

Selection Criteria for Software Engineering Tools in Small and Medium Enterprises (SMEs)

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Abstract. Software-developing Small and Medium Enterprises (SMEs) must make investment with little resources and usually under severe pressure driven by competitiveness and productivity needs. From the study of the characteristics of software-developing SMEs and the changes affecting Software Engineering Tools (SETs), we aim at proposing criteria to support them in the evaluation and selection of tools that best suit their needs. These criteria have been formulated based on ISO/IEC 14102, by adopting their guidance on the assessment and selection process. For validation purposes we applied these criteria to three SETs. We expect these criteria to provide support to the establishment of selection models.

Keywords: SMEs, tools, software engineering, selection criteria, tools selection.

1 Introduction

Small and Medium Enterprises (SMEs) share characteristics that clearly distinguish them from large organizations being translated into restrictions for the selection of Software Engineering Tools (SETs). SMEs require facilities from SETs to work under these conditions. SETs are constantly increasing in number and have various scopes, thus adding complexity to the selection process. The SMEs characteristics and the changes in SETs affect the decisions of managers, who must make investments with little resources under competitive and productivity pressures.

The formulation of selection criteria for SETs assessment is described in the DESMET methodology [1] and ISO/IEC 14102 [2]. Although this assessment is clearly contextual; however there is no evident consensus as to the criteria to be used, given the complexity of the aspects involved in each organization's context. Furthermore, difficulties for the application of standards in small projects have been identified [3] and certain criteria have been proposed for specific Software Engineering (SE) domains [4, 5]; however, they are not targeted to organizations with particular characteristics such as SMEs [3]. As part of a broad scope project, we have worked recently on the identification of general criteria, in the context of Venezuelan SMEs, based on the agility - discipline factors proposed by Boehm [6].

This work proposes a more detailed set of criteria that support SMEs in their SETs' selection, which are applied to three SETs for validation purpose. These criteria are

aimed at guiding the decision making regarding the acquisition of one or more SETs, and as basis for establishing selection models. In section 2 we describe a contextual frame for this type of companies; we define the characteristic and changing factors of SETs in section 3 in order to identify their lacks and possibilities for support that are closely linked to the reality of SMEs. Based thereon, in section 4 we propose a set of criteria which are applied to three SETs in section 5.

2 Small and Medium Enterprises (SMEs)

In order to provide a new framework to define the context of SMEs, we have arranged a set of characteristics to define them in terms of: (a) people; (b) availability of financial resources; (c) organization and development process; and (d) communication.

People. SMEs face restrictions to hire experts [7]. They have *few employees*, yet perform the same range of activities than large organizations [8, 9]. People usually play *multiple roles* [9] and constitute multidisciplinary teams. In addition, establishing *distributed* teams helps them to fulfill their responsibilities even when working *part time* or *remotely*. Employees work under *time pressure*, which translate into higher standards as to their capacities for *management* and *information technology* (IT) [6]. Both areas' needs are reflected in the lack of information on available technologies, *little experience in IT adoption*, and *managers' scarce motivation to invest* in such fields, etc. [10]

Financial resources. SMEs are known for having limited financial resources [11], but they usually make *alliances and arrange to form networks* in order to compete in large projects at national and international level. SMEs *must be efficient* in the use of resources. To take greatest advantage of their personnel, they concentrate their efforts on developing *products aimed at filling in market gaps* [12] left by other companies; creating components for software products developed by companies, and providing services or maintenance produced by them or other companies [8]. Frequently, SMEs apply a *strategy that is much more focused on the product* than on individual contracts [9, 11].

Organization and development process. People work in *organizational structures that are generally flat or have few hierarchical levels*, where workflow is flexible and mostly governed by the needs of the moment [10, 12]. Roles are played according to *informality of the personnel relationships* and *informality of the infrastructure* supporting their activities. Hence, SMEs usually have *flexible development processes* adapted to their needs and barely defined [11], which are generally *adapted* to the characteristics of these organizations. *Change management* is also a strategic aspect for SMEs, since changes may significantly affect their budget. Consequently, they try to minimize risks by keeping contact with the client since the first stage of the development process and by leaning on the performance of *continuous iterations* [9, 11].

Communication. Flat structures and few hierarchical levels allow for a dynamic information flow among people. SMEs' decisions entail a subjective component fostered by the communicational flow, which is both dynamic and inaccurate, given

the weaknesses of rule definition [6]. This fluency in communications can be seen in how SMEs relate to their environment. Productivity pressures exerted by clients lead to regular communication between them and SMEs, which supports certain company practices such as frequent deliveries and incremental development. Fig. 1 provides a model for UML concepts including the characteristics aforementioned and the critical factors derived thereof.

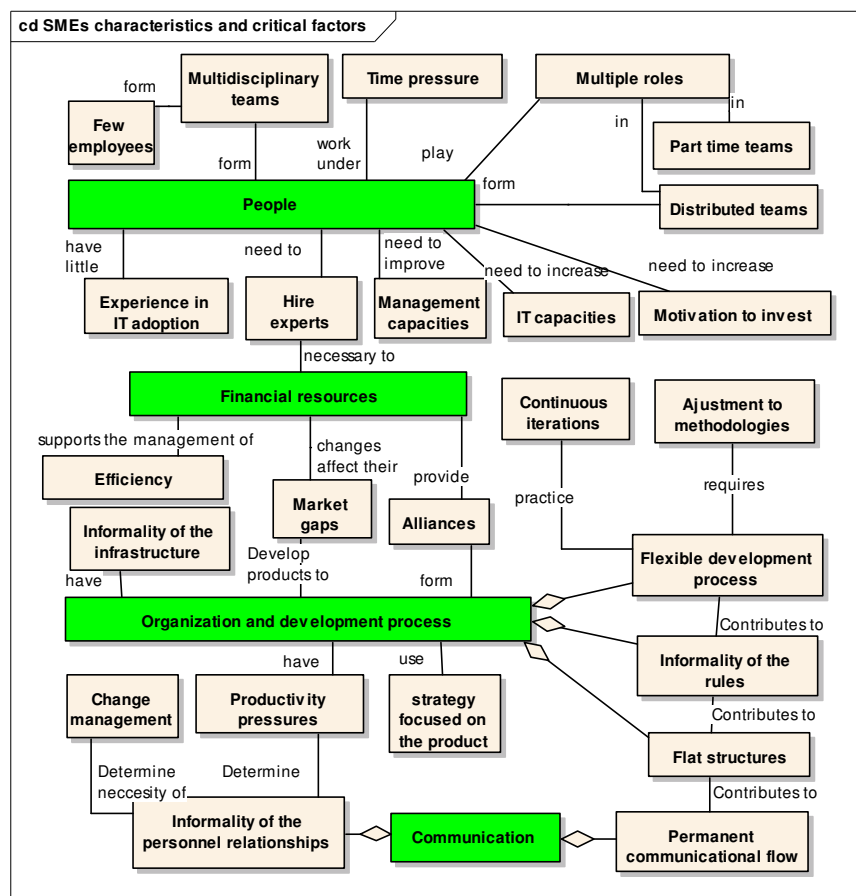


Fig. 1. Characteristics of SMEs and critical factors derived thereof.

3 Software Engineering Tools

Once the SMEs' context is established, the next step is to identify the SETs' context. These tools are mainly designed to support tasks and processes during the lifecycle of

software development systems and provide support that translates into improvements in quality and productivity of systems design and development [13, 14]. However, several changes are affecting SETs, which leads organizations to find more difficulties in their selection. This reality is even more complex for SMEs.

SETs are constantly increasing in number and scope. Expectations towards them are becoming more demanding as a consequence of new software development methods and processes, growth of multidisciplinary teams, needs for effective metadata exchange, development of information visualization, collaboration requirements, increased distributed applications, etc. [15, 16, 17]. Table 1 shows a summary of the support provided by SETs [18], together with their main changing areas [15, 16, 17].

Table 1. Support of SETs and change areas affecting them.

SE topics dealt with by SETs	Changes affecting SETs
<i>Software requirements tools:</i> requirements modeling, requirements traceability <i>Software design tools:</i> design specification and modeling <i>Software Construction tools:</i> program editors, compilers and code generators, interpreters, debuggers <i>Software maintenance tools:</i> comprehension, reengineering <i>Software configuration management tools:</i> defect, enhancement, issue and problem tracking, version management, release and build <i>Software Engineering Management tools:</i> project planning and tracking, risk management, measurement <i>Software engineering process tools:</i> process modeling, process management, integrated CASE environments, process-centered software engineering environments <i>Software testing tools:</i> test generators, test execution frameworks, test evaluation, test management, performance analysis <i>Software quality tools:</i> review and audit, static analysis.	Support to new software development methods and processes Support to shared, distributed and multidisciplinary work teams Need for effective metadata exchange New developments on information visualization Support to collaborative work Increase in distributed applications

4 Proposed Criteria for Tool Selection in SMEs

This work has been oriented by the evaluation and selection process defined in ISO/IEC 14102 [2], which relates to the establishment of criteria upon management consensual decision to tool acquisition.

After having analyzed the context of the SMEs and having presented the possibilities for tool support and their change trends, we can now identify the needs of SMEs. Some of them can be summarized as follows:

- The importance of risk management, organizing team efforts, efficient resource management, and effective response to productivity demands determine the needs for support to *project management*.
- The flexible nature of the client-oriented development processes at SMEs, adapted to project needs and company's own capabilities, determines SMEs' needs for support to *the development process*.

- Difficulties to hire and train personnel, and the fact that the personnel play multiple tasks in different roles, under time pressures, determine the need for SETs that help users *understanding supported tasks and their proper use*.
- Formation of distributed teams, Internet and groupware availability, informality in the infrastructure, and global trends towards collaborative work determine SMEs' need for support to *collaboration and communication*.

All these needs are related to the elements that we identify in our initial analysis. Fig. 2 provides an overview of the relations among the main groups of proposed criteria, the critical factors of SMEs which were summarized in Fig. 1, and the main needs that can be supported by SETs.

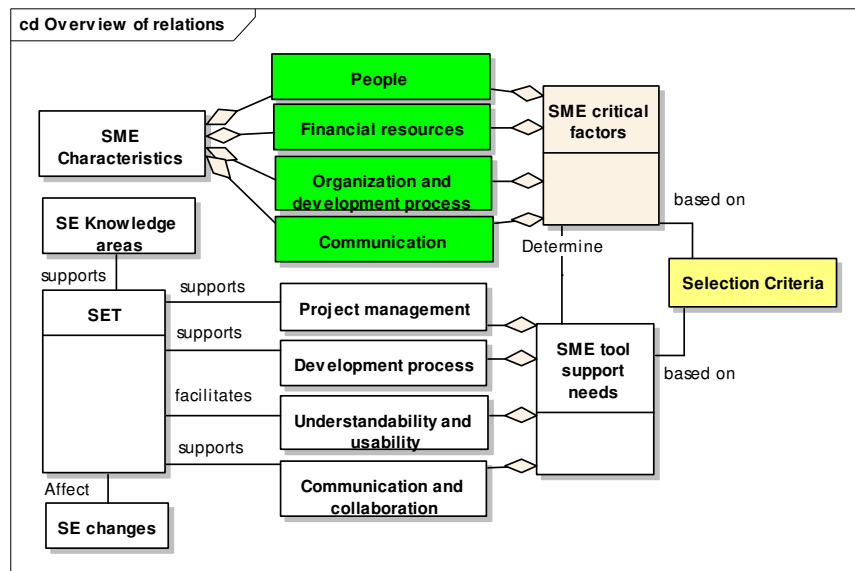


Fig. 2. Overview of relations among the proposed criteria, the critical factors of SMEs and their main needs.

Criteria for flexible project management. SMEs need to efficiently and effectively channel their efforts. Their decisions entail a qualitative component that may negatively affect financial resources management or people's efforts planning. Frequently, they lack historical cost/time records to support new project planning. *Effort items* records may help supporting planning of activities. *Project resource and time estimations* may support the efficiency of the development process. The support to *project planning and tracking* will create opportunities for SMEs to manage projects through flexible, efficient and objective decisions based on the use of *metrics* or *risk items*.

Criteria for development process support. SMEs' development process is flexible. The possibility of counting on a tool that allows *adjusting to the SMEs process* is of special relevance. Communication with clients is permanent, usually

need SETs that are easy to learn so to incorporate them to their daily work and obtain rapid benefits. Consequently, we have also proposed criteria for *Flexibility in information visualization*. Lastly, we have proposed criteria to determine *Tool usability*. This support contributes to minimizing the technological adoption barriers that characterize SMEs.

Criteria for communication and collaboration support. Equipment at SMEs requires the possibility of working from different locations. Support to communication would help allocating project progress [7]. Collaborative requirement engineering represents an advantage to SMEs, since it adapts to people's configuration [19]. Accordingly, we have proposed criteria for *Support to collaboration in requirement management*. Support to collaborative work would allow for joint preparation and modification of documents; therefore we have proposed criteria for *Support to collaboration in the documentation*. Lastly, available and affordable technologies such as Internet and groupware make of information and data exchange at work teams an easy, feasible, and efficient task; therefore, we have proposed criteria for support to *team communication*. After having introduced these criteria in general terms, we will describe the results of their application on three SETs. In Section 5, we will also present all proposed criteria in detail.

5 Initial Application of Proposed Criteria on Three SE Tools

For validation purposes, selection criteria were applied on three representative SETs: *Enterprise Architect 7.1* (EA), *StarUML 5.0* (SU), and *Visual Paradigm* (VP) – specifically, the *VP products for UML 3.2* and *VP Teamwork Server 3.2*. We identified EA and VP from the list of suppliers of OMG [20]; and SU, for being a free-access open source tool [21]. The results are shown in Table 2.

According to information provided at the supplier's websites, EA is a modeling and construction tool; SU focuses on modeling; and VP products are oriented to modeling, construction and support to equipment operating in a simultaneous and integrated manner. Differences in their scope must be considered for purposes of objective comparison. If a SME requires support in one activity or process, then the criteria relating to such activities will become more relevant. Likewise, decision makers may consider possibilities of support in other activities to take maximum advantage of the investment made.

Flexible project management criteria were fully satisfied by EA, as opposed to the rest of the tools, which did not meet any of these criteria. This reveals EA's potential for a SME with remarkable needs in this area (during our work, we consulted VP technical service as to the lack of support to project management and we were informed that this functionality would be added shortly). On the other hand, VP accounted for the highest satisfaction percentage of development process support (94.11%), followed by EA (77.77%) and SU (11.11%). This is mainly due to support to modeling and version control. Criteria relating to tool understandability and usability showed a 100% satisfaction for EA, 87.5% for SU, and 100% for VP. This shows that vendors concentrate their efforts on characteristics increasing usability, which is a relevant aspect within the SMEs context.

Table 2. Application of selection criteria on three SETs.

CRITERIA		EA	SU	VP		
FLEXIBLE PROJECT MANAGEMENT	Project resource and time estimation	√				
	Planning	√				
	Project tracking	√				
	Risk items	√				
	Effort items	√				
	Attaching custom metrics	√				
DEVELOPMENT PROCESS SUPPORT	Adjustment to SME's Process	Flexible selection of activities and diagrams	√	√	√	
		Orientation and follow-up during the development process				
	Modeling	Diagram development	√	√	√	
		Prototyping			√	
		Requirement analysis	√		√	
		Requirement specification	√		√	
		Requirement modification	√		√	
		Requirement import	√		√	
		Requirement organization	√		√	
	Version Control	Requirement traceability	√		√	
		Access control	√		√	
		Local copy updating	√		√	
		Commit to project changes	√		√	
		Modification control	√		√	
		Comparison of versions			√	
		Detection of conflicts between versions			√	
	TOOL UNDERSTAND ABILITY AND USABILITY	Documentation Flexibility	Support to DBSM-based repositories	√		√
			Flexibility in data transfer	√		√
Reports based on forms			√	√	√	
Information Visualization Flexibility		Reports in different formats	√	√	√	
		Facilities to <i>copy and paste</i>	√	√	√	
		Arrangement of windows	√		√	
		Save and restore custom window layouts	√		√	
		Customization of toolbars and menus	√	√	√	
		Links between models	√		√	
		Search facilities	√	√	√	
Tool Usability		Color options	√	√	√	
		Diagrams in different formats	√	√	√	
	User friendliness	√	√	√		
	User guidance	√	√	√		
	Homogeneity	√	√	√		
Requirement Management	Adaptability	√	√	√		
	Conciseness	√	√	√		
	Easy of learning	√	√	√		
COMMUNICATION AND COLLABORATION SUPPORT	Requirement Management	Remote requirement modification			√	
		User notification services				
	Documentation Collaboration	Create requirement views for remote access			√	
		HTML reports	√		√	
		Collaborative artifact editing				
	Team Communication	Document updating and download			√	
		E-mail				
		Chat capabilities				
Group management.			√			

For support to communication and collaboration, less favorable results were obtained: 11.11% for EA; 0% for SU, and 55.55% for VP. Based thereon, it is very likely that a SME, whose work is mainly focused on the interaction of people performing activities at different locations, should point to VP. Lastly, considering differences in both, the scope of SETs and requirements of SMEs, which determine the criteria effective use, general satisfaction percentages reached were as follows: 72.22% for EA; 24.65% for SU; and 62.42% for VP.

Even though certain criteria were fully satisfied by different SETs, there are still differences as to *how* they are satisfied. Criteria such as Search facilities, Generation of report in different formats, for instance, provide for various options from one tool to another. Upon criteria application on these tools we are currently working in their refinement by means of both metrics and importance grades use, according to the SMEs reality. Based thereon, we will make further evaluations of tools presenting diverse scopes and characteristics. This way we expect to obtain both theoretical and practical results by simulating organizational restrictions and particular SME requirements.

6 Conclusion and Future Work

Software industry has found in SMEs a strategic mechanism to boost local capabilities in this sector. Even though SMEs have experienced a remarkable growth, variables as to their environment remain complex, thus posing significant challenges for decision making at SMEs managers' level.

We have proposed a set of criteria aimed at supporting SMEs in SETs' evaluation and selection. These have been divided into four groups, namely flexible project management, support to development process, tool understandability and usability, and support to communication and collaboration. The manner how these are organized may suggest other perspectives to analyze the most suitable options for SMEs, thus facilitating evaluation and selection tasks. These criteria were initially applied to three representative tools in order to guarantee the generalizability of our proposal. The main results of their application were: flexible project management criteria were fully satisfied by EA; VP accounted for the highest satisfaction percentage of development process support; criteria relating to tool understandability and usability showed the highest satisfaction for EA and for VP; and VP had the highest satisfaction of support to communication and collaboration.

The application of the proposed criteria proved their feasibility, their internal and external validity, as well as their need for operationalization. Future stages in this research will be focused on establishing a selection model that allows for process calculation, besides qualification, so it can be applied to SMEs in Venezuela.

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