Viable System Model structuring of success factors in software projects

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Abstract

This work seeks to identify the principal success factors of a software project structured upon the basis of the Viable System Model (VSM). To do so, an exploratory empirical analysis is conducted of a set of software projects, in which the degree of compliance with the requirements set down by the VSM and the success rating of their development are identified. The results of the study indicate that the most influential factors in achieving global viability in a software project are the local environment, the organizational units, and the intelligent system. Building on those factors, a mathematical prediction model is developed, reaching an accuracy of 63.16% in its predictions. Moreover, the present study sets out a further example of the empirical application of the VSM in quantitative terms, contributing in a substantial way to deconstructing the principal criticisms concerning its abstract nature and difficulties over its practical application; all of which in support of its universality.

Keywords: Cybernetics, Organizational Cybernetics, Viable System Model, Software Project.

1 Introduction: presentation of the problem and the objective

The importance of software in modern-day society is well known. The production process of that software is usually focused from a project-based viewpoint. The reasons why the percentage of successful projects is not sufficiently high have been widely studied, both from a qualitative and a quantitative viewpoint, by a large number of authors who have sought to detect interrelations between success factors and their effects on the development of software projects. In this sense, it is of interest to note the works of Fortune and White (2006), Pankratz and Loebbecke (2011), Nasir and Sahibuddin (2011), Ahimbisibwe et al. (2015) and Standish Group International (The Chaos Report) (2015), especially because of their summaries and their review of the literature in this field.

In summary, although some authors question its validity (Eveleens & Verhoef, 2010), Standish Group International presented a classification of the principal success factors in the development of software projects: (1) executive sponsorship; (2) emotional maturity; (3) user involvement; (4) optimization; (5) skilled resources; (6) standard architecture; (7) agile process; (8) modest execution; (9) project management expertise and (10) clear business objectives. Thereby, if these success factors are improved, we can think that the success of the project will be improved.

Apparently, this assumption is not quite certain. Despite having identified the main success factors in the development of software projects, the number of failed software projects is not falling to sufficiently low levels (Standish Group International, 2015). For this reason, in this work we offer a different management approach for software projects, which allows not only to identify the main factors of success but to interrelate them in a scientific way. Thereby, we intend to advance in the world of project management, reducing the number of failed projects. The way to do it is based on the application of a holistic approach to the development of software projects.

Systems Thinking seems to be an appropriate framework to us in which to visualize a software project from another perspective, in such a way that all the elements with a role in that project may be related, including its immediate environment. Within this framework, we can apply the Viable System Model (VSM) (Beer, 1979; 1981; 1985) as a tool to diagnose or to design the organizational structure of software projects in a scientific manner, applicable to any other type of organization, in favor of its viability. Ensuring viability is the way of contributing to reducing the failure rate of these sorts of projects. The advantages of using the VSM arise from its systemic, comprehensive and multi-level nature.

In consequence, we define the identification of the factors with the highest influence on the success of a software project as a working objective, on the basis of the guidelines laid down in the VSM. These success factors may be reinforced, affecting the viability or success of the projects in a positive way, thereby contributing to the reduction of the number of failures. Therefore, the novel aspect of the work centers on the application of the VSM to design the organizational structure of a software project and on the quantitative exploratory empirical analysis through which the success factors may be identified, so that the application increases the percentage of successful projects. Furthermore, the analysis allows us to define a mathematical prediction model to estimate the probability of success or failure of a structured software project based on the VSM, and in particular, on the values taken by the most influential factors defined by the VSM.

In addition to the initial proposal and the objective that are presented here, we will go on to detail the theoretical background of VSM; subsequently, we will develop the research methodology, present the results that were obtained and we end with the section containing the conclusions and possible research lines.

2 Viable System Model (VSM)

Stafford Beer presented the VSM stating the necessary and sufficient conditions for an organization to be viable in a scientific manner. In other words, that it ensures its capabilities for an independent existence, self-regulation, learning, adaptation and evolution, all needed to guarantee its survival in the face of changes that may occur in its environment (even though they may not have been foreseen) over time. More specifically, he identified as essential in every organization the presence and proper functioning of a series of functions or subsystems (System One, System Two, System Three, System Four and System Five) and a series of relations of communication either between such functions or subsystems or between them and the environment in which they operate.

In this sense, System One is responsible for producing and delivering to the environment the goods or services that the organization produces. It is constituted by the productive processes (operational elements), that make it possible for the organization to generate such goods or services. These independent operational elements (management units) interact between each other. Each separately will be a complete viable system, with a separate existence within the organization, that is, with its environment, nature, purpose and particular responsibilities.

In Figure 1 we can see an example in which System One is formed by two operational elements. Each of these operational elements is composed of a fundamental unit of operation (circle), a fundamental unit of management (square) and an environment where it is affected (amoeba). The operational elements are connected to each other by the fundamental units of operation. The rest of the Systems, from Two to Five, have as mission to serve System One, that is, to contribute to fulfill its purpose (delivery of goods or services to the environment).

System Two aims to achieve a harmonic operation for all operational elements that compose System One. To do this, it will have to damp the oscillations that occur as a consequence both of its autonomous operation as the interactions that occur between them. Each operational element has a local System Two (triangles with upper vertex) that provides information regarding the operation of the rest of operational elements with the aim of coordinating their operations and interactions.

All local Systems Two are connected to the corporate System Two (triangle with upper vertex) that feeds System Three with information on the progress of the operational elements and in the opposite direction, transmits to the operational elements the necessary information to coordinate their activities. To achieve this coordination, System Two employs mechanisms and tools that make it occur in an almost automatic way and, if possible, without the need for intervention of any type of authority (System Three).

System Three is in charge of optimizing the operation of the whole of System One composed of the different operational elements. It is the system that has a vision of the whole and that none of the operational elements alone possesses and it is the only one able to identify the integration and potential synergies that may appear among the operational elements that compose System One. It can be said that the main function of System Three is to ensure that everything works correctly “here and now”, it takes care of the present of the organization, monitoring its operation in the short term. System Three, therefore, will try to maintain the internal stability of the organization, addressing the internal scope in real time.

To do this, System Three (lower square) is related to the operational elements of System One to: 1) transmit information, instructions, goals, objectives and guidelines from System Four and Five to System One. In short, to convey information about how, in general, the organization as a whole should act. In the opposite direction, it also channels relevant information regarding the operation from System One to System Four and System Five; 2) manage the use and distribution of available resources with the operational elements of System One and 3) follow the operation of these through the accountability they have to perform (reporting on the progress of operations, meeting objectives and additional resource requirements). In short, System Three controls the performance of operational elements.

Another functionality of System Three appears in the case that conflicts between operational elements that compose System One, have not been resolved neither through interaction between the operational elements themselves or through coordination mechanisms (System Two). In this case, in addition to extraordinary circumstances that require it, System Three will intervene directly using its authority.

Finally, supporting System Three appears System Three* (triangle with lower vertex), whose main mission is to obtain information about System One that is not obtained neither through the direct relationship between System Three and System One or through System Two. It is therefore responsible for providing information directly from the operational elements, avoiding trust on the information they send to System Three. It allows audit the operation of System One, representing control and review mechanisms both internal and external.

System Three is not able to act foreseeing the future, it is not able to recognize the potential risks that can appear. We need a structural function that solves this problem. This function is System Four (intermediate square), in charge of monitoring the evolution of the organization's environment. Its main mission is to deal with the "external and future" of the organization, in order to keep it constantly prepared for change. In addition to monitoring the environment at the present time, System Four should seek information on expected times or possible situations for the future.

All the novelties identified by System Four as necessary for the organization, must be understood and accepted by System Three and consequently implemented in System One, this ensuring the adaptability of the organization. To complete this process of adaptability, System Four will receive from System Three information about what is happening in the present within the organization itself as well as about the ability of System One to incorporate the changes proposed by System Four. In the same way, System Four will send to System Five information relevant to it.

Among other elements, System Four will ideally consist of the "operating room", where different future scenarios are continuously explored to help in decision making that increase the likelihood of achieving the desired future. The changes detected in the environment are analyzed with reference to the main objectives of the organization, resulting in possible recommendations for action.

Finally, System Five (upper square) deals with the ideological and normative aspects of the organization, defining its mission, global objectives, style and identity and establishing its character, that is, allowing to shape what you want the organization to be, how you want the organization behave internally and how you want the organization be perceived from outside of it.

System Five must ensure that the organization adapts to the environment while maintaining internal stability. It has to achieve, therefore, an adequate balance between the demands of day to day and internal (System Three) with the demands of future and external (System Four), sometimes contradictory. For this, System Five will receive information from System Four about issues that could not be resolved between System Three and System Four, so that System Five decides based on the ideology and regulations of the organization.

After reviewing the main structural elements that compose the VSM, we are going to pay attention to the communication relations that connect these elements to each other and to the organizational environment. These communication relations seek to achieve a continuous balance in the interaction between the elements that connect. The equilibrium is achieved when the information (quantity, content, format and time) is adequate so that the relationship between both elements is a dynamic but harmonious relationship, in the sense that it works in the way desired by the two parts. Among them, there is one of special importance to what we call alarm channel or algedonic channel that connects the operational elements of System One directly with System Five. This alarm channel has the function of alerting System Five of any circumstance that has occurred in System One which has not been resolved by either this system or System Three and which may mean a serious risk to the viability or function of the organization.

In these communication relations, eight elements intervene. The transmitter, the "transducer" that encode the information coming out of the transmitter to be transported, the communication channel that must be able to drive the amount of information per unit of time required, again “transducer” that decodes the information from the communication channel and converts it to the appropriate format so that it can be interpreted by the receiver. In opposite direction, the receiver and the transmitter switch their roles, rediscovering the same elements but in reverse way.

Another essential aspect of the VSM is its recursive character. The Principle of Recursion (another component of System Thinking) states that any viable system contains viable systems and, at the same time, is part of systems that are also viable. Figure 1 shows how within the circles and squares representing the operational elements of System One, an exact replica of the structure of the Model is contained. The direct consequence of this recursion is that any viable system, regardless of the level of recursion that it occupies, must contain the five subsystems or functions defined by the Model, i.e., the viability of the system requires that all five functions exist recursively at all levels of the organization.

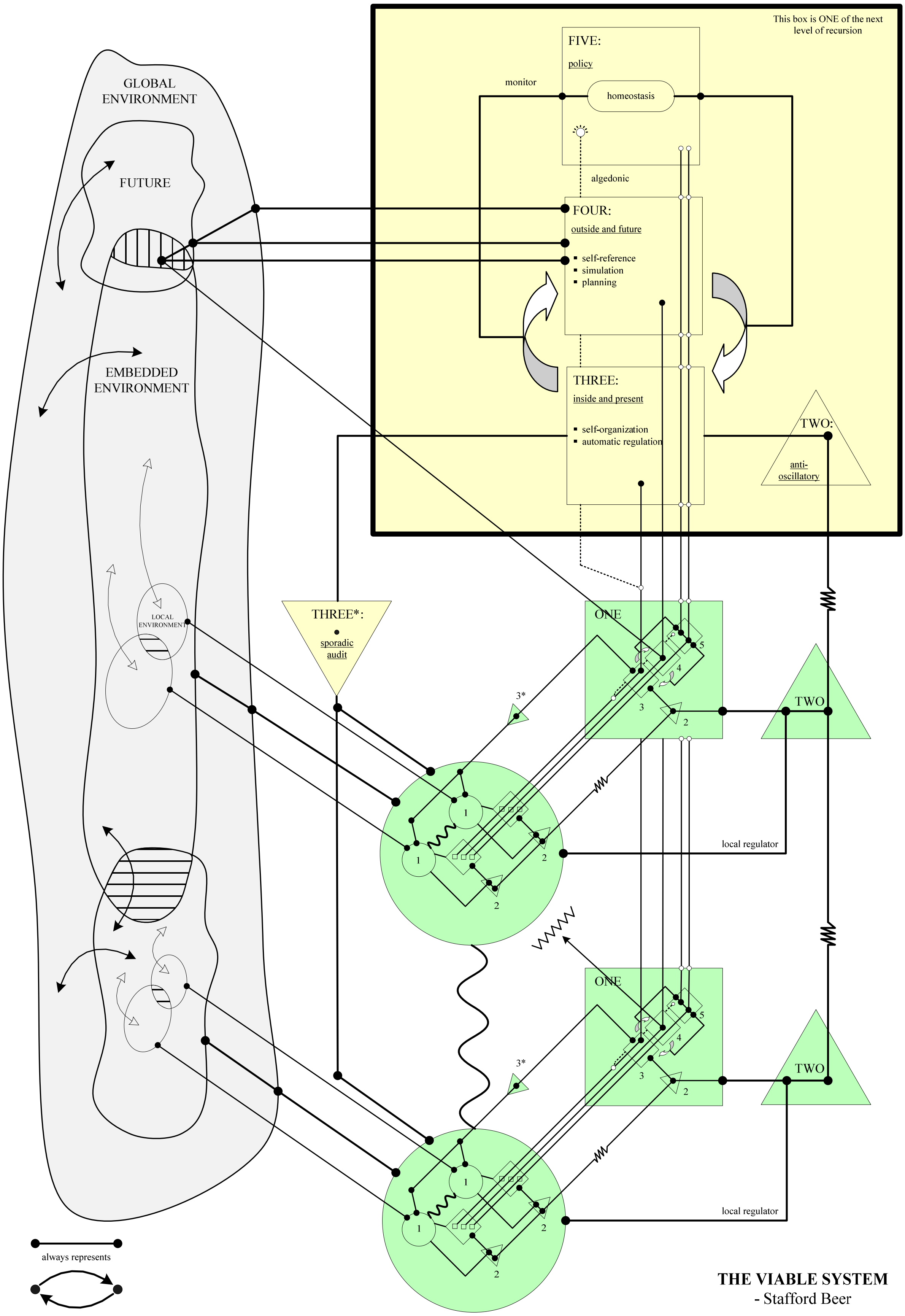


Figure 1: Viable System Model. Authors' own preparation based on Beer (1985)

Different studies have illustrated the breadth of application of the VSM. Table 1 is a small example. The majority of these studies are descriptive or qualitative in nature (using the VSM as the basis to evaluate and to diagnose the viability of certain organizations), while those of a quantitative nature are fewer (Crisan Tran, 2005; 2006; De Raadt, 1987; Frost, 2005; Puche Regaliza, 2015). These quantitative studies obtain a series of hypotheses based on the VSM that are tested on a set of empirical data. Although their results can be considered successful, we should consider them with some caution, due to the difficulty of demonstrating a hypothetical proof in terms of cybernetic theory. This difficulty is reflected in the study conducted by Van der Zouwen (1996) who analyzed different scientific publications. Of the 44 cybernetic studies under evaluation, only 12% used empirical data to test a set of hypotheses that were theoretically established. The principal problem appears to be in the operationalization of the concepts and in guaranteeing the validity of the instrument of measurement (Anderton, 1989). On the other hand, other authors have proposed their vision of the VSM in favor of its better understanding (Jackson, 1992; Adam, 2001; Büttner, 2001; Schwaninger, 2006; Yolles 2006; Tsuchiya, 2007; Leonard, 2008; Espejo & Reyes, 2011, Schwaninger & Scheef, 2016). All of them are based on the original work of Beer.

Application of the VSM	Authors
Small companies	Espejo (1979); Al-Mutairi et al. (2005); Chan (2011)
Political systems	Beer (1981); Willemsen (1992)
Insurance company sector	De Raadt (1987)
Miscellaneous	Espejo & Harnden (1989); Espejo (1990); Herold (1991); Espejo & Schwaninger (1993); Leonard (2009)
Hotel sector	Schwaninger & Haff (1989)
Financial sector	Leimer (1990); Navarte et al. (2006); Trueba et al. (2012)
Project management, Information Systems and Innovation Systems	Britton & Parker (1991); van Kempen (1991); Schuhmann (1991); Devine (2005); Amar et al. (2006); Nyström C.A. (2006); Morales Arroyo et al. (2012); Murad & Cavana (2012); Preece et al. (2013); Puche Regaliza (2014a; 2014b; 2015); Bathallath et al. (2016)
Production, logistics and supply chain	Thiem (1998); Contreras (1999); Herrmann et al. (2008); Chronéer & Mirijamdotter (2009); Badillo et al. (2011); Azadeh et al. (2012); Brecher (2013); Hildbrand & Bodhanya (2013); Ortiz & del Valle (2014);

	Stich & Groten (2015); Tavella & Papadopoulos (2015)
Health sector	Bachmann & Michel (2001); Monreal-Álvarez (2004); Midgley (2006)
Energy sector	Shaw et al. (2004); Terra et al. (2016)
Large companies (franchises)	Bröker (2005)
Start-ups	Crisan Tran (2005; 2006)
Waste Management	Dodis et al. (2005)
Communities of practice	Frost (2005)
Virtual companies	Grizelj (2005)
Communications media sector	Türke (2006)
Education sector	Ramírez et al. (2009); Oliveira (2010); Rojas & Tuesta (2011); Fitch et al. (2014)
Social organizations	Vargas & Alonso (2011); Espinosa & Walker (2013)

Table 1: Studies on the application of the VSM

In fact, although the socio-cybernetic theories enjoy greater recognition because of their theoretical plausibility, their principal criticisms are as follows: (1) their purely theoretical design, abstract nature, scant formalization and the inexistence of clear procedures for their application, complicating their empirical confirmation (Adam, 2001; Jackson & Flood, 1988); (2) the questionable analogy between the human brain and other organizations (Jackson, 2000); and, (3) their hierarchical layout, authoritarian nature and lack of flexibility, minimizing the importance of individuals that form part of an organization in favor of its structural design (Jackson, 1986; Thomas, 2006). This criticism, related to the scant importance of individuals, is especially sensitive to social systems such as a software project.

3 Research methodology

The research methodology was structured into three stages to achieve the objective of this work, by identifying the principal factors that have a decisive influence on the success of a software project structured upon the basis of the VSM. In the first place, the potential success factors were reviewed in the VSM-related literature (structural factors). Viability factors on project viability and success and complementary factors relating to specific aspects of the project were also defined. With all of these factors and the review of catalogues of existing questions (Bröker, 2005; Crisan Tran, 2005; 2006; De Raadt, 1987; Espejo et al., 1999; Frost, 2005; Herold, 1991; Jackson, 2003; Malik, 2002), a structured questionnaire[1] was designed by

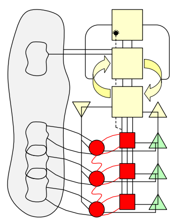
[1] Questionnaire is available on request from the authors.

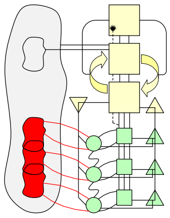
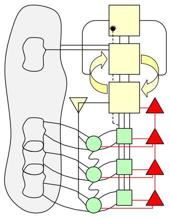
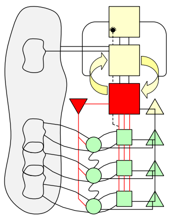
adapting the questions to the field of software projects. The responses were ordered by using a descending Likert scale (0 indicating the best qualification). This standardized measurement instrument, which has been developed and evaluated in terms of reliability and validity, allows us to detect the degree of compliance with the VSM-related requisites and the degree of success reached by a software project. A first version of the factors in use and the questions included in the questionnaire may be reviewed in Puche Regaliza et al. (2007).

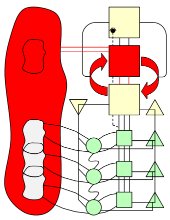
In second place, once designed, the questionnaire was used to gather information on 42 projects of different companies in the ICT sector in Castilla y León, through personal interviews with their respective project managers. The companies that were selected formed part of the Asociación de Empresas de Tecnología de la Información, Comunicaciones y Electrónica de Castilla y León (AETICAL) [Association of Information Technology, Communications and Electronics Companies of Castilla y León]. Specifically, the companies had reached a level of at least 3 of maturity in accordance with the Capability Maturity Model Integration (CMMI). The last completed project was analyzed in each of the companies.

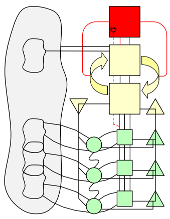
Data were collected over a period of approximately 6 months. From among the 42 companies selected, only 2 declined to participate, reaching an acceptance level of 95.24%. We consider this acceptance rate especially deserving, taking into account the extension of the interview (approximately 75 minutes), and the confidentiality and the complexity of the topic, which required a high level of detail and in-depth information on each of the projects and companies in the survey. In addition, from among the 40 remaining companies, 2 groups of 2 companies of each group reported about the same project, as it concerned consortium projects in which more than one company participated. Therefore, we finally gathered a total of 38 different projects.

The questionnaire included crossed control questions, with the objective of increasing the degree of validation of the factors obtained. Each set of questions with a similar semantic field was grouped into a single structural factor (Table 2), in the interests of greater clarity and in order to complete this study. The diagrams highlight the structural part linked to each factor in red.

Structural Factor	Description	Diagrams
Organizational Units (OUs)	Detection of the existence and the differentiation of the Organizational Units (OUs) (work environments, operational elements, work teams, etc.) in which a software project may be divided. For example: analysis of requirements, development of software, implantation of the system, etc. It also represents the autonomy of each organizational unit, detecting the existence of a function that is in charge of separately managing each OU. It detects whether each OU has acceptable channels of information and their degree of use, which permits correct communication between the different OUs and between each operational unit with its own management unit in charge of managing it within each OU. For example, there are meetings, reports, metrics, etc.	

Local Environment (LE)	The Local Environment (LE) detects the existence of various client parties and the way in which each party is related to an OU. In addition, the existence and the degree of utilization of appropriate information channels are reviewed so that each OU can obtain the necessary information from the client as required as well offer the client its own information. For example, meetings with the client, specific personnel to handle the client, forms, etc. It establishes whether the degree of communication with the different client parties is acceptable. In other words, whether there are periodic meetings between the different parties.	
Coordinating Mechanisms (CMs)	Coordinating Mechanisms (CMs) detect the existence and the degree of utilization of routine mechanisms aimed at facilitating the coordination of the activities carried out by the different OUs. For example, periodic meetings, definition of a process model, definition of templates, standards, safety conditions, working rules, norms, temporal programming, detailed plans, defined procedures, etc. Considering that the relation between the OUs is a dynamic one, in other words, that it varies over time, the existence and the degree of utilization of such different mechanisms as contingency plans are detected, which cushion the mismatches (i.e. delays) in the work that is carried out in each OU. It detects the degree of participation that the OUs have when designing these CMs together with the project manager and the degree of flexibility of these CMs. In other words, up to what point are the CMs adaptable in case some– OU finds itself in a stressful situation (budgetary, time and resource-related problems, etc.).	
Project Manager (PM)	This function establishes the extent to which the Project Manager (PM) is clear about being responsible for a global, integral, coherent view, etc. of all the OUs that constitute the project. It detects whether the PM has sufficient elements and to what degree they are used to develop the work in an effective way. For example, planning methods, methods of estimation etc. It detects whether each OU is totally clear that the operational guidelines, norms, policies, lines of action, etc., which the PM marks out are elements in favor of its cohesion and whether each OU is quite clear about the resources that are assigned by the PM and what activities it should develop. It detects whether some method and some degree of utilization exists, which permits the PM to confirm	

	whether the OUs do in effect fulfill what is asked of them. It detects whether the PM takes decisions or carries out activities that correspond to the OUs. It detects the degree of participation that the OUs have when agreeing the objectives of each one with the PM. It detects the degree of intervention required by the PM so that the OUs function in an harmonious way. It detects the degree to which the PM transmits technological and any other type of developments to the OUs. It detects whether the PM has specified “alarm thresholds” and a channel of information (and its degree of utilization), so that alerts will come from the OUs, in case those thresholds are exceeded. It detects the point to which there is clarity over the critical variables to be controlled by the PM, so as to ensure compliance with the project objectives. For example, costs, deadline and compliance with requirements. It detects the existence of an appropriate channel of information and its degree of utilization (in other words, up to what point the information it contributes is taken into account), which indicates the behavior of those critical variables and the discrepancies with the objectives. It detects the existence of audit mechanisms and random inspections over what is happening in the OUs, which inform PM about their behavior. For example, quality audits, working environment, etc. It detects the point to which the results of these mechanisms are taken into account to modify the behavior of the OUs. It detects the extent to which the OUs perceive these mechanisms as a sign of mistrust towards them more than as a service.	
Intelligent System (IS)	The Intelligent System (IS) detects the existence and the degree of utilization of a function in charge of supervising the project environment (formed of agents, actors, elements, etc., which can have an impact on the project). It detects the degree of necessity attributed to exploring the future evolution of the environment. It detects the existence of exploration mechanisms and their degree of use that allow us to evaluate possible alternative actions in the face of different future scenarios for the project. For example, simulation models, prospective studies, etc. It detects whether these exploration mechanisms permit an analysis of the evolution of relevant project variables over time and the amount of relevant variables it can analyze. It detects whether the PM is regularly informed of possible	

	changes in the environment, so that the PM is aware of the impact that they may have on the project. It detects the degree to which the PM uses the information that is transmitted to prepare the projects (the OUs) in view of those changes in favor of their adaption and flexibility. It detects whether the PM regularly informs this IS of the present situation of the project and to what degree the IS considers this information to carry out a correct inspection of the environment and its possible evolution. It detects whether tools exist and their degree of utilization that assists effective interaction between the PM and the IS. For example, meetings, collaborative working software, simulation models, etc. It detects the extent to which the PM is clear that the IS is a supporting element instead of a problem, constituting the organ for project adaption (in so far as the IS is aware of the future circumstances that will affect the project). It detects the extent to which the PM is considered of equal importance to the IS. It detects the extent to which the IS is sacrificed to reinforce the execution of the project faced with short-term demands on time, costs, compliance with requirements, etc.	
Identity Element (IE)	Identity Element (IE) establishes the existence of elements that allow the definition of the identity, the mission, the ethical code, goals, philosophy, intention, etc. of the project and the extent to which this IE are assimilated by all the integral parts of the project. It detects the degree to which this IE serves as assistance to resolve the conflicts that have not been resolved in another way between the PM and the IS. It detects the number of people or entities related with the project (stakeholders) that participate in the definition of this IE. It detects the point to which the previously defined IE is periodically examined and adapted, if necessary, during the project. It detects the existence and the degree of utilization of some formal or informal channel of information, from OUs to IE, which warn of any serious danger of project failure.	

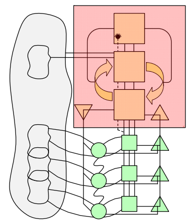
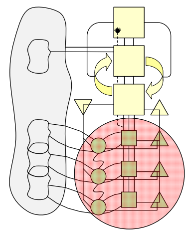
Next Higher Level of Recursion (NHLR)	The Next Higher Level of Recursion (NHLR) detects the degree of the relation between the software project and other company projects. It detects whether the PM has sufficient information of a general nature on the company and the degree to which it is taken into account; for example, information on the global strategy of the firm. It detects whether the objectives of the project are coherent with the general objectives of the company. It detects whether the IE of the project are coherent (are in harmony) with the IE of the company as a whole.	
Next Lower Level of Recursion (NLLR)	The Next Lower Level of Recursion (NLLR) detects whether the OUs are organized into smaller units with some level of autonomy. For example, the development of software is divided into analysis, design, implementation, systems of proof and error correction.	

Table 2: Structural Factors related to the VSM. Authors' own preparation based on Beer (1985)

In this way, we can link the conventional software projects success factors defined by Standish Group International with the structural factors defined by VSM. In Table 3, number and name of conventional factors, their description and the structural factors related are showed.

Number	Conventional factor	Description	Structural factor
(1)	Executive sponsorship	When an executive or group of executives agrees to provide both financial and emotional backing. The executive or executives will encourage and assist in the successful completion of the project.	Identify Element (IE) Next Higher Level of Recursion (NHLR)
(2)	Emotional maturity	Is the collection of basic behaviors of how people work together. In any group, organization or company it is both the sum of their skills and the weakest link that determine the level of emotional maturity.	Organizational Units (OUs) Coordinating Mechanisms (CMs) Project Manager (PM)
(3)	User involvement	Takes place when users are involved in the project decision-making and information-gathering process. This also	Local Environment (LE)

		includes user feedback, requirements review, basic research, prototyping, and other consensus-building tools.	
(4)	Optimization	Is a structured means of improving business effectiveness and optimizing a collection of many small projects or major requirements. Optimization starts with managing scope based on relative business value.	Project Manager (PM) Intelligent System (IS)
(5)	Skilled resources	Are people who understand both the business and the technology. A skilled staff is highly proficient in the execution of the project's requirements and deliver of the project or product.	Organizational Units (OUs) Project Manager (PM) Intelligent System (IS)
(6)	Standard architecture	A consistent group of integrated practices, services, and products for developing, implementing, and operating software applications.	Coordinating Mechanisms (CMs)
(7)	Agile process	Means that the agile team and the product owner are skilled in the agile process. Agile proficiency is the difference between good agile outcomes and bad agile outcomes.	Coordinating Mechanisms (CMs)
(8)	Modest execution	Is having a process with few moving parts, and those parts are automated and streamlined. Modest execution also means using project management tools sparingly and only a very few features.	Next Lower Level of Recursion (NLLR)
(9)	Project management expertise	Is the application of knowledge, skills, and techniques to project activities in order to meet or exceed stakeholder expectations and produce value for the organization.	Project Manager (PM) Intelligent System (IS) Identify Element (IE)
(10)	Clear business objectives	Is the understanding of all stakeholders and participants in the business purpose for executing the project. Clear Business Objectives could also mean the project is aligning to the organization's goals and strategy.	Project Manager (PM) Identify Element (IE) Next Higher Level of Recursion (NHLR)

Table 3: Connection between the conventional software projects success factors and the structural factors. Authors' own preparation.

With regard to the viability factors, the degree of global success of the project (Overall Project Succcess - OPS) and the degree of overall success in terms of cost compliance (Successful Compliance with Costs - SCC), deadline (Successful Compliance with Deadline SCD) and initially established requirements (Successful Compliance with Requirements - SCR) are all detected. The complementary factors were set aside in this study, due to the number of projects that were surveyed.

Finally, in third place, quantitative multivariate analysis techniques were used to analyze the resulting factors and the available data in an exploratory manner (Backhaus et al., 2006; Tabachnick & Fidell, 2007), identifying the causal relations between independent variables (structural factors) and the dependent variable (viability factors) through a multiple regression (Shook et al., 2004). In particular, the Ordinal Logistic Model (Hosmer & Lemeshow, 2000; Tabachnick & Fidell, 2007)[2] was used. The correlations matrix and the Variance Inflation Factors (VIFS) of the explanatory variables of the model are shown in Table 4. Despite the structural factors of the next lower level of recursion (NLLR) and identity element (IE) showing a significant correlation –greater than 0.7 for small samples- (Feintein, 1985), we decided to include them in the study, as all the values obtained for the VIFs are below the halfway level of 10 recommended by Neter et al. (1985), Kennedy (1992) and Studenmund (1992) as well as the stricter limit of 5.6 proposed by Hair et al (1999), indicating the global adaption of the model, which allows us to affirm that there are no serious problems of multicollinearity.

Correlation and VIFs: NHLR; NLLR; LE; OUs; CMs; PM; IS; IE

	NHLR	NLLR	LE	OUs	CMs	PM	IS	IE	VIF
NHLR	1.000								1.19
NLLR	0.241	1.000							3.63
LE	0.039	-0.095	1.000						1.24
OUs	0.110	0.260	-0.233	1.000					1.36
CMs	0.175	-0.212	-0.005	-0.011	1.000				1.30
PM	-0.086	0.097	-0.211	0.338	0.063	1.000			1.23
IS	0.238	0.172	0.261	0.199	0.312	0.005	1.000		1.57
IE	0.318	0.829	-0.065	0.318	-0.083	0.013	0.355	1.000	4.06

Cell Contents: Pearson correlation

Mean VIF 1.95

Table 4: Correlations matrix and Variance Inflation Factors (VIFs)

4 Results

Having analyzed the data, we moved on to evaluate the results for the global success viability factor (OPS), which may be seen in Table 5. The low p-value (0.001) of the global significance test (Test that all slopes are zero) allowed us to reject the hypothesis that the

[2] The Minitab v.17 statistical software package was used. (http://www.minitab.com/es-mx/).

coefficients of all the explanatory variables are zero, concluding that at least one of the regression variables has an effect on global success. The probabilities of the values that represent this classification occurring will therefore vary for some of the combinations of the independent variables (Hosmer & Lemeshow, 2000). The Goodness-of-Fit tests showed no evidence pointing to a lack of adjustment (the null hypothesis was accepted as the p-value was higher than the level of significance[3]). This result means that the probabilities of the dependent variable values occurring, which are estimated with the model for the different combinations of independent variables, are not significantly different from the frequency with which the values of the dependent variable occur in sample for those same combinations (Hosmer & Lemeshow, 2000; Nagelkerke, 1991).

Ordinal Logistic Regression: OPS versus NHLR; NLLR; LE; OUs; CMs; PM; IS; IE

Link Function: Logit

Response Information

Variable	Value	Count
OPS	0	5
	1	25
	2	3
	3	4
	4	1
	Total	38

Logistic Regression Table

					Odds	95% CI	
Predictor	Coef	SE Coef	Z	P	Ratio	Lower	Upper
Const(1)	0.232068	1.13733	0.20	0.838			
Const(2)	5.81461	1.65724	3.51	0.000			
Const(3)	6.72019	1.74538	3.85	0.000			
Const(4)	10.7588	3.27365	3.29	0.001			
NHLR	0.0669226	1.27328	0.05	0.958	1.07	0.09	12.97
NLLR	-0.178838	0.800542	-0.22	0.823	0.84	0.17	4.02
LE	-0.711734	0.273246	-2.60	0.009	0.49	0.29	0.84
OUs	-0.483546	0.209933	-2.30	0.021	0.62	0.41	0.93
CMs	-1.91091	1.14612	-1.67	0.095	0.15	0.02	1.40

[3] A level of significance of 5% is considered in the whole study.

PM	**0.0887566**	**0.291353**	**0.30**	**0.761**	**1.09**	**0.62**	**1.93**
IS	**-0.613534**	**0.266017**	**-2.31**	**0.021**	**0.54**	**0.32**	**0.91**
IE	**-0.0408964**	**0.495820**	**-0.08**	**0.934**	**0.96**	**0.36**	**2.54**

Log-Likelihood = -27.041

Test that all slopes are zero: G = 27.655. DF = 8. P-Value = 0.001

Goodness-of-Fit Tests

Method	**Chi-Square**	**DF**	**P**
Pearson	**63.9249**	**120**	**1.000**
Deviance	**45.7634**	**120**	**1.000**

Table 5: Ordinal Logistic Model for the global success viability factor (OPS)

The Z values of the Wald statistic associated with each independent variable and its corresponding p-value allow the individual significance of the explanatory variables to be analyzed (Hosmer & Lemeshow, 2000), such that we can consider that the local environment (LE) (0.009), the organizational units (OUs) (0.021), and the intelligent system (IS) (0.021) have a significant relation with the global success of the project (OPS).

The coefficients of the structural factors with negative values have lower odds ratios than one, indicating that increases in these factors increase the probability of obtaining higher and therefore worse results (when using a decreasing scale) for the viability of global success (OPS). This affirmation is made by observing the fact that for the odds ratio to be lower than one, a unitary increase in the factors should provoke a reduction in the cumulative probability ratio of all the values that the global success can take (OPS). If by increasing the factors value, the cumulative probability decreases for any of the values, then there is a greater likelihood of higher values occurring. The fact that the confidence interval of 95% for the odds ratio does not include one, means that we can affirm, with a probability of being mistaken of under 0.05, that the fall in the cumulative probability ratio caused by the increase in the factors is significant (Agresti, 1990; Hosmer & Lemeshow, 2000). In this sense, the value of 0.54 of the odds ratio of the IS factor indicates that a unitary increase in this factor simultaneously increases by up to 54% the probability that the global success of the project will increase any of its values by one unit. In the same way, the LE and OUs factors show values of 0.49 and 0.62, respectively, for their odds ratios.

These results were also obtained for the other viability factors. In particular, for the successful compliance with costs (SCC), a p-value of 0.004 was obtained for the total significance test, values of 0.565 and 0.994 for the Goodness-of-Fit tests, and the project manager (PM) factor obtains, as a significant structure factor, a p-value of 0.011 and an associated odds ratio of 0.51. A p-value of 0.032 was obtained for the total significance test of the successful compliance with deadline (SCD), while the Goodness-of-Fit values were 0.436 and 0.966. The project manager (PM) and the coordinating mechanisms (CMs) were the significant structural factors with p-values of 0.035 and 0.028 and an associated odds ratio of 0.61 and 0.15, respectively. Finally, for the successful compliance with requirements (SCR), a p-value was obtained for the total significance test of 0.030, while the Goodness-of-Fit tests yielded values of 0.752 and 0.997. The local environment (LE) and the organizational units (OUs) were obtained as significant structural factors with p-values of 0.032 and 0.030 and some associated odds ratios of 0.66 and 0.70, respectively.

Therefore, in a practical way, if a manager, who structures a software project based on VSM, wants to increase the probability of overall project success (OPS) he places special emphasis on strengthening the local environment (LE), organizational units (OUs) and the intelligent system (IS). If what the manager wants to improve is the success compliance with cost (SCC) he has to strengthen the factor project manager (PM). If what he wants to improve is the success compliance with deadline (SCD) he has to reinforce the factors project manager (PM) and coordinating mechanisms (CMs). Finally, if what the manager wants to improve is the success compliance with requirements (SCR), he has to strengthen the factors local environment (LE) and organizational units (OUs). See Table 3 to find the relationships between the factors based on the VSM and the classic success criteria of a software project.

In addition, the results allow us to define a mathematical prediction model to predict and to estimate the probability of success or failure of a project (viability factor) based on values that take the aforementioned significant structural factors. The model associated with the global success viability factor (OPS) may be represented by the following equation:

$$P(project\ success\ \leq category\ i\ /\ value\ of\ factors) = \frac{\left(e^{\alpha_i+\beta X}\right)}{\left(1+e^{\alpha_i+\beta X}\right)}$$

$$P(project\ success \leq category\ i\ /\ value\ of factors) = \frac{\left(e^{\alpha_i+(-0.71*valueLE-0.48*valueOUs-0.61*valueIS)}\right)}{\left(1+e^{\alpha_i+(-0.71*valueLE-0.48*valueOUs-0.61*valueIS)}\right)}$$

In the evaluation of the effectiveness of the model, the first category was considered to be 0 (very good), the second was 1 (good), the third was 2 (regular), the fourth was 3 (bad) and the fifth category was 4 (very bad). We took the intercepts associated with each of the categories of the dependent variable from Table 5, in such a way that α_1=0.23; α_2=5.81; α_3=6.72 and α_4=10.76. As a prognosis for the success of the project, we selected the category that offers a higher probability. The results obtained for the 38 projects that constitute part of the study may be seen in Table 6.

Proj.	Prob. of 0	Prob. of 1	Prob. of 2	Prob. of 3	Prob. of 4	Prognosis	OPS	RESULT
1	0.55725	0.43976	0.00178	0.00118	0.00002	0	1	ERROR
2	0.55725	0.43976	0.00178	0.00118	0.00002	0	0	ACCURATE
3	0.02847	0.85748	0.06479	0.04835	0.00091	1	1	ACCURATE
4	0.10248	0.86554	0.01886	0.01289	0.00023	1	1	ACCURATE
5	0.05841	0.88426	0.03343	0.02346	0.00043	1	2	ERROR
6	0.55725	0.43976	0.00178	0.00118	0.00002	0	0	ACCURATE
7	0.02231	0.83584	0.07947	0.06122	0.00117	1	1	ACCURATE

8	0.01927	0.81963	0.08935	0.07040	0.00136	1	1	ACCURATE
9	0.05841	0.88426	0.03343	0.02346	0.00043	1	1	ACCURATE
10	0.03261	0.86674	0.05754	0.04232	0.00079	1	1	ACCURATE
11	0.55725	0.43976	0.00178	0.00118	0.00002	0	1	ERROR
12	0.01630	0.79827	0.10149	0.08233	0.00161	1	1	ACCURATE
13	0.03489	0.87062	0.05418	0.03957	0.00074	1	1	ACCURATE
14	0.01927	0.81963	0.08935	0.07040	0.00136	1	1	ACCURATE
15	0.00016	0.03939	0.05325	0.76042	0.14679	3	4	ERROR
16	0.00265	0.41073	0.22307	0.35360	0.00995	1	3	ERROR
17	0.00171	0.31046	0.21780	0.45467	0.01537	3	3	ACCURATE
18	0.38225	0.61169	0.00361	0.00240	0.00004	1	1	ACCURATE
19	0.00097	0.20327	0.18512	0.58378	0.02686	3	1	ERROR
20	0.01477	0.78422	0.10905	0.09018	0.00178	1	3	ERROR
21	0.02960	0.86033	0.06265	0.04655	0.00088	1	1	ACCURATE
22	0.00265	0.41073	0.22307	0.35360	0.00995	1	2	ERROR
23	0.01056	0.72829	0.13660	0.12206	0.00250	1	1	ACCURATE
24	0.03261	0.86674	0.05754	0.04232	0.00079	1	1	ACCURATE
25	0.05315	0.88388	0.03663	0.02586	0.00048	1	1	ACCURATE
26	0.17222	0.80997	0.01056	0.00712	0.00013	1	0	ERROR
27	0.55725	0.43976	0.00178	0.00118	0.00002	0	1	ERROR
28	0.01630	0.79827	0.10149	0.08233	0.00161	1	1	ACCURATE
29	0.10248	0.86554	0.01886	0.01289	0.00023	1	1	ACCURATE
30	0.00265	0.41073	0.22307	0.35360	0.00995	1	3	ERROR
31	0.55725	0.43976	0.00178	0.00118	0.00002	0	1	ERROR
32	0.40613	0.58839	0.00327	0.00218	0.00004	1	1	ACCURATE
33	0.01927	0.81963	0.08935	0.07040	0.00136	1	2	ERROR
34	0.02960	0.86033	0.06265	0.04655	0.00088	1	0	ERROR
35	0.15578	0.82419	0.01187	0.00802	0.00014	1	1	ACCURATE

36	0.10248	0.86554	0.01886	0.01289	0.00023	1	1	ACCURATE
37	0.10248	0.86554	0.01886	0.01289	0.00023	1	1	ACCURATE
38	0.55725	0.43976	0.00178	0.00118	0.00002	0	0	ACCURATE

Table 6: Effectiveness of the mathematical prediction model for the global success of a software project

As may be seen, from among the 38 projects with a prognosis, there were 24 correct predictions and 14 errors; in other words, a prediction accuracy rate of 63.16%. This accuracy rate may be considered acceptable, especially in view of the exploratory nature of the study and the number of projects that were surveyed.

This means that managers can predict the viability of the software project they are managing, with a 63.13% probability of guessing their forecast, simply by knowing the characteristics of the key factors, i.e. local environment (LE), organizational units (OUs) and intelligent system (IS). For example, suppose project number 7 (Table 6). The value set for local environment (LE) was 0 (very good), for organizational units (OUs) was 2 (regular) and for intelligent system (IS) was 4 (very bad). With these characteristics for the key factors, the manager can predict with a 63.13% probability of guessing that the viability of his project will take the value 1 (good), which in this case coincides with the actual value of the project viability considering the response of the manager surveyed.

This same process to obtain a prognostic model and its effectiveness may be applied to the other viability factors, considering that for the degree of success with regard to cost compliance (SCC), the significant structural factor was the project manager (PM); for the degree of success with regard to compliance with deadline (SCD), the significant structural factors were the project manager (PM) and the coordinating mechanisms (CMs); and, finally, for the degree of success with regard to compliance with requirements (SCR), the significant structural factors were the local environment (LE) and the organizational units (UOs).

Moreover, we would like to highlight the importance detected in the success of the global project in relation to the balance between internal control of the organization (software project) through coordination with the different organizational units and their relation with the client (OU and LE), and external control, with the importance of supervision of the environment, both the present environment and the future environment that the project will have to face (IS). With regard to the success of the project, based on cost compliance (SCC), the importance of the project manager (PM) stands out, which is in charge of setting the guidelines for action, of assigning the resources and the corresponding accountability to different organizational units and, in consequence, of balancing the budget thanks to a global, integral, coherent and cohesive vision of the project as a whole. With regard to compliance with deadline (SCD), as well as the project manager (PM), the coordinating mechanisms (CMs) also appear as a significant structural factor that cushion the disruption that can occur between the organizational units (OUs), thereby avoiding possible delays to the project. In these last two cases (cost and deadline), the greater importance within the project than in its environment stands out. Finally, with regard to compliance with requirements (SCR), the importance of client relations stands out (EL and OUs), with the main objective of complying with their functional needs.

We would also underline the absence in all models of any influence of the following factors: next higher level of recursion (NHLR), next lower level of recursion (NLLR) and identity element (IE), which indicates a certain degree of independence between the success of the project and the success of the firm that develops various projects and between the internal functioning of each part of the project with its overall functioning. This result appears striking in contrast with the necessary alignment between the results of an organization and its strategy (Crawford et al., 2006) and between its strategy and the management of its projects (Cooke-Davies et al., 2009), leading to acceptable management of the firm's portfolio of projects (Kwak & Anbari, 2009a). Management of the portfolio has emerged over recent years as part of a strategic, dynamic and systemic organizational governance, pointing to the organization and management of resources, to ensure the return on a strategically aligned set of investments (Kwak & Anbari, 2009b).

5 Conclusions and possible research lines

The development of projects that stay within the initially budgeted costs, the initially estimated deadline, and that comply in a sufficient manner with the established requirements, is one of the principal challenges pursued in the field of project management and administration, in general, and in the field of software projects, in particular. The successful achievement of these objectives may be conditioned by compliance with a series of factors that have been widely studied in the literature. Even so, the increase in the percentage of successful projects is in no way sufficient. There is therefore a need to develop new contributions that allow this percentage of success to increase.

In this work we have offered a new systemic approach to the organizational structure of a software project. The application of the Viable System Model to that structure means the necessary and sufficient conditions may be defined so that a software project is viable. In consequence, the identification of the most influential factors in the viability or the success of software projects structured upon the Viable Systems Model allows us to reinforce them in favor of that viability, thereby contributing to the reduction of the number of failed projects. A quantitative exploratory empirical analysis was performed to validate this proposal, on the basis of the data taken from a survey of a series of software projects developed by different ITC firms in Castilla y León (Spain). The novelty of this study is therefore principally found in the application of the Viable System Model to the organizational structure of a software project in such a way that it allows us to detect key factors in its success. Besides, building on the validation of this proposal through the completion of a quantitative empirical analysis, this study also offers a prediction mathematical model that relates key factors with the success of the project.

The results have indicated that the most influential factors in achieving the global success of a software project structured upon VSM are the local environment (LE), the organizational units (OUs) and the intelligent system (IS). These conclusions coincide with those of Puche Regaliza (2015), where the significant influence of Systems One and System Four stand out when achieving successful software projects, by contrasting a hypothesis with a Structural Equations Model, confirming, at least partially, the positive influence of the application of VSM on the success of a software project.

In this way, structuring a software project based on VSM allows us to relate all its components in a scientific and systemic way, thus offering the main difference with the classic structure of a software project. In addition, three of these components have been highlighted as key factors in improving their viability. Managers of a software project that apply the VSM to their projects and ensure the existence and proper functioning of the local environment (LE), organizational units (OUs) and intelligent system (IS) factors, will manage viable software projects and as a consequence will help to improve the number of successful projects.

In addition, the results have allowed us to define a mathematical prediction model that both predicts and estimates the probability of success or failure of the project (viability factor), on the basis of the values taken by the significant structural factors, obtaining a prediction accuracy rate of 63.16%. This accuracy rate may be considered acceptable, especially in view of the exploratory nature of the study and the number of projects in the survey.

We wish to point out that due to the number of projects employed in the statistical analysis, the results have to be interpreted with caution and are of an exploratory nature. We will present a series of possible future research lines to reduce this level of caution and to maintain the scientific progress commenced in this work, which lead to its evolution and improvement.

Firstly, we believe it necessary to develop additional studies in the field of software projects, to extend the reliability of the results that we have obtained and to increase them. We consider it advisable to enlarge the number of projects that are surveyed, so as to allow us, on the one hand, to employ statistical techniques that offer confirmatory results and that verify the hypotheses arising from theory and, on the other hand, to segment the number of projects, taking aspects such as size and type of software project into account and subsequently analyze each segment. We propose to improve the instrument of measurement that is used to complete this first line of work, as some aspects of the VSM have not been dealt with in detail.

A second line of research is proposed to carry out the same work completed at the software project level, at adjacent recursive levels. In particular, we propose to perform the design and subsequent empirical validation of the next higher level of recursion, i.e. the organization that manages various software projects, where each one represents an operational element of System One and in the same way, to perform the design and subsequent empirical validation of the next lower level of recursion; i.e. each operational element that comprises System One.

In third place, we propose the completion of a personalized diagnosis for each of the projects that participated in the study (a global diagnosis may be seen in Puche Regaliza, 2014a). This proposal was outlined in the letters of presentation sent to the companies, which served as an incentive, in a disinterested way, to achieve their participation in the study.

Finally, we think that it could be of interest to extend this study to other different fields of software production, such as engineering and architecture, where the project-based activities are also common.

With these conclusions and possible lines of research, we seek to show that the VSM is an extremely useful tool for the management of software projects and, by extension, projects of a general nature. We therefore suggest that knowledge of VSM would be of incalculable value for managers wishing to manage projects successfully and to survive in such a complex and rapidly changing environment as the software project environment is. Its application allows us to diagnose and to detect the critical factors to achieve such success[4]. In addition, the research seeks to increase the universality of VSM, contributing to a better understanding of it and a better and greater formalization of it in favor of its acceptance and its practical use, seeking in this way to palliate some critical principals related with its abstraction and limited

[4] See Puche Regaliza (2014b), to consult a detailed reference for diagnosis and design of the organizational structure of a software project with marked characteristics of viability.

applicability and to increase its rigor and validity as an instrument for the diagnosis and the design of viable organizations.

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