

REQUIREMENTS FOR PRODUCT DEVELOPMENT SELF-ASSESSMENT TOOLS

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ABSTRACT

The successful execution of complex PD projects still poses major challenges for companies. One approach companies can use to improve their performance is self-assessment tools to optimize their organization and processes. This paper investigates the requirements regarding self-assessment tools for PD organizations. It summarizes the current literature on PD-related self-assessment tools and derives tool requirements from an industry focus group (US aerospace and defense industry) as well as from interviews at a major American defense contractor. The resulting requirements are: 1. Focus on proven PD best practices; 2. Formalized implementation process; 3. Tool customization guidelines; and 4. Integration with other process improvement approaches. A gap analysis comparing these requirements to the previously identified tools is performed. The paper concludes with the outline of an example PD self-assessment tool that addresses these requirements.

Keywords: Self-assessment, product development

1 INTRODUCTION AND MOTIVATION

Successfully executing product development projects remains a major challenge. In the US Aerospace and Defense industry, which forms the context of this paper, development cost overruns of 45% and schedule overruns on the order of two years are the average [1].

One approach to improve the performance of product development projects is the use of self-assessment tools. The primary goals of organizational self-assessment are increasing quality awareness, driving the quality improvement activities, and improving business performance [2]. Rather than leading to *strategic change* – which is an externally focused organizational change resulting from strategy development and implementation – self-assessment primarily results in *process change*, which aims at changing organizational “infrastructures”, i.e. the organizational processes for achieving results [3]. Furthermore, a successful implementation of self-assessment promotes organizational learning on the basis of communication and feedback on the self-assessment results [2]. Self-assessment is one of many events in the organizational change process. It is linked with two main processes: the first process regards the firm-level organizational transformation processes on how to create and sustain organizational change, often with a time frame of years. A frequently cited example is John Kotter’s eight-step process [4]. Self-assessment can play a decisive role in this organizational transformation process. However, it may have a different scope and different goals depending on the particular stage of a company in its organizational transformation process. The second process type regards problem solving processes for implementing improvement ideas. The successful application of self-assessment may lead to a variety of different improvement ideas. Their time frame is usually much shorter, on the order of weeks or months. Examples are the Six Sigma DMAIC Cycle [5] or the Deming Cycle [6, 7].

2 CURRENT STATE OF PRACTICE AND LITERATURE REVIEW

When discussing self-assessment tools, a number of different terms are used in the literature, sometimes interchangeably. For the context of this paper, self-assessment tools are defined as assessments performed in a self-administered way within the company, as opposed to audits, which are assessments involving external assessors. Both self-assessments and audits are forms of organizational assessments [8].

Twelve PD-related self-assessment tools could be identified in the literature [9-20]. This paper reviews and compares these tools along four dimensions – process scope, purpose, sources, and measurement method. The first dimension, process scope, specifies to what degree a tool focuses on the product development process. The second dimension, purpose, classifies the tools in terms of their goals, i.e. the intended goals that are to be achieved by conducting a self-assessment. The third dimension, sources, describes the tools according to different sources on effective PD practices used for their development. Finally, the last dimension, measurement method, categorizes the tools based on the methods and metrics used to evaluate the PD process. Table 1 presents an overview of how the twelve tools address these four dimensions and what the possible values are.

The twelve reviewed self-assessment tools vary in their **process scope**. Conn et al. [12], Kahn et al. [16], McQuater et al. [17], and Radnor & Noke [19] present approaches that focus on the assessment of the new product development (NPD) process. Tennant & Roberts [20] and Gardiner & Gregory [14] have developed assessment methods with a very similar scope, but refer to new product introduction (NPI) as their application area. A frequently cited audit on a slightly higher level (technical innovation management, TIM) has been developed by Chiesa et al. [11]. Probert et al. [18] and Cormican & O'Sullivan [13] have a very similar scope to their approaches; however, they refer to technology management (TM) and product innovation management (PIM) as the application area of their assessment tools. The approaches of Ainscough et al. [9] and Caffyn [10] both address one specific aspect of the product development process (concurrent engineering and continuous improvement, respectively). A very different innovation audit based on high-involvement (participation and learning with a feedback mechanism) has been developed by Hallgren [15].

The **purpose** of the twelve self-assessment tools can be summarized into three main types. The identification of improvement opportunities is the prevalent intent of the majority of the twelve compared tools [9-14, 16-20]. The second major purpose of using PD self-assessments is business diagnosis, i.e. assessing the current state and gap against “ideal” state of a particular unit of analysis (project-level, program-level, firm-level) of a PD organization [9-14, 16, 19]. The third main purpose identified is benchmarking, either within a company or with other companies [9, 11-14, 16, 19]. The self-assessment by Hallgren [15] can be regarded again as an exception. Its main purpose is facilitating employee involvement and implementing employee-selected improvement projects.

Table 1. Comparison of twelve PD-related self-assessment tools along four dimensions

Dimensions	Values	Corresponding Tools
Process scope	Technical Innovation Management (TIM)	[11]
	Technology Management (TM) or Product Innovation Management (PIM)	[13, 18]
	New Product Development (NPD)	[12, 16, 17, 19]
	New Product Introduction (NPI)	[14, 20]
	Concurrent Engineering (CE)	[9]
	Continuous Improvement (CI)	[10]
	High Involvement Innovation	[15]
Purpose	Identification of improvement opportunities	[9-14, 16-20]
	Business diagnosis	[9-14, 16, 19]
	Benchmarking within a company/with other companies	[9, 11-14, 16, 19]
	Employee involvement	[15]
Source	Literature on PD best practices	[9, 11, 12, 14-16, 18, 20]
	Case study evidence	[17, 19]
	Research- or theory-based	[10, 13]
Measurement method	Capability/maturity scale	[9-12, 16]
	Likert scale	[13, 14]
	Open questions	[11, 17, 20]

The development of the twelve identified self-assessment tools is based on a variety of different **sources**. Most of the tools mainly draw from a literature review either on existing best-practice models, published journal and conference papers or books [9, 11, 12, 14, 16, 18, 20]. Some authors such as McQuater et al. [17] and Radnor & Noke [19] use a combined case study and literature review

evidence for the development of their tools. Cormican & O'Sullivan [13] have developed a self-assessment tool solely based on their research and theory on product innovation management. The continuous improvement self-assessment tool created by Caffyn [10] is a research-based tool as well. The innovation audit based on high-involvement developed by Hallgren [15] uses material from traditional innovation audits, as well as literature on high-involvement innovation.

Three different **measurement methods** have been identified. The first is capability/maturity scale, i.e. different levels of maturity ranging from poor performance (lowest level) to exceptional performance (highest level). Each level is briefly described with a few sentences. The second is Likert Scale, i.e. the measurement of a level of agreement with a statement or proven PD best practice. The third is open questions, i.e. asking detailed questions on a set of best practice categories in order to provide focus and address the specific circumstances of a respective PD organization. Ainscough et al. [9], Caffyn [10], Conn et al. [12], Kahn et al. [16] have developed a real capability/maturity-based measurement scale. Cormican & O'Sullivan [13] and Gardiner & Gregory [14] use a Likert scale approach, i.e. they measure the level of agreement with a statement or best practice. Tennant & Roberts [20] and McQuater [17] use a very different approach again; they ask open questions regarding NPI/NPD best practices in order to focus on certain aspects. Chiesa et al. [11] draw on a combination between capability measurement and open questions. The two publications of Probert et al. [18] and Hallgren [15] provide no detailed information about the measurement method of their tools.

3 RESEARCH METHOD

This paper uses a combined approach of an industry focus group survey (US aerospace and defense industry) and interviews as research method. Both the survey and the interviews aimed at obtaining exploratory information about the requirements of PD self-assessment tools. Based on the identified requirements from the survey and the interview, an analysis of the existing product development-related self-assessment tools was conducted to understand to what degree they conform to the requirements.

The survey was web-based [21-23], and sent out to an industry focus group consisting of fifteen industry and government organizations, all in the field of aerospace and defense. The survey was emailed to eighty-one employees in product development, both engineers and managers. Fourteen responses were collected: a response rate of 17%. The survey was pre-tested with students and research assistants. The final survey was organized into six main sections and comprised sixteen pages and sixty-one questions. On the one hand, the survey asked the respondents general questions about product development self-assessment, f.e. about barriers to the use of self-assessment, goals of self-assessment, responsibility for self-assessment, or link to other process improvement activities. On the other hand, feedback questions about a proposed customization and implementation process were asked. Two modes of questions were used – multiple choice and open-ended questions.

Two interview sessions [24, 25] lasting two and a half and four hours were held at a major US defense contractor with three employees in the product development area of the company.

4 EXPLORATION OF PD SELF-ASSESSMENT TOOL REQUIREMENTS

4.1 Evidence from the industry focus group survey

The first result from the industry focus group survey was that only fifteen percent of the respondents indicated they were using a PD-specific self-assessment tool in their organization.

Regarding the purpose of the self-assessment tool (see Table 2), the identification of improvement opportunities was indicated as most important (rating average of 3.6 on scale of 1 (not important at all) to 4 (very important)). Assessing the current state and gap against "ideal" state of the PD organization was the second most important purpose (rating average of 3.5). Benchmarking within the company or with other companies seemed to be of minor importance (rating average of 3.1 and 2.8).

The respondents were also asked to rate different barriers to the use of product development self-assessment tools. Table 3 summarizes the results. The statement that was agreed to most strongly was "*There is a general high resistance towards change*". This statement provides evidence that in developing as well as using product development assessment tools, practices from the field of organizational change have to be taken strongly into consideration. The results of the assessment of the current state of a product development system have to be linked with ongoing business improvement processes. Moreover, the circumstances in the respective organization have to be

considered. The second strongest agreement was on the statement “*There is no time to investigate possible assessment tools*”. The third strongest agreement was on the statement “*It is difficult to do properly*”. This is an important response since it may lead to the assumption that companies expect a holistic and integrated product development self-assessment approach with helpful guidelines and formalized processes on how to use and implement the tool in their particular environment. The statement that applied least strongly was “*We are doing well right now and do not need to improve our product development processes.*” This statement shows that the majority of respondents are not satisfied with the current state of their product development system. Other statements that did not apply in general were “*Senior management is not interested*” and “*Employees are opposed to the idea that their work is judged by an official tool*”. These statements show that there is a general interest in improving product development processes, both among employees and senior management.

Table 2. Evidence from the industry focus group on the purpose of PD self-assessment

Types of purposes of PD self-assessments (n = 14)	Rating Average	Standard Deviation
Identification of improvement opportunities in our existing PD organization and PD processes	3.6	0.6
Business diagnosis: Assessing the current state and gap to "ideal" state of our PD organization and PD processes	3.5	0.7
Benchmarking of a project/program/organization within our company	3.1	0.7
Benchmarking of a project/program/organization with other companies	2.8	1.0

Scores are based on a scale from 1 (not important at all) to 4 (very important)

Table 3. Evidence from the industry focus group on barriers to PD self-assessment

No.	Barriers to the use of PD self-assessments (n = 14)	Rating Average	Standard Deviation
1	There is a general high resistance towards change	3.0	0.8
2	There is no time to investigate possible assessment tools	2.8	0.8
3	It is too difficult to do properly	2.7	1.0
4	Too many failures of process improvement initiatives in the past	2.6	0.7
5	We lack the necessary knowledge regarding assessment tools in PD	2.6	1.0
6	Paralyzing bureaucracy prevents employees from introducing new process improvement tools	2.6	0.6
7	It would not result in significant improvements	2.5	0.6
8	Employees are opposed to the idea that their work is judged by an "official tool"	2.4	0.8
9	Senior management is not interested	2.3	1.0
10	We are doing well right now and do not need to improve our product development processes	1.5	0.7

Scores are based on a scale from 1 (does not apply at all) to 4 (fully applies)

The respondents were asked if their organization was using one or more process improvement approaches. The Capability Maturity Model Integration (CMMI) [26] and Lean Management [27-29] were the two most common approaches. Thirteen out of fourteen respondents pointed out that their company was using CMMI. Eleven out of fourteen respondents stated that their company was employing Lean Management. Six Sigma [5] and the Malcom Baldrige National Quality Award [30] were popular process improvement approaches as well. Six out of fourteen respondents indicated a use of Six Sigma. Two respondents pointed out that their company had established the Malcom Baldrige National Quality Award. There were many more additional process improvement approaches used by the industry focus group. However, they seemed to be not as prevalent as the four approaches already mentioned.

Since the authors expected the common use of established process improvement approaches, the survey respondents were also asked about their opinion on linking product development assessment tools with existing process improvement approaches (this is referred to as *integration* in the following

sections). The vast majority of the respondents (86%) thought that it was “important” to link a product development self-assessment tool to already existing process improvement approaches. Only seven percent indicated that it was “somewhat important”. Another seven percent considered this link to be “somewhat unimportant”.

In summary, the industry focus group survey found three essential requirements for product development self-assessment tools. The first requirement regards the **implementation** of the tools. A number of statements shown in Table 3 (No. 1, No. 3, No. 4, No. 5) indicate that the respondents need more detailed and formalized guidelines and help in implementing such an instrument. The second requirement considers the organizational **integration** of PD self-assessment tools. The vast majority of the industry focus group already uses process improvement tools, mainly on firm-level. As already mentioned, they explicitly highlighted the importance of linking a PD self-assessment tool to already established process improvement approaches. Moreover, this requirement is supported by a number of statements shown in Table 3 (No. 1-5). The third requirement regards the **customization** of the tools. The respondents were asked to rate four proposed customization dimensions (see Section 6 and Figure 1) according to their relevance. All four dimensions were rated between “somewhat relevant” and “relevant”. Moreover, a number of respondents provided further customization dimensions to support the process of tailoring the tools to the specific needs of particular organizations.

4.2 Evidence from the interviews

The two interview sessions with employees of a major American defense contractor revealed three main requirements for a new PD self-assessment tool, which were not addressed sufficiently either by an old internal assessment tool of the company or instruments found in the literature.

The first requirement regards the **focus on proven best practices for the entire PD process** of the tool. A self-assessment tool existed at the company. However, it has not been used for the last ten years because of its focus on the software development part of programs. Moreover, it was not detailed enough and needed to be updated. Discussions with the employees revealed that a more generic self-assessment tool focusing on best practices for the overall product development process would be very helpful for the engineering division of the company.

The second requirement regards the **integration** of a PD self-assessment tool with already existing process improvement processes. Since the company strongly relies on the Capability Maturity Model Integration (CMMI), linking a new PD self-assessment tool with this process improvement approach turned out to be of very high importance. This requirement is also supported by the survey.

The third important requirement regards a possible **customization** of the self-assessment tool, i.e. a process of tailoring the self-assessment tool according to the specific circumstances in an organization. A first version of the example PD self-assessment tool (see section six) was presented and discussed with three employees from product development. The employees argued that there were certain areas which were either not important for their company or where there were no issues that had to be addressed. Moreover, it turned out that a number of metrics would have to be customized (e.g. selecting, adding, deleting, rephrasing, re-titling, or re-ordering certain metrics) in order to sharpen their focus on the specific circumstances of this company. The discussions revealed that a possible customization process would probably be a bigger step than expected. One main reason mentioned was that there were few people within the organization who had the expertise on the whole set of PD best practices covered by the example PD self-assessment tool. Therefore, a formalized customization process would make sense.

4.3 Derivation of the requirements for a new product development self-assessment tool

To sum up, the industry focus group survey and the interviews identified four general requirements for a new product development self-assessment tools:

1. Focus on proven PD best practices;
2. Formalized implementation process;
3. Tool customization guidelines; and
4. Integration with other process improvement approaches

5 GAP ANALYSIS OF EXISTING PD SELF-ASSESSMENT TOOLS

Table 4 compares the twelve PD-related self-assessment tools in terms of the four main requirements identified from the interviews and the industry focus group survey. A number of shortcomings with the existing self-assessment tools become apparent:

The first shortcoming regards the process scope of the majority of the assessment tools. One fourth of the twelve identified self-assessment approaches have a relatively high level process scope on technical innovation management and thus do not address the product development process in a sufficient way [11, 13, 18]. Other tools focus on very specific parts of the overall innovation process such as the deployment of continuous improvement [10] or concurrent engineering [9] and therefore address too small a part of the product development process. Four out of the twelve identified assessment approaches put an emphasis on new product development (NPD)/new product introduction (NPI) [14, 16, 19, 20]. However, only Gardiner & Gregory [14], Radnor & Noke [19], and Tennant & Roberts [20] cover a broad and detailed enough extent of the product development process.

Table 4. Comparison of 12 PD-related self-assessment tools along four main requirements

PD self-assessment tools	Focus on proven PD best practices	Formalized implementation process	Tool customization guidelines	Integration with process improvement tools
Chiesa et al. 1996 [11]	●	○	○	○
Ainscough et al. 2003 [9]	●	●	●	○
Cormican & O'Sullivan 2004 [13]	●	●	○	○
Tennant & Roberts 2003 [20]	●	●	○	○
Caffyn 1999 [10]	●	●	○	○
McQuater et al. 1998 [17]	●	○	○	○
Conn et al. 2009 [12]	●	○	○	○
Probert et al. 2000 [18]	●	●	○	○
Gardiner & Gregory 1996 [14]	●	●	●	○
Radnor & Noke 2002 [19]	●	○	○	○
Hallgren 2009 [15]	●	●	○	○
Kahn et al. 2006 [16]	●	○	○	○

Legend: ○ = does not apply; ● = somewhat applies; ● = fully applies

Second, the majority of the tools do not provide guidelines and instructions of how to implement them. Exceptions are Caffyn [10], Probert et al. [18], and Tennant & Roberts [20]. Although Caffyn [10] recognizes the importance of providing a formalized self-assessment implementation process (“*The process followed in carrying out the self-assessment is just as important as the end assessment scores.*”), none of the twelve analyzed assessment tools can be regarded as a truly integrated approach. From the authors’ point of view, providing a simple but sufficiently comprehensive and formalized process on how to use and implement the self-assessment within a company is the most promising lever in diffusing and promoting the use of self-assessment tools.

The third major shortcoming of the twelve self-assessment tools is the lack of opportunity to customize them according to specific needs. The vast majority of the tools are based on one model for every type of organization and do not provide opportunities to tailor them to an organization’s specific circumstances. Two publications recognize the idea of customization. Gardiner & Gregory [14] mention the possibility of customization, Ainscough et al. [9] provides a very high-level tailoring process. The authors of this paper believe that a well formulated customization process considerably will improve most of the tools. Formal customization guidelines will enable a more focused and therefore a less extensive approach.

Fourth, a major weakness of all compared product development self-assessment tools, is their lack of integration with established and popular company-wide process improvement approaches. Product

development-related self-assessment tools are insufficiently classified, if classified at all, and linked to firm-level process improvement frameworks. Authors such as Ainscough et al. [9] recognize this, and point to company-wide holistic frameworks such as the Malcom Baldrige National Quality Award or the European Quality Award [31] as a prerequisite to effective self-assessment. However, no publication has been found that formally links a product development self-assessment tool to company-wide process improvement frameworks.

In summary, some authors of the twelve self-assessment tools have recognized parts of the shortcomings of existing self-assessment tools. There are PD-related self-assessment tools that address one or two of the four identified requirements highlighted in this paper. However, no tool has been found that addresses all four requirements.

6 EXAMPLE PD SELF-ASSESSMENT TOOL

As section 5 indicates, there are a number of arguments that justify the development of a new self-assessment tool for product development. Hence, this section presents a new, holistic and integrated self-assessment framework for product development that addresses all four requirements found in the industry focus group survey and the interviews. It consists of a PD self-assessment questionnaire, a formalized 9-step process on how to use and implement the questionnaire, guidelines and instructions of how to customize the questionnaire, and mappings between the questionnaire and relevant process improvement frameworks (a complete description can be found in [32]).

The questionnaire is structured into three main categories and comprises 91 metrics, all based on a five-scale maturity-level measurement method. The questionnaire evaluates to what extent product development best practices (45 metrics) and change management best practices (22 metrics) are implemented. Furthermore, it consists of 24 metrics which measure actual results of PD projects from multiple dimensions. An example metric is shown in Figure 1. The questionnaire was developed mainly for assessing projects. However, it provides guidelines and instructions of how to customize it for the application on different levels of analysis such as PD programs or the whole PD organization. The 91 metrics are drawn from four main sources. A main part of the metrics is based on the PERFORM Tool, an already validated PD capability assessment instrument [33]. Moreover, the metrics comprise a selection of the most important factors for Lean Product Development identified by [29]. Furthermore, additional best practices both on product development [28, 34-43] and change management [4, 44-52] identified from the literature were integrated into the questionnaire.

A formalized 9-step process for implementing the self-assessment tool was developed and intensively discussed with employees of a major American defense contractor. Furthermore, feedback from the industry focus group survey was collected and used for improving the process. The final process includes the following steps:

1. Define purpose (WHY) and goals (WHAT) of the self-assessment process
2. Define organizational integration of PD Self-Assessment Tool (WHERE)
3. Define roles and responsibilities for the self-assessment process (WHO)
4. Create and customize the PD Self-Assessment Tool (HOW)
5. Pretest and improve the PD Self-Assessment Tool
6. Prepare the self-assessment implementation
7. Execute self-assessment
8. Identify and communicate improvement opportunities
9. Implement and monitor actions

The self-assessment framework provides guidelines and instructions on how to customize the self-assessment questionnaire according to specific circumstances of different companies. The 91 metrics are characterized along a number of dimensions such as functional area affected by the metric, organizational role affected by the metric, level of analysis, and Lean management related metric. These four customization dimensions are shown in the example metric (*Transition to Sales*) in Figure 1. The highlighted areas in magenta either characterize the particular metric (level of analysis, specific Lean management practice) or are especially important for implementing the specific PD best practice (functional area, organizational role).

In order to facilitate the integration of the PD self-assessment questionnaire with existing process improvement frameworks, all 91 metrics were mapped in table form with the structure of the Capability Maturity Model Integration (CMMI), the Malcom Baldrige National Quality Award and the

LESAT [53], a lean enterprise self-assessment tool. Moreover, the 9-step implementation process was linked with the DMAIC Process from Six Sigma.

PDC 15		1.4.2 Transition to sales									
Competence Level Description:	Sales presence is completely absent during the PD cycle.	Sales organization develops sales plans when PD "releases" to sales. Readiness takes great effort. Sales presence is largely absent during PD cycle except when the product is tossed "over the wall."		Sales participates in all key review checkpoints during PD. Sales has reviewed and critiqued the product specs and prototypes during PD.		Product is validated with lead users and beta customers with sales groups as full-fledged team members. Sales is confident of the product and its ability to perform in customer environment.		Product readiness is a non-issue. Sales has been a co-developer from the concept development stage. Product issues from sales are resolved as they arise throughout development.			
Competence Level:	Level 1 (poor)	Level 2 (fair)		Level 3 (good)		Level 4 (very good)		Level 5 (excellent)			
	Functional area:	Product Design Systems Eng.	R&D (Techn. Dev.)	Finance & Accounting	Production & Quality	Sales & Marketing	Human Resources	Customer Services	Administration IT Support		
	Organizational role:	Executive level	Project leader	Function leader	Project staff	Function staff	CI organization				
	Level of analysis:	Individuals	Teams	Projects Programs	Organization						
	Specific Lean Management Practice:	Specific Lean	Not specific Lean								

Figure 1. Example of a metric from the questionnaire

7 CONCLUSION, LIMITATIONS AND OUTLOOK

7.1 Conclusion

This paper investigated the requirements for self-assessment tools to be used in PD organizations. Four main requirements were derived from an industry focus group survey and from interviews at a major American defense contractor: 1. Focus on proven PD best practices; 2. Formalized implementation process; 3. Tool customization guidelines; and 4. Integration with other process improvement tools.

Twelve PD-related self-assessment tools were analyzed in terms of these four requirements. In summary, there are tools that meet parts of the requirements. However, no tool has been identified that addresses all four requirements listed above.

For this reason, this paper presented a new product development self-assessment framework consisting of a questionnaire with 91 metrics, a formalized 9-step process on using and implementing the questionnaire, guidelines and instructions of how to customize the questionnaire, and mappings between the questionnaire and relevant process improvement frameworks.

7.2 Limitations

The results in this paper have two main limitations. First, the industry focus group survey results are based on a rather small sample of 14 responses. Second, both the survey and the interviews represent the aerospace and defense industry only.

7.3 Outlook

The new product development self-assessment tool presented in this paper (see section 6) has not been implemented yet. Future research could aim at field-testing the self-assessment tool with a number of different companies from different industries. This would lead to insightful evidence whether the specifications of the new self-assessment framework – in particular the formalized implementation and customization process, as well as the integration with other process improvement frameworks – would improve the self-assessment process.

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