TOOLS SELECTION CRITERIA IN SOFTWARE-DEVELOPING SMALL AND MEDIUM ENTERPRISES

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ABSTRACT

Nowadays, it's well-known that Small and Medium Enterprises (SMEs) generate important contributions to the software industry. Their particular characteristics constitute a challenge to decision makers when selecting technologies, like Software Engineering Tools (SETs). Deciding in which SET to invest requires managing limited resources as well as productivity pressures. Additionally, changes in SETs also affect the selection process. This article proposes a set of criteria, which were formulated with support on the Goal Question Metric approach and considered standards like ISO/IEC 14102 and IEEE 1209, to support SMEs in the selection of SETs. These criteria were also applied to three SETs, including both commercial and open-source, to obtain a set of opportunities for supporting software engineering areas, such as project management and software development process. This proposal is aimed at forming the basis to establish a SETs selection model for SMEs.

Keywords: SMEs, Tool, Software Engineering, Selection Criteria, Tool Selection.

1. INTRODUCTION

Nowadays, software-developing *Small and Medium Enterprises (SMEs)* represent a growing sector of organizations [1, 2]. Most SMEs share characteristics that distinguish them from large enterprises. However, such characteristics may also impose restrictions with impact on their economic, human and technological aspects, such as technology adoption. Such is the case of the *Selection process* of *Software Engineering Tools (SETs)* This selection process is influenced by the enterprise context; therefore, we began our research by establishing a framework for conceptualizing the software-developing SMEs context, and arranging their characteristics in four general groups: *financial resources, people, organization & development process, and communication*.

Although these tools may support a wide range of activities and processes along the software development life cycle, they constantly increase in number and vary in scope, as a consequence of the development of *Information Technologies* (IT) and changes in *Software Engineering* (SE), which adds complexity to the selection process. For deciding on a specific SET, managers can obtain support from certain standards and processes already in place, which have been designed to guide software-developing organizations along the tool selection process. However, certain application difficulties and a need for a consensus on which criteria may be used as orientation has arisen in SMEs.

In this context, general questions could be formulated to managers regarding the selection of SETs; for instance, Which software development methods and processes require automatic support?, How much flexibility can the stakeholders expect from this support? Do these tools support the team organization?, among others. As a response to this situation, we have suggested a set of *selection criteria*, which are based on SMEs characteristics, to support SETs selection. At first, these criteria are aimed at providing orientation to SMEs in their decisions of acquiring one or more SETs.

To do this, we have relied on the process logic defined in two international standards: ISO/IEC 14102 Standard - Information Technology—Guideline for the evaluation and selection of CASE tools [3] and IEEE 1209 Standard - IEEE Recommended Practice for the Evaluation and Selection of CASE Tools [4]. We have also based on the characteristics established in ISO /IEC 9126 - Information Technology—Guideline for the evaluation and selection of CASE tools [5]. Likewise, in order to lay the bases for defining metrics, we have considered the *Goal Question Metric* (GQM) approach [6]. Once proposed these criteria, our research continued with their application to three SETs as an initial validation.

After presenting the related works, we describe the framework that guided the formulation of criteria. Then, we present the selection criteria with basis on the SMEs necessities; as well as the results obtained from their application. Finally, we provide our conclusions and future works.

2. RELATED WORKS

SETs, also addressed in field literature under the denomination of CASE Tools, are constantly subjected to evaluation at software developing organizations. The selection of one SET can occur in different manners, either through Checklists [7], evaluation methods and methodologies [8]; or by means of processes defined in standards, such as ISO/IEC 14102 or the IEEE 1209. In general, most tool selection processes recognize the need of establishing selection criteria in the early activities [4].

Even though certain processes have been exclusively defined for the selection of SETs, mainly in international standards, several difficulties have been identified in their application to certain corporate contexts, such as SMEs [1]. This has been reasoned in the number and complexity of the characteristics involved; their internal structure, as well as the need for reaching a consensus as to the selection criteria, given the diversity of the organizational aspects involved in the organization [7]. Even though criteria for specific SE domains have been suggested [9,

10], there is an increasing need for counting on criteria addressed to the particular SMEs characteristics [11].
Several current initiatives aim at supporting SMEs in different areas. A case in point is IT Mark, which is being used by SMEs, especially in European countries [12]. On the other hand, ISO/IEC JTC1/SC7 establishes a work team which addresses all difficulties faced by SMEs in the application of existing standards, by focusing on the development of a SE standard in accordance with the SMEs characteristics [13]. Nevertheless, available information on SETs and SMEs is very scarce.
From related works, we took the following aspects as fundamentals for our proposal: (a) The importance of defining criteria prior to task selection, (b) Formal structuring of a selection process, and (c) Need for objectively defining such criteria. The contribution of this work is providing criteria for guiding SETs evaluation and selection clearly framed in SMEs, by establishing the necessary context to support the decision process at these organizations.

3. CRITERIA FORMULATION FRAMEWORK

The selection processes help minimizing the risks of selecting an inappropriate tool and then reduce all costs associated therewith, since the selection is made under certain criteria previously adopted by the organization. These criteria are usually defined early in the selection process. For instance, in ISO/IEC 14102 standard the selection criteria are defined in the first of these processes. A similar structure is suggested in IEEE 1209 standard, wherein criteria are established upon definition of all tasks for the evaluation exercise. [4]
In the case of ISO 14102, selection criteria reflect the approval/rejection of the feasibility of making a tool selection decision [3]. Criteria will be determined by the needs of the organization planning on selecting one or several tools. Hence, selection criteria are dependant on the context of the organization that applies them.
Thus, for purposes of this work, the evaluation objectives were limited to establish selection criteria according to the characteristics and needs of the software-developing SMEs. In order to define this context, below we provide a domain area, both for SMEs and SETs. This way, criteria will be subsequently defined on this basis.

Software-developing SMEs

In order to provide for a framework that defines the context of SMEs, on the basis of contributions made by several authors, who addressed SE topics in small organizations and gathered a set of characteristics that define such organizations in terms of: (a) people; (b) financial resources; (c) organization and development process; and (d) communication, among others. All such groups are described below [11, 14, 15, 16, 17].

People: SMEs count on *few employees*, who cover the same range of activities than large organizations [11, 16]. This is one of the reasons why people assume *multiple roles* [17], which results in multidisciplinary employees**,** performing a wide range of activities, generally under *time pressure* that make harder to deepen their experience in individual areas.
This fact has led to higher standards which demand high-level capabilities; for instance, a more clear and efficient *management*, better advantages of available IT. The absence of such capabilities may be reflected in: lack of IT resources, little *experience* in IT adoption, managers' scarce *motivation* to invest in these matters, fear of adopting a wrong technology, etc. [18]**.** Fortunately, the practice of working in *distributed teams* - in response to *informal infrastructure* [19] - and their *flexible* organizational schemes, makes easier for the personnel to perform their tasks even when working *part time* or from remote locations.

Financial resources: SMEs are known for their limited financial resources [20]. However, these organizations develop strategies that allow for successfully moving in highly competitive environments. They usually form *alliances* and operate as a network to compete in large projects at national and international levels.
In response to these restrictions, SMEs need to make *efficient* use of their resources. To take greatest advantage of the available personnel, they concentrate their efforts in developing products for specific *market gaps* [20] set aside by other companies; creating components for software products developed by other companies and providing services or maintenance for them [11]. Thus, mostly SMEs apply a strategy that is more product-oriented than individual-contract oriented [16, 20]. However, they must be very careful, because changes to project scope during the development process may significantly affect them from a financial point of view. Therefore, they manage themselves with flexibility in their realm of operation.

Organization & development process: Limited resources and team characteristics mostly determine the way how people at SMEs structure: *flat structures* (with few hierarchical levels), flexible workflows, and *changing rules* (depending on the current needs) [18, 21]. Different roles are played based on the degree of *informality* in both, relationships among individuals, and the infrastructure supporting their activities. Such particularities also influence the software development process. Consequently, SMEs usually apply flexible development processes, adapted to their needs [20]. This flexibility is based on a close relation with clients.
Thus, *change management* becomes strategic, since changes may significantly affect their budgets. SMEs strive to reduce change risks by keeping contact with client from early development stages. To achieve this, they rely on a growing development practice based on *continuous iterations* and intensive client communication [20]. This practice makes easier to developing the product through progressive increments [16].

Communication: As aforementioned, SMEs present flat structures, what allows for dynamic information flow among the personnel. Therefore, it produces a subjective component in their decisions: a dynamic, and even inaccurate, *communication flow* which is also a consequence of a weak definition process of rules [17]**.** This fluency is also reflected in how SMEs relate to their environment. Likewise, *productivity pressures* exerted by clients foster frequent communication between them and SMEs, thus supporting certain company practices, such as regular deliveries and incremental development.
We have described the characteristics defining the context of software-developing SMEs. SETs' support needs may derive from these characteristics, which are critical for the context of SMEs, and serve as a basis for our selection criteria proposal. Fig. 1 provides a model for UML concepts including the characteristics aforementioned.

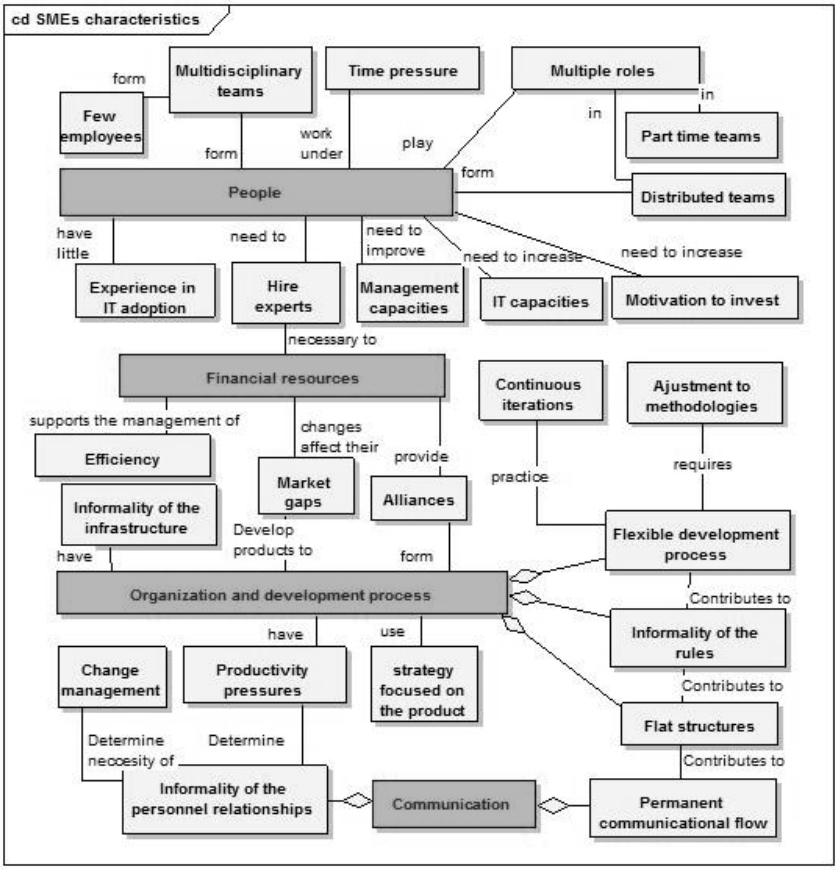

Fig. 1. SMEs characteristics.

Once SMEs' context is defined, next step is identifying the context of the SETs from which it may be possible to obtain concrete elements regarding the support capabilities of these tools for such organizations. In the following section, we will address this topic to introduce the proposed criteria.

Software Engineering Tools (SETs)

SETs are aimed at supporting tasks and processes along the software development lifecycle. Considering changes in IT and SE, expectations towards SETs are more demanding every day, as a consequence of new software development methods and processes, growth of multidisciplinary teams, data visualization developments, collaboration requirements, etc. [22, 23, 24].

In general, SETs provide benefits to the development team. They allow automating well-defined actions, by significantly reducing administrative load associated with its application and giving people the opportunity to focus on the creative aspects of the development process. SETs provide support at different levels depending on the tool scope (tools, workbenchs, CASE environments). In any such cases, it is widely known that SETs' support can be measured as quality and productivity improvements for systems development [25, 26].

Nevertheless, literature has already revealed that changes affecting software industry are increasing and may make more complex to selecting a tool that suits the needs of a software-developing organization [22]. Therefore, it is relevant for them to improve and deepen in tools' systematic evaluations, especially when resources are limited or when technology and organizational capabilities in general must be strengthened, as it usually happens with SMEs.

A renowned group of experts has defined in SE Book of Knowledge (SWEBOK), SETs' structure according to the support provided to SE knowledge areas [27]. Accordingly, we have taken this structure as reference to analyze the support offered to SMEs. Considering SWEBOK, we identify possibilities of a flexible support to areas of special interests for SMEs, e.g. SE project management, which comprises activities to support to people's time and effort organization. On the other hand, change areas have revealed possibilities of support to SMEs in matters, such as collaborative work or facilities for communication among distributed teams. As observed in the next section, a context analysis of SETs based on SMEs' reality served as a basis for identifying the selection criteria proposed herein.

4. PROPOSED CRITERIA FOR TOOL SELECTION AT SMES

Through the analysis of SMEs, we identify activities that, given their characteristics, require a significant amount of support from SETs. First of all, SMEs have characteristics that affect their development process, and other that represent significant competitive advantages. Criteria proposed in this work are inspired on the need

for SETs support that makes easier for team members to work under restrictions and that provides them with mechanisms to improve their advantages.
This objective constitutes the main reference for the formulation of criteria and allows raising certain questions:

- How can SETs support SME's Risk Management requirements, which derive from informality in project planning? How can they support SME's requirements of structuring peoples' efforts? How can they support SMEs to efficiently manage available resources? Such questions have led us to determine the importance of project management support.
- How can SETs support SMEs by considering their process flexibility, generally adjusted to project needs and the entity's capabilities? This question led us to determine the importance of development process support.
- How can SETs support SMEs' teams, which consist of few people with a common mission working under time and productivity pressures, so they can easily understand tasks and use them properly? This question led us to determine the importance of usability in SETs.
- How can these tools support distributed teams at SMEs and take the greatest advantage of available technologies to overcome weaknesses derived from structure informality and incorporate them to collaborative work? This question led us to determine the importance of support to collaboration and communication that SETs can provide to SMEs.

From these questions, we have suggested an initial set of SETs' selection criteria which make emphasis on the SMEs' context. For this, we consider the approach proposed by Basili, which is based on objectives (conceptual level) and allows for the identification of elements at operating (question formulation) and quantitative (metrics) levels. Table 2 shows the proposed selection criteria.

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, specification, modification, import, organization and traceability
Version Control
Access control -Local copy updating -Commit to project changes -Modification control -Comparison of versions -Detection of conflicts between versions Support to DBSM-based repositories -Flexibility in data transfer
TOOL USABILITY
Documentation Flexibility
Reports based on forms -Reports in different formats Facilities to *copy and paste*
Information Visualization Flexibility
Arrangement of windows -Save and restore custom window layouts -Customization of toolbars and menus -Links between models -Search facilities Color options -Diagrams in different formats
Tool Usability
User friendliness -User guidance .Homogeneity Adaptability -Conciseness -Easy of learning
COMMUNICATION AND COLLABORATION
Requirement Management
Remote requirement modification -User notification services -Create requirement views for remote access
Documentation Collaboration
HTML reports -Collaborative artifact editing -Document updating and download
Team Communication
E-mail -Chat capabilities -Group management.

Table 2: Proposed selection criteria

Flexible Project Management Criteria
SE management [27] offers a systematic approach for all project stages, which guarantees that each step is properly planned, monitored and measured [28]. Thus, coordination of activities requires a management effort because of the dynamic and complex nature that characterizes SE projects.
This is more evident when the project is developed under restrictions that may affect resource availability, which occurs in SMEs. Such restrictions determine the need for adopting a simplified approach for project management [29]. The following situations stand out in project management at SMEs:

1) Decisions entail a strong qualitative component that may affect financial resources management or people's effort planning; 2) Usually, communication mechanisms do not keep a historical of cost/time records, which makes impossible to support the planning of new projects; 3) The team's structuring plans must be efficient and effective enough when distributing effort, by considering all the possible work and the relevant project information in an exhaustive way.

The possibility of counting on detailed records of effort items may help supporting activities organization. Likewise, estimates of costs and agendas may support the development team efficiency. Counting on the support of a tool for project planning and follow-up will give SMEs the opportunity to efficiently manage projects as to the use of resources and incorporate elements that ensure objectivity in the decisions made (through the use of metrics or risk items). Based thereon, we have proposed selection criteria for project management: *Project resource and time estimation, Planning, Project tracking, Risk items, Effort items*. Their relation with the characteristics of SMEs is shown in Fig. 2. Due to space limitations, we only represent relations among those concepts most closely related to these criteria.

Software development process criteria
As shown above, management scope encompasses the entire software development project. The process implies the use of methods comprising several set of tasks, as well as tools that provide support to the automation of the process and methods. On the other hand, it should be noted that, process flexibility may imply the use of techniques associated with several methods.

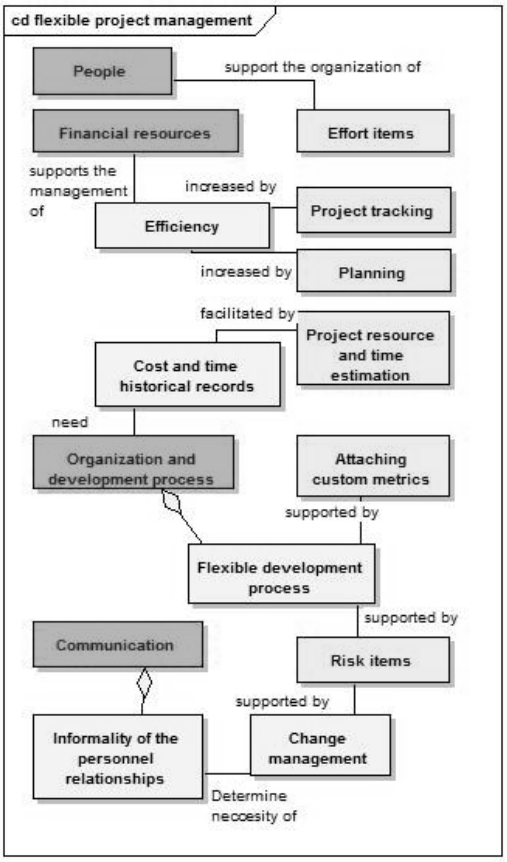

Fig. 2. Proposed criteria for flexible project management

We identified that SMEs rely on short-cycle development processes and show informality in several aspects of their organization, which may affect the development process. Hence, these processes are essentially flexible processes, which have been adapted to the SMEs' needs. In this context, the possibility of counting on a tool that allows *adjusting the SME process* is of special importance within the context of these organizations. In addition, we have seen that usually SMEs' development process is characterized by a permanent, informal and subjective communication flow with clients. Based on such characteristics, we suggested some criteria aimed at supporting this discipline.

Likewise, analysis and design activities in the development process of the SME are impacted by the flexible character of the process. Thus, we proposed *modeling* criteria in this section. In the same way, we proposed a set of criteria to support *version control*, as support to the change and configuration management discipline, taking into account that they support the team at SMEs in the efficient performance of activities during the development process.

Usability Criteria

SMEs usually face problems to hire experts; hence, it is important to count on SETs that provide for usability of supported tasks and their automation methods. As support to these practices, we proposed a set of criteria addressing the tool functional characteristics (*Flexibility in the Documentation* and *Flexibility for Information Visualization*), and others related to tool *Usability*, which is a software product quality characteristic defined in ISO/IEC 9126, referring to the software product facility to be understood, learned and used, and be considered appealing to users as well [5].

This support may significantly contribute to take advantage of the team abilities. Likewise, it helps minimizing technology adoption barriers through fostering people's approach to technologies, with positive effects on their motivation and disposition to invest time and resources, etc.

Communication and Collaboration Criteria

Communication and collaboration have marked an important trend in the development of SETs. For SMEs, this trend may entail significant advantages, when counting on appropriate technologies.

Communication support may help the fluent distribution of project effort and the knowledge flow generated during the process [11, 30]. Likewise, availability of technologies, like Internet and groupware, represent opportunities to support internal communication. Internet-based deliveries allow for rapidly counting on deliverables and making them available to all persons (either clients or analysts team). Also, they may support efficiency in the use of limited financial resources, since they save on printing costs. In addition, support provided by the tools to integrate software environments [27] offers the possibility of notification services for better cooperation and collaboration.

On the other hand, collaborative requirement engineering represents a great advantage for SMEs, since it adapts to people's configuration [31]. Accordingly, we suggested some criteria for supporting *collaboration in requirements management*. These criteria supplement those presented at the beginning of this section (requirements' specification, traceability, modification, etc.); however, those proposed herein are specifically targeted to distributed and part-time team members.

Likewise, support to collaborative work tools may represent advantages for joint preparation of documents along the development process. In this regard, we added to this section a set of criteria to support *collaboration in the task of documentation*. Lastly, available technologies, such as Internet and groupware will make information and data exchange an easy, feasible task. Therefore, we developed a set of criteria for supporting *team communication tools.*

In addition to the theoretical bases used to define these criteria, we identified coincidences with some proposals presented by software developing SMEs in Venezuela [32]. In those proposals, the following requirements have been confirmed: *usability*, modeling support, requirements' management support, project management support, methods and tools that best suit their reality.

5. INITIAL APPLICATION OF PROPOSED CRITERIA ON THREE SE TOOLS

Selection criteria must be established in response to user needs. However, there are differences in the manner how they are proposed. In certain cases, criteria are the basis to guide requirements' definition and the most specific characteristics to be subsequently evaluated [3]. In other cases, they directly serve the evaluation, once metrics and acceptance levels of each criterion are established [4]. For purposes of this work, we considered that criteria

may, by themselves, define the characteristics to be evaluated at an operational level. In this case, criteria application responded to identification of the presence or not of expected characteristics in the evaluated SETs.

Upon definition of the selection criteria, we selected three SETs: *Enterprise Architect (EA), Star UML (SU) and Visual Paradigm (VP*, specifically, *VP for UML* and *VP Teamwork Server)* for purposes of their initial validation. Identification of such tools was as follows: a preliminary random consultation made in the list of OMG Group suppliers [33] allowed us for selecting two SETs: EA and VP. SU was selected for its support characteristics and for being an open-source tool, which may bring advantages for SMEs in terms of investments.

Once these SETs are evaluated, we observed that EA fully met project management criteria, 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. As discussed above, SETs may have well-defined scopes on which their functionality should be focused. Particularly, VP and UML are clearly oriented to supporting certain SE activities. Hence, the fact that these tools cannot support other activities – such as project management –is decision-relevant only to the extent that (a) SME considers this issue as a need, and (b) such activities are not being effectively supported by any other tool available at the organization.

VP accounted for the highest percentage of satisfaction as to support to the development process (94.11%) followed by EA (77.77%) and SU (11.11%). This is mainly due to modeling and version control support..General results are presented in Fig. 3.

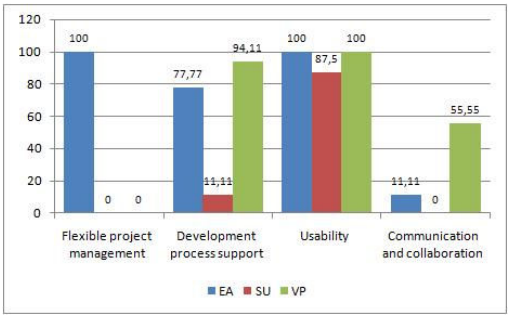

Fig. 3: General results of criteria application

Since SU is an open source tool, it is possible to establish investment schemes oriented to the combined use of SETs in order to support specific activities, rather than schemes oriented to invest in one wide-scope tool. Thus, provided that one SET meets the particular SME's modeling requirements, the non-satisfaction of other criteria will not necessarily have an impact on the final selection of such tool.

On the other hand, while EA and VP satisfied usability criteria at a 100%; SU achieved 87.5% of satisfaction. This shows that vendors concentrate their efforts on characteristics increasing usability. Lastly, less favorable results were obtained for communication and collaboration support criteria: while VP obtained a 55.5% satisfaction, EA achieved 11.1% and SU did not satisfied criteria at all. Thus, when communication and collaboration support is considered as a need that should be supported by an SET, VP will be the best choice, from the evaluated set of tools, for a particular SET. The general percentage of satisfaction for each tool was as follows: 72.22% for EA; 24.65% for SU; and 62.42% for VP. This way, despite SETs can present different scopes (integrated corporate versions or specific products), weighted characteristics will mainly depend on the SMEs' requirements, in addition to other variables such as costs, licensing schemes, and technical support, among others, beyond the scope of our work.

Although we identified criteria satisfied by these three SETs, there might be differences in the level of specialization applied to address each of the functionalities involved. Such differences will be addressed in the next stage of our research, wherein we intend to develop metrics within the context of creation of a SETs' quality model targeted to SMEs.

6. CONCLUSION

Software industry has found in SMEs a strategic mechanism to improve local capabilities in this sector. Even though SMEs have experienced a remarkable growth, environmental variables remain complex, thus posing significant challenges for decision making.

We proposed a set of criteria aimed at supporting SMEs in SETs' evaluation and selection. These criteria were divided into four groups: flexible project management, development process support, understandability and usability, and communication and collaboration support. The manner how these are organized may suggest other perspectives to analyze the most suitable options for SMEs, thus facilitating evaluation and selection tasks.

The proposed criteria were initially applied to three tools: Enterprise Architect, StarUML, and Visual Paradigm. Next step in our research will be focused on establishing a quality model that allows for accurately quantifying criteria, and that may be applied to SMEs in Venezuela to support their effective SET selection.

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