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Quantitative analysis of viable systems model on software projects in the ICT sector in Castilla y León

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Abstract

Purpose – The purpose of this paper is to detect the degree of influence between applying the Viable Systems Model (VSM), developed by Stafford Beer, on a software project and its viability or success.

Design/methodology/approach – The authors performed a quantitative analysis in which it was necessary to identify theoretical constructs of the VSM (Systems One to Five) and of the viability or success of the software project, measuring each of the indicators together. These indicators have been included in a questionnaire or standardised measurement tool, which was subsequently used for data collection by a number of companies in the information and communications technology sector in Castilla y León. The obtained data served as the basis for a number of results through the definition of a structural equation model.

Findings – The results support the particular importance of Systems One and Four in a software project. In other words, software projects need to clearly define their operational elements (e.g. organisational units, business units, working environments, and working teams) and the relationships that appear between them. Additionally, in software projects it is necessary to determine the appropriate prevention actions to be able to observe the changes that take place in their environment and thus make decisions that allow the project to adapt to these changes.

Originality/value – The originality is based on the VSM application in software projects organisation. The value is based on VSM formalisation and practical application, to overcome the criticism about its abstract nature.

Keywords Project management, Cybernetics, Viable systems

Paper type Research paper

1. Introduction

The importance of software in today's society is well-known. Software investments have continued to increase with the primary objective of increasing the performance of organisations. Therefore, software production must be examined in detail to attempt to increase the effectiveness and efficiency of the software production process and consequently its profitability (Boehm, 1987). To perform this production, it is common to focus the activity from a project standpoint. Generally, a software project seeks to fulfil three additional goals besides the technical result itself. These goals are: first, obtain such a product with minimum cost; second, obtain such a product within the estimated time and third, provide a guarantee of quality customer service (Pressman, 2005). In this regard, failure to meet these three goals in the expected degree leads to an unsuccessful product or failures in the software. In spite of the improvements provided by different studies relating to both technical and managerial aspects, the number of software project failures does not sufficiently decrease. Clearly there is a need,

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therefore, for new contributions in software production that ensure quality at a reasonable cost and expected delivery time (Ramos, 1997).

In this work, we propose an organisational change that can facilitate the treatment of complexity, which implicitly encompasses a software project. The system thinking approach offers a wide variety of methodologies, models, methods and techniques that are especially suitable for this purpose because it allows all of the elements involved in the project to be linked as a whole, including the surrounding environment. Of the wide range of available tools, we consider the application of the principles of Organisational Cybernetics (the science of efficient organisation) (Beer, 1959) to be very appropriate, and more specifically the Viable System Model (VSM) (Beer, 1985), the advantages of which are derived from the systemic, comprehensive and multi-level nature of Organisational Cybernetics, as well as its ability to treat complexity (Pérez Ríos, 2008).

This model is used as a management tool that allows organisations (software projects) to scientifically diagnose or design with a decentralised and participatory structure. The model proposes the necessary and sufficient conditions for viability, to ensure the independent existence, regulation, learning, adaptation and evolution necessary to guarantee the organisation survives changes that may take place in the environment over time (even though, changes were not foreseen when the organisation was initially designed). These capabilities are critical in changing environments, such as those affecting software projects, which can be regarded as social systems that are themselves considered open complex systems (Piattini *et al.*, 1996). Ensuring viability is our way of contributing to reducing the rate of failure in projects of this type.

We consider it appropriate to empirically validate the positive effects that the application of such a model produces in the failure rate of software projects. To make such an empirical validation, we seek to answer the question: does the VSM contribute to improving the viability or success of software projects? In other words, we verify if the viability or success of software projects is positively influenced by the structural conditions initiated by the VSM. Accordingly, we will see whether, indeed, software projects that are organised cybernetically have a lower likelihood of failure in terms of their fulfilment of requirements, time and cost.

To accomplish our objective, we initially show the framework in which our proposal is located to try to decrease the failure rate of software projects. Specifically, we describe the most relevant theoretical foundations of the VSM. Subsequently we conduct empirical validation of the VSM on software projects in the information and communications technology (ICT) sector in Castilla y León. Finally, we present the conclusions of the study's development. Furthermore, several conditions or starting points are presented for further research to improve and expand this work.

2. VSM

Stafford Beer took the first step in Organisational Cybernetics (Beer, 1959) by applying the principles of Cybernetics[1] to the study of organisations. This researcher argued for the possibility of designing an organisation scientifically to constitute a system equipped with the capabilities of independent existence, regulation, learning, adaptation and evolution (Pérez Ríos, 2008). Accordingly, he deduced the VSM (Figure 1) (Beer, 1972, 1979, 1981, 1985), in which the existence of five structural components (Systems One to Five), seen as necessary conditions for an organisation's viability, was proposed. Thus, the VSM helps us understand an organisation's complexity, allowing them to be simply structured to facilitate their understanding and analysis. The VSM can, therefore, be considered a design or diagnostic tool that either allows a new organisational

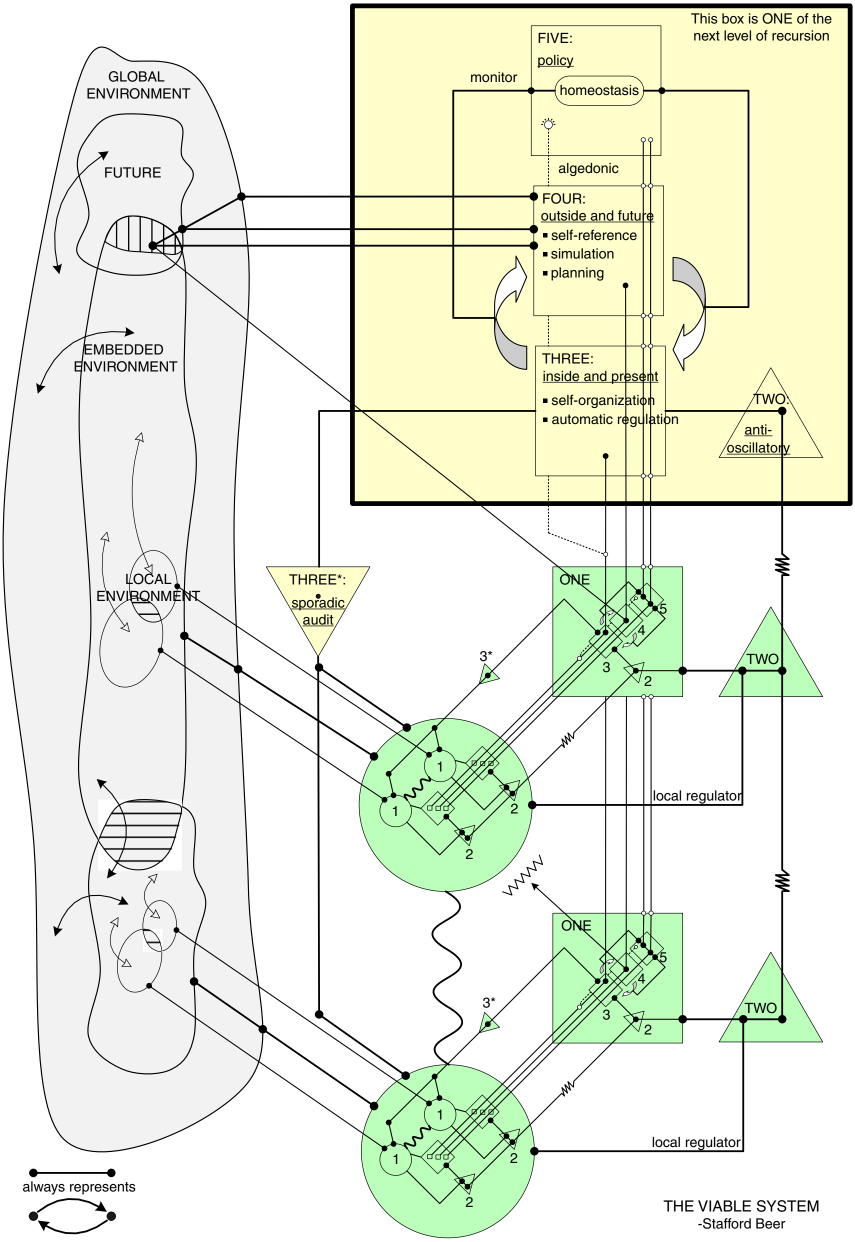

Figure 1.
Viable system model

Source: Beer (1985, p. 136)

structure to be designed or the health of an existing organisational structure to be examined, offering, if necessary, a set of recommendations for improving their effectiveness (Pérez Ríos, 2008). Following, we summarise components of the VSM, its primary contributions and some of its criticisms.

2.1 VSM components

System One (green colour in Figure 1) depicts the production processes that enable the organisation to generate its products or services. The remaining Systems, Two through Five, have the mission of serving System One (Schwaninger, 2006). System One may be split into a series of autonomous operational elements that self-interact. Each operational element, which is a viable system, consists of an operational unit (shown as a green circle), where activities of each operational element are performed, a management unit (represented by a green square) and the environment (represented by the grey amoeba). In addition to these three components, each operational element also has a regulation centre (represented by a green triangle) responsible for providing a self-regulating capacity (Beer, 1979).

The primary function of System Two (represented by a yellow triangle in Figure 1) is to dampen the uncontrolled oscillation that occurs as a result of the operations of System One's operational elements and their interactions (Beer, 1979). System Two is responsible for collecting information from the regulation centres (green triangles) of each operational element and transmitting it to System Three (reviewed below), and the necessary information is transmitted to operational elements to coordinate their activities. Therefore, System Two is a support system for System Three, which attempts to minimise this one intervention, maximising System One's operation automation by designing the appropriate coordination systems (Pérez Ríos, 2008). These coordinate systems can be achieved through standards, programmes, procedures, information and communication rules, information and budgeting systems implementations, internal coordination teams and service units (Schwaninger, 2006).

System Three (represented by the yellow square in Figure 1) manages the system's internal environment in real time. The primary function of System Three is managing the inner and present situation (Beer, 1985). The mission of System Three is to communicate objectives, instructions and guidelines from Systems Four and Five (reviewed below) to the operational elements that compose System One, conduct resource bargaining, account for the use of operational elements, perform audit operations (System Three* (reviewed below)) and eventually, only if organisational coherence as a whole is endangered, intervene in cases where coordination (System Two) has been unable to resolve conflicts between the different operational elements. System Three is also responsible for identifying synergies between operational elements and provides an integrative approach between them, trying to create an organisational global optimum and internal stability. System Three will use the support elements at its disposal and those whose designs must intervene, such as Systems Two and Three* (Jackson, 2000).

System Three* (represented by the yellow inverse triangle in Figure 1) provides non-routine information to System Three that is directly from the operational elements, avoiding what can be filtered. Through System Three*, System Three gets immediate feedback on what is happening in the operational elements without having to trust the information sent (Jackson, 2000). System Three* can be viewed as being internal and external audit activities and informal control mechanisms (Schwaninger, 2006).

Systems One, Two and Three are responsible for the internal organisation in the short term, but that which is external to the organisation must also be monitored in the medium and long-term. System Four (represented by the yellow square in Figure 1) continuously explores different future scenarios to help decision-making increase the likelihood of achieving the desired future outcome. System Four provides possible recommendations for future actions depending on the observed evolution in the organisational environment, thus ensuring adaptation to such changes (Beer, 1985). Its primary mission is dealing with external and future scenarios, to keep the organisation constantly ready for change (Beer, 1985). This research and development function completed by System Four assumes that not only must the organisation consider the known environment but it must also take into account the unknown or enigmatic environment (Beer, 1979, 1985).

To perform System Four tasks, surveillance systems must be available to monitor both what is happening in the present, in the environment in which it operates, as well as the possible changes that may arise in the future. Such systems can be represented as prospective tools (Delphi study), using scenarios and ideally building simulation models of the organisation itself through System Dynamics (Schwaninger and Pérez Ríos, 2008). Beer (1979) proposed that System Four serves as an Operating Room, as a suitable medium for decision-making, and hosts all the important meetings. Ideally, therefore, System Four will consist of an Operating Room.

Finally, to control the interaction between System Three and Four, thus preserving the organisation's identity, System Five is presented (represented by a yellow square in Figure 1), which is also in charge of defining the identity, mission, style, ideological and policy aspects as well as the general principles and objectives of the organisation. System Five must ensure that the organisation suits the environment maintaining, at the same time, an adequate degree of internal stability, balancing the organisation's internal and external needs, which are often contradictory. Beer (1979) recommended that System Five organise itself according to a series of meetings that must be present to everyone involved in the organisation. In addition, System Five must become more active, in particular, it must develop a fully organisational representative role as a previous recursion level, System One, is the operational element management unit (represented by a large yellow square in Figure 1).

This role representation leads to a VSM-essential aspect, the recursive nature of viable systems. In a recursive organisational structure, each viable system contains viable systems and, in turn, is part of the systems that are also viable (Beer, 1979). A direct consequence of this recursion is any viable system; whatever place it occupies should contain five structural systems or components that characterise its viability. In other words, the system viability requires the five functions exist, recursively, at all organisational levels. All operational elements of System One replicate, in structural terms, the whole in which they are contained (Pérez Ríos, 2008). Thus, science offers a natural invariant that provides enormous savings in analysis, diagnosis and calculation, strengthening the viability and making every effort to provide a standard description (Beer, 1979).

Therefore, for Beer, organisation (structure) is somehow the solution to the complexity problem. VSM recursion allows for a break down in the complexity an organisation has to face into more manageable parts (Beer, 1985). These parts are not initial system pieces but should have complete requirements to be fully operational systems that are similar to the original system only with a more limited scope.

2.2 VSM contributions and criticisms

Throughout his work, Beer combines descriptive concrete examples for obtaining a VSM. Complementing these examples, there are a large number of contributions and qualitative studies that use the VSM as a basis for assessing an organisation's viability. A diagnosis or new design permits a transformation or reorganisation of the organisation. From political systems (Beer, 1981; Willemsen, 1992) to specific sectors, such as the hotel sector (Schwaninger and Haff, 1989), banking sector (Leimer, 1990), health sector (Bachmann and Michel, 2001) and media sector (Türke, 2006), large companies (Bröker, 2005), small companies (Espejo, 1979) and even virtual companies (Grizelj, 2005) can be found. All these works illustrate the breadth of the VSM application.

In addition to the studies that are qualitative, there are others where the focus is clearly quantitative. These studies derive a series of hypotheses based on the VSM that are then tested on an empirical data set. For example, we note the study conducted by De Raadt (1987) on an Australian insurance company, the study conducted by Frost (2005) on practice communities and the study conducted by Crisan Tran (2006, 2005) on start-up companies. Although these studies' results can be considered successful, we must consider them with some reservations because of the difficulty of implementing a hypotheses test derived from cybernetic theories. This difficulty is reflected in the study by Van der Zouwen (1996) that analyses different scientific publications. Of the 44 cybernetic studies evaluated, only 12 per cent use empirical data to test a hypotheses set that is theoretically established. Thus, although socio-cybernetic theories have increasingly greater recognition for their theoretical plausibility, weak empirical testability is the primary criticism.

In general, the VSM is viewed as having a purely theoretical design and abstract character; the difficulty encountered in its practical application is the primary target of much criticism and, consequently, in its empirical validity (Adam, 2001). Other criticisms refer to the questionable analogy between the human brain and any other organisation (Jackson, 2000), and its hierarchical arrangement, authoritarian nature and lack of flexibility, minimising the importance of individuals who are part of an organisation in favour of managers who design it (Jackson, 1986). Finally, poor formalisation and a lack of clear procedures for application are criticised (Jackson and Flood, 1988).

3. Methodology

In this section we develop an empirical validation of the VSM applied to software projects in the ICT sector in Castilla y León, using quantitative techniques because of the tool's mathematical rigour and the possibility to explain or confirm postulated causal relationships between different variables according to the theory of strict statistical methods (Malhotra and Grover, 1998). In particular, we want to confirm the following hypothesis: The better Systems One to Five of the VSM are defined, the better they work and cooperate in a software project, the greater their probability of success will be. This general hypothesis can be broken down into mini-hypotheses that allow each of the Systems, One to Five to relate with the software project's viability or success:

H1. The greater System One development is, the greater the software project's viability or success will be.

H2. The greater System Two development is, the greater the software project's viability or success will be.

H3. The greater System Three development is, the greater the software project's viability or success will be.

H4. The greater System Four development is, the greater the software project's viability or success will be.

H5. The greater System Five development is, the greater the software project's viability or success will be.

For these hypotheses, we detected a set of causally related variables to be measured. These variables are called constructs, latent variables or abstract variables, i.e., they are not directly observable variables during research development (Bollen, 1989) (Table I).

These constructs should be linked to directly observable facts, referred to as indicators, empirical variables or observable variables (Bollen, 1989). These indicators have been classified into structural variables related to the VSM, viability variables related to project viability or success and complementary variables related to different project-specific aspects. Based on these indicators, a structured questionnaire was designed that allowed us to extract information about the projects of 42 companies in the ICT sector in Castilla y León through personal interviews. The companies selected were those that were part of the Association of Information Technology, Communications and Electronics of Castilla y León (AETICAL for its acronym in Spanish). Among the companies, those that had a higher level of maturity based on Capability Maturity Model Integration were selected, specifically those that had attained at least a level 3 of maturity. For each of the companies the last completed project was selected. To obtain indicators and design the questionnaire, catalogues of existing questions were adapted to study the subject being reviewed (Crisan Tran, 2005, 2006; Frost, 2005; Bröker, 2005; Malik, 2002; Espejo *et al.*, 1999; Herold, 1991; De Raadt, 1987). To see in detail these indicators and the questions that compose the questionnaire's first version, Puche Regaliza *et al.* (2007) can be revised.

Data collection was conducted for approximately six months. We consider the acceptance rate to have been especially high. Of the 42 companies selected, only two refused to participate, resulting in a 95.24 per cent completion rate. We therefore consider the findings worthy considering the extent of the survey (approximately 75 minutes) and complexity of the topic, requiring a high-level of detail and depth in each one of the projects and companies surveyed.

Data processing and subsequent analysis were performed with the information gathered. At this stage of analysis, indicators were gradually eliminated that did not

Table I.
Construct definition

Construct name	Description	Causal relationship
System One	Presence and quality of components defined in the VSM to represent System One	Produces a direct effect on the software project's viability or success
System Two	Presence and quality of components defined in the VSM to represent System Two	Produces a direct effect on the software project's viability or success
System Three	Presence and quality of components defined in the VSM to represent System Three. System Three* is also included	Produces a direct effect on the software project's viability or success
System Four	Presence and quality of components defined in the VSM to represent System Four	Produces a direct effect on the software project's viability or success
System Five	Presence and quality of components defined in the VSM to represent System Five	Produces a direct effect on the software project's viability or success
Viability or success	Outcome variable that evaluates software project success	

Source: Personal elaboration

meet certain quality levels. In particular, the Cronbach α coefficient[2] and Item-to-Total correlation[3] were initially used for each of the defined constructs (Systems One to Five and the project's viability or success). Thereafter, a partial confirmatory factor analysis (CFA) was also performed for each of the defined constructs. This approach is recommended by Jöreskog (2005) especially if the sample is too small.

To complete this partial CFA, the diagonally weighted least squares (DWLS) estimation method has been used according to the use of ordinal scale variables, so that it was necessary to obtain the asymptotic covariance matrix. Furthermore, we have used the correlation matrix because of the occurrence of high variance value variables (Coenders Gallart *et al.*, 2005; Jöreskog, 2005; Kline, 2005; Batista Foguet and Coenders Gallart, 2000; Diamantopoulos and Siguaw, 2000; Bollen 1989; Muthén, 1984). The eliminated indicators will be those that do not reach a typically demanded value for certain quality indexes (Table II). In complex theory and small sample size situations, values of quality indexes below the usual benchmarks can be used. In addition, compliance is often difficult to achieve with all the indexes at once, as discussed in some of the literature (Vom Hofe, 2005; Homburg and Baumgartner, 1995). Therefore, the work that concerns us regard as sufficient at least half indexes satisfactory fulfilment, so it may be that any individual index is not satisfied.

In this way, we have tried to strengthen partnerships of each construct with their respective indicators. Furthermore, a theoretical justification is sought to avoid the indicators removal which measure construct important dimensions (Albers and Hildebrandt, 2006), i.e., to avoid information loss through their removal. Indicators removal which represent facts similarly represented by other not eliminated indicators, involves no loss construct content, so that the point measured by the remove indicator remains measured by other indicator. Indicators remaining[4] after this removal process are represented in Table III.

Finally, to extract the empirical validation final results, a global CFA is performed. The parameters were estimated using the DWLS estimation method with the same conditions discussed above. Both CFA, partial and global, have been developed on the basis of causal analysis principles offered by structural equation modelling (SEM)[5] due to its suitability for link data and theory through the definition of causal relationship between variables that cannot be measured in a direct way and that they are object or study (Raykov and Marcoulides, 2006; Batista Foguet and Coenders Gallart, 2000; Bollen, 1989). Following we represent path-analysis (Figure 2) showing remaining indicators, constructs measured by them and causal relationships between indicators and constructs and between constructs themselves.

Quality indexes	Threshold values
Indicators correlation	< 0.4
Indicators adjusted multiple correlations (R^2)	> 0.4
Constructs composite reliability	> 0.6
Construct incorporated average variance	> 0.5
Load factor T-value	$> \lvert 1.645 \rvert$
χ^2/degrees of freedom number	< 3
p-value	> 0.1
GFI, AGFI, NFI, CFI	> 0.9
RMR, RMSEA	< 0.1

Sources: Homburg and Baumgartner (1995) and Bentler and Bonett (1980)

Table II.
Threshold values for quality indexes

Indicator name	Description
LVES1_2	Existence of relationship between the System One and System Three
LVES1_4	Internal working of System One
LVES1_11	Quality of relationship between the System One and System Three
LVES2_1	Using the System Two
LVES2_2	Quality of System Two (definition)
LVES2_3	Quality of System Two (flexibility)
LVES3_2	Quality of System Three
LVES3_9	Relationship with the previous level of recursion
LVES3_10	Existence of alarm thresholds (critical variables)
LVES3_11	Existence of alarm thresholds (information channels)
LVES3_12	Existence of System Three*
LVES3_13	Quality of system Three*
LVES4_2	Existence of System Four
LVES4_3	Importance of System Four
LVES4_4A	Quality of System Four
LVES4_5	Existence of relationship between System Three and System Four
LVES4_7	Quality of relationship between the System Three and System Four
LVES4_10	Significant relationship between the System Three and System Four
LVES5_1	Existence of System Five
LVES5_2	Quality of System Five (utility)
LVES5_3	Quality of System Five (definition)
LVES5_4	Quality of System Five (adaptability)
LVES5_6	Relationship with the following level of recursion
LVV_2	Deadline for completion of the project
LVV_3	Project cost
LVV_4	Project quality

Source: Personal elaboration

Table III.
Indicators definition

To identify the model, and ensure that all defined parameters have solution, it was necessary to complete a principal component analysis[6] (PCA) for each of constructs and of the principal component obtained two original variables with best score were selected, eliminating in this way the information least amount possible. The reason for this analysis was the need for the number of observations obtained from the sample must be greater than the number of parameters to be estimated (Backhaus *et al.*, 2006; Marsh *et al.*, 1988; Bearden *et al.*, 1982).

4. Results

We first review the results from model global point of view to judge to what extend defined relationship or hypotheses, can be demonstrated by empirical data. Subsequently, the review will be individual to each model parts together estimates reliability (Backhaus *et al.*, 2006).

To perform the global model evaluation, we use several quality indexes and their threshold values shown in Table II. In this way, we have obtained a value of 0.85 for the ratio[7] between χ^2 and degrees of freedom number. El p-value reaches a value of 0.74. The goodness of fit index (GFI), adjusted goodness of fit index (AGFI), normalised fit index (NFI) and comparative fit index (CFI) indexes reach values of 0.99, 0.98, 0.88 and 1.00, respectively. At last, obtained values for root mean residual (RMR) and root mean square error approximation (RMSEA) were of 0.072 and 0.00. These values

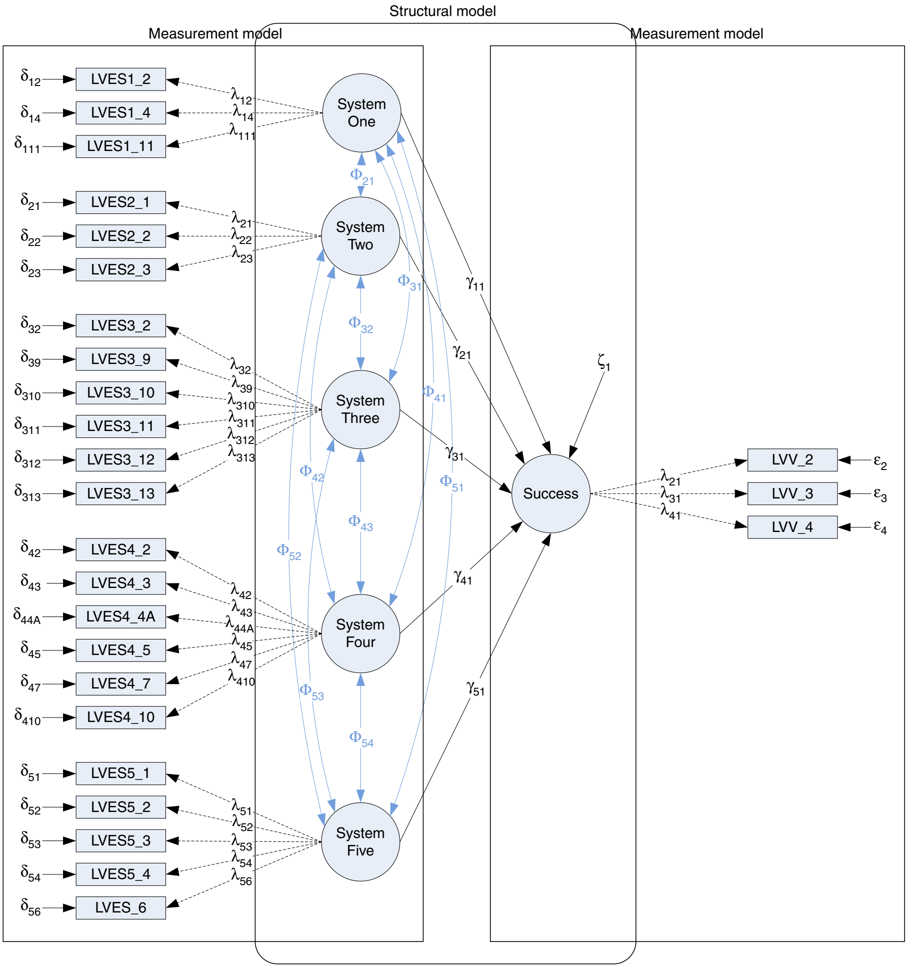

Figure 2.
Path-analysis

Source: Personal elaboration

allow us to consider a good model fit, i.e., there is an appropriate correlation between the defined theoretical model and the data obtained in the sample. In either case, it is recommended to interpret this conclusion with caution due to small sample size (Backhaus *et al.*, 2006; Diamantopoulos and Siguaw, 2000).

Regarding measurement model (Figure 2) evaluation, we intend to review the adequacy with which the constructs are measured by their respective indicators. We first review values represented by correlation matrix. Most of correlations take values lower than 0.4, indicating that there is no excessive correlation between indicators (Backhaus *et al.*, 2006). Solely correlations between indicators LVV_2 and LVV_3, LVES1_11 and LVES1_4, LVES3_13 and LVES3_12, LVES4_3 and LVES4_2 and lastly LVES5_3 and LVES5_1, show values higher than 0.4 so that may be presume likely redundancy between these indicators (Backhaus *et al.*, 2006). This situation can be justified by indicators grouping performed through the PCA carried out in Section 3.

Second, we review not standardised load factors and their *t*-values. Indicators LVES1_11, LVES4_3 and LVES5_3 offer a *t*-value[8] above the minimum demanded of |1.645|, therefore indicate an appropriate behaviour (Diamantopoulos and Siguaw, 2000). Regarding indicators that do not reach demanded value, can be justified because indicators are measured by different measurement scales and the small sample size (Diamantopoulos and Siguaw, 2000). Finally, we use information provided by adjusted multiple correlations (R^2), which measure explained variance proportion by each indicator, thus representing each indicator appropriateness for measuring related construct (Homburg, 2000). In the validated model, all indicators reach demanded minimum value of 0.4[9] except LVES2_3.

Results of the indicators quality evaluation, allow us accept that the indicators used are suitable for measuring the constructs defined in the structural model (Figure 2). Thus, we avoid the subsequent underlying statements in relationships between such model constructs can be compromised (Diamantopoulos and Siguaw, 2000; Jöreskog and Sörbom, 1996b).

Additionally to quality indicators, we evaluate constructs quality through composite reliability, which indicates what extent the indicators set is suitable for measuring respective construct and through its complementary, construct incorporated average variance which indicates variance proportion generated by measurement errors and not by construct itself (Diamantopoulos and Siguaw, 2000). All values for constructs composed reliability exceed required value of 0.6. Similarly, all values for construct incorporated average variance exceed required value of 0.5 except for System Dos, possibly caused by R^2 low value for LVES2_3 indicator.

These results were expected because as mentioned in Section 3, low quality indicators were eliminated for each construct. We recall that in the first place indicators were removed to obtain Cronbach α coefficient value greater than 0.7 for each construct and in second place indicators were removed with values below demanded to R^2 and *t*-value for partial CFA load factor for each construct too. In this indicators removal process efforts were made to maintain the each construct content as far as possible.

Regarding the assessment of structural model (Figure 2), it will allow us to examine whether starting hypothesis linking System One, Two, Three, Four and Five constructs to viability or success construct are confirmed by empirical data. To evaluate this model we use standardised estimates due to their greater significance for interpreting relations between constructs (Diamantopoulos and Siguaw, 2000).

The sign of parameters standardised estimates or structural model regression coefficients[10] provides information on whether relationships between constructs direction corresponding to defined hypotheses. *H1*, *H3* and *H4* show a positive sign, i.e., Systems One, Three and Four have a positive influence on software project viability or success. Against the hoped results, *H2* and *H5* show a negative sign, so System Two and System Five have a negative influence on software project viability or success. Furthermore, the regression coefficients allow a comparison between five systems relative effects width viability or success, i.e., they measure the connection or causal relationships strength between constructs. In this regard, regression coefficients values allow us to conclude that System Four is having a greater positive effect on viability or success, followed by System One and Three. On the contrary, System Five is having a greater negative influence followed by System Two.

Regression coefficients *t*-values[11] are significant[12] for System One and System Four. On the contrary, for System Two and Three, *t*-values are clearly lower to demanded value and therefore not significant. The same goes to System Five, although it is slightly below to demanded level in this case. These values allow us to confirm the *H1* and *H4*, whereas we do not collect enough evidence to reject *H2*, *H3* and *H5*.

Moreover, we obtain that 79 per cent[13] of viability or success variance is explained by Systems One to Five, indicating that approximately only 20 per cent of viability or success variance is measured by factors not represented through the model.

Finally we do a constructs coupling evaluation by χ^2 difference test (Bagozzi *et al.*, 1991). The difference obtained between χ^2 values presents significant values[14] in almost all cases, so we can consider that the constructs are decoupled, thus reinforcing the structural model validity and consequently the validity of the conclusions drawn.

5. Conclusions and future research

With this work, we have wanted to review the need to improve software projects development to increase their success rate. Despite of the existence of contributions and improvements in different scopes, the failure rate does not decrease sufficiently. For this reason, we propose a contribution in the organisational scope. In particular, we propose the use of the VSM for structuring the software project organisation so that it is viable, i.e., endowed with regulatory, learning, adaptation and evolution necessary capacities to ensure their survival along time in face of changes that might occur in their environment, although these were not foreseen at the project beginning.

With the objective to validate this contribution, we have developed a quantitative analysis of software projects in the ICT sector in Castilla y León. Specifically, we have tried to check the hypothesis of whether the viability or success of software projects is positively influenced by structural conditions characterised by VSM. In this regard, through a SEM, we attempted to verify empirically that the more close to structure indicated by the VSM the projects analysed is, the greater their likelihood of success is.

The results obtained indicate that *H1* and *H4* are significantly confirmed[15], whereas for *H2*, *H3* and *H5*, we have enough evidence to be able to reject, i.e., the Systems One and Four have a positive and significant influence on the project software viability or success, whereas we have not been able to obtain the same conclusion for Systems Two, Three and Five.

Interpretation of some of these results is problematic. Positive and significant influence between System One and viability or success allows us to accept *H1*. That is, it indicates that in most software projects, the various operational elements are clearly demarcated. Although they are composed by few people, from project earliest stages their responsibilities are completely defined.

The System Two negative influence on viability or success is not significant, so *H2* cannot be rejected. This result can be justified through software projects robustness. Strong relationships between various operational elements cause the appearance of few oscillations between them, so that coordination strong system or strong System Two existence requirement is not necessary. Moreover, unstable environment existence, it can cause that an inflexible System Two will be unable to absorb operational elements oscillations caused by such instability. In this way, strong System Two existence is not only does not necessary but might even become counterproductive.

One possible reason whereby System Three influence on viability or success is positive but not significant, and therefore, does not allow us to reject *H3*, may be the fact that in most projects treated, Systems Three, Four and Five tasks are performed by the same group of people, so that associated functions delimitation to each system is not entirely clear, and therefore, System Three part of influence on viability or success is hidden within System Four influence significant value on viability or success. It is also likely that System Three another part of influence on viability or success is hidden within System One influence significant value on viability or success, i.e., in the operational elements autonomy.

Positive and significant association between System Four and viability or success enables us to accept *H4*. This association indicates the importance that is awarded to environment and future inspection in a software project, that is, the importance that is awarded to software project maintenance and updating over time. It is likely that this inspection is not only referring to software project, but that implies the recursion next level and consequently implies future projects within organisation.

Regarding possible reasons whereby System Five influence on viability or success is negative and does not significant, so we cannot reject *H5*, first highlight the same justification given above for System Three. In addition, other justification can be added related width confusion between recursion levels, both with the next level of recursion (organisation that produces various projects) as with the previous recursion level (each of the operational elements that compose the System One). It is not considered excessively necessary project software values structured and systematic specification, but they are inherent to organisation itself that produce several software projects and shares therefore, all or at least some of these values, principles, policies, etc. Moreover, it is likely that persons performing the functions of operational elements System Five also form part of project System Five and even of the organisation that produces various projects System Five, which can cause some confusion in regard to differentiate the different recursion levels.

As a final conclusion, we can state that although the results are relatively modest, allow us to consider that most software projects have the five structural components specified by the VSM, influencing at least partly its viability or success. Therefore, we can consider that the application of VSM to organise the software project structure in favour of its viability or success is partially validated by empirical data used.

These results should be interpreted as an indication under constraint dragged along the study, mainly highlighting the used estimation method, DWLS, which is only reliable when it is used with large samples (Jöreskog, 2005; Diamantopoulos and Siguaw, 2000) and indicators removal with significant content for constructs which they are related. Furthermore, SEM application on real data, always provide an ambiguity degree, so many times, some quality indexes offer good fit whereas others offer dubious fit or even point to model rejection. In this regard, model fit assessment should be based on a review of all quality indexes jointly (Bagozzi *et al.*, 1991).

The last conclusion rests solely on the author's discretion, considering that the effort to complete this empirical validation, despite the constraints and encountered problems, is justified as it contributes first, to VSM better understanding and greater formalisation in software projects field, extending its application and providing a more example its universality (for more details review Puche Regaliza (2014a)), second, to weaken the main criticisms related to its abstraction and limited applicability and third, to increase its rigour and validity as a tool for viable organisations diagnosis and design.

Finally, to keep open scientific progress started with this work, we present a series of possible future research works that will lead its evolution and improvement.

First, we believe necessary to conduct additional studies in software project field to extend the results obtained. New studies can choose two different sides: on the one hand increase the sample size and on the other hand, can be tested through other statistical techniques that improve outcomes using small sample sizes or for indicators removal other methods can be used too. Second, we propose the sample segmentation taking into account aspects such as size or type of software project and the subsequent analysis of each one of these segments. To complete this work, we propose to improve the measuring instruments because some VSM aspects have not been dealt in detail.

A second area of work is to conduct the same study in the software project level, in contiguous recursion levels. Specifically, we propose conducting recursion next level empirical validation, that is, each of operational elements that compose System One and the same way, recursion previous level empirical validation, that is, of the organisation that conducts various software projects, where each of them represents a System One operational element.

Third, we propose a customised diagnostic completion for each one project that has participated in the study (a global diagnostic can be reviewed in Puche Regaliza (2014b)). This proposal was outlined in presentation letters sent to companies, which served as an incentive to achieve their participation in the study selflessly.

Finally, we thought it might be interesting to extend this study to other fields different than the production of software, such as engineering or architecture, where the performance of activities through projects is also common.

Notes

1. Science of communication and control in animal and machine (Wiener, 1948). Control concept always appears associated to Cybernetics, which is understandable if we consider their origin from the greek word *Kybernetes*, referring to the person at the helm of the ship to lead to the desired destination.
2. The internal consistency coefficient required values above 0.8 or 0.7 depending on the authors. Even values above 0.4 are accepted, if there only two or three indicators (Vom Hofe, 2005).
3. This indicates the discrimination or correlation between an indicator and the total. It provides information about the suitability of an individual indicator on the total construct.
4. LVESN_N: L = LISREL, VE = Estructural Variable (for its acronym in Spanish), SN = System N, *N* = identification number; LVV_N: L = LISREL, VV = Viability Variable (for its acronym in Spanish), *N* = identification number.
5. We used the LISREL version 8.71 licence student software tool (Jöreskog and Sörbom, 1996a, b).
6. To perform the PCA it has used correlation matrix despite provides less information than covariance matrix due to variables ordinal scale.
7. 34.00/40. Among different values for χ^2, Santorra-Bentler χ^2 was used, the most suitable for small samples considered (Jöreskog, 2005).
8. With 5 per cent significance level.
9. Although there is relative controversy to minimum value demanded in the literature, values greater than 0.5 are recommended, 0.4 even when sample is very small (Homburg, 2000).
10. System One (0.78), System Two (−0.67), System Three-Three* (0.12), System Four (1.14) and System Five (−0.81).
11. System One (2.06), System Two (−0.86), System Three-Three* (0.64), System Four (1.82) and System Five (−1.50).
12. Values above $|1.645|$ and significance level of 5 per cent.
13. This percentage exceeds 40 per cent demanded clearly (Homburg and Baumgartner, 1995).

14. Difference greater than 3.841, based on χ^2 distribution with one degree of freedom and significance level of 5 per cent. 10.823 with significance level of 1 per cent (Bagozzi *et al.*, 1991).
15. At the 5 per cent signification level.

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