 Internal attributes of software .

External attribute (figure 3) are measured in terms of how the software product, process or resource relate to the environment of operation. The measures are aimed at evaluating the software from the users perspectives in terms of its usability, reliability, efficiency, reusability, maintainability, portability, testability e.t.c. ISO 9126 [25] proposed a standard which species six areas of importance, i.e. quality factors, for measuring external software attributes. These include functionality, reliability, efficiency, maintainability, portability, and usability. This model was has since evolved into the ISO/EC 9128 [26] software product evaluation standard as shown in figure 3.

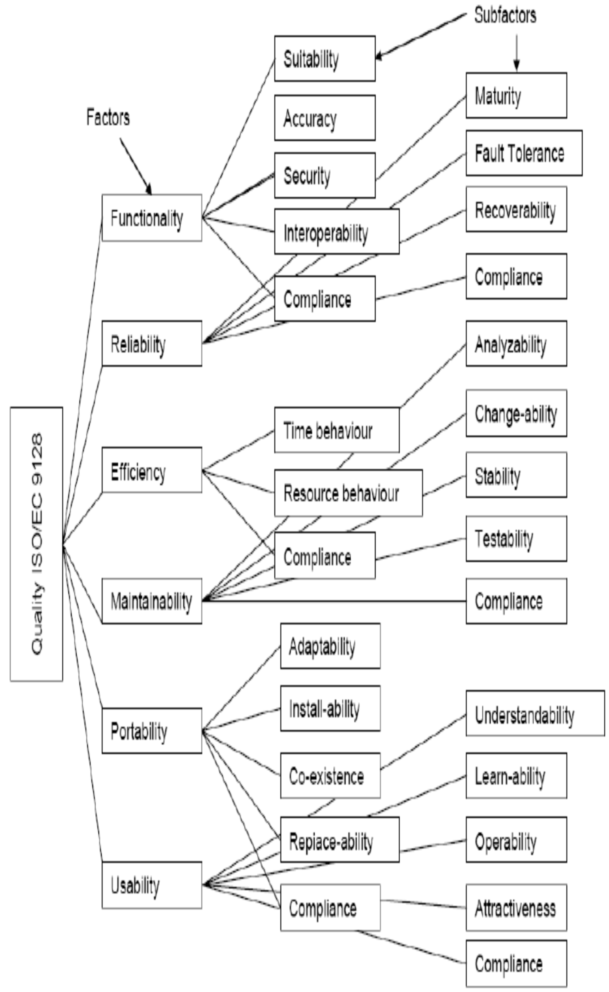

Fig. 3 ISO/EC 9128: Software Product Evaluation: Quality Characteristics and Guidelines for their Use.

2.4 Project management axioms

Jenkins [27] proposed 10 project management axioms for project management success namely:

i) Know your gaol. A clearly stated and known goal of the project
ii) Know your team. A selected united team
iii) Know your stakeholders. A supportive and communicable stakeholders
iv) Spend time on planning and design. Deciding how to solve the problem in the most efficient way
v) Promise low and deliver high
vi) Iterate increment and evolve
vii) Stay on track
viii) Manage change

ix) Test early, test often
x) Keep an open mind.

These factors according the author are self-evident truths for successful projects.

3. Axiomatic and Measurement theory based framework for Selecting Success Factors in SoftWare Project Management

Equations (1), (2), (3), and (4) are measures which can be represented as a mapping function, F:

$$F: x \to y \tag{5}$$

where F is a mapping with x as its domain and with its range contained in y. Let x $\in x$, then there is a unique y$\in y$ such that xFy. The unique element may also be denoted as F(x) known as the image of x under F.

Using Axiomatic Design (AD) principle [23], we define five domains of interest for selecting success factors in software project management namely :

i) The Customer-User-Stakeholder Domain
ii) The Software-Functional-Requirements Domain
iii) The Physical-Design-Parameters Domain
iv) The Process-Standard Domain
v) Constraint Domain

Each of these domains may be accurately represented and captured in equations (1), (2), (3), (4), and (5).

4. Conclusion and future research

In this paper, the basis for selecting success factors in software project management based on axiomatic and measurement theory framework has been established on five domains of interest. An approach for selecting degree of success in software projects are already discussed in Okike and Ofaletse (2017). Our future direction will be the empirical validation of the five domain principle identified in this paper.

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