Applying VE and TRIZ to Universal Research Supervision

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Abstract

This paper aims to propose an application of value engineering (VE) and theory of inventive problem solving (TRIZ) to universal research supervision across various engineering fields in university education. In recent years, university education, especially in master and doctor courses, focuses on not only expert knowledge but also general skills that can be applied across various fields for students' better employability in industry. The general skills, which are also important for research, include analytical, problem solving, communication skills and others. Under this background, many universities in the world are encouraging their students to recognize the general skills. These contents, however, are often not directly linked to their research; so, the students who want to devote themselves into research are sometimes reluctant to participate in these activities. Then, the authors believe that Value Engineering (VE) and Theory of Inventive Problem Solving (TRIZ) are practical methodologies for fostering general skills that has direct link to research activities. The first author, so far, has provided, journal paper writing support, interdisciplinary workshop and others, in which VE and TRIZ are included as their contents, with engineering students. Although the students show strong interest on creativity and problem solving, which are the concepts included in VE and TRIZ, they are reluctant to proactively utilize them in their research activities. In this research, we have explored the practical application of VE and TRIZ, which are mainly used for business improvement and product development, to university research supervision in engineering fields based on the experience through the journal paper writing support and interview survey conducted on engineering students.

Biographies

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Graduated from Waseda University in Science and Engineering in 2003 and completed his doctor's course at Birmingham University (UK) in Mechanical Engineering in 2008. He joined Toyota Industries Corporation and later became lecturer in Engineering at Nagoya University. He is specialized in advanced education (English teaching and education for overseas students) focusing on Engineering field. He aims at developing meaningful International exchange programs for Engineering students with the use of VE.

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Graduated from KEIO University, Faculty of Technology, Department of Mathematical Engineering and got a position as a researcher at the SANNO Institute of Management in 1985. As a visiting researcher, he visited University of Michigan IOE (Industrial and Operations Engineering) in 1997. After that, he earned a doctoral degree in Engineering at WASEDA University in 2005. He had worked 30 years of experience in practical technology management And, now, he is an advisor of SJVE, a vice Chairman of JTS (Japan TRIZ Society), a director of Value Innovation Institute Co., Ltd., a visiting professor at RITSUMEIKAN University and an invited researcher at WASEDA University.

1. Research background

In recent years, university education, especially in master and doctor courses, focuses on not only expert knowledge but also general skills that can be applied across various fields for students' better employability in industry. The general skills, which are also important for research, include analytical, problem solving, communication skills and others. University faculties, who are professional researchers, also spend considerable time on issues caused by the lack of general skills of the students in research supervision [1].

Under this background, university and industry are encouraging their students to recognize the general skills. Vitae, for example, which is a UK organization for supporting the professional development of researchers, has collaborated with industry to develop Researcher Development Framework (RDF), a list of necessary skills for researchers' successful career, based on interview survey on hundreds of researchers [2]; RDF includes many definitions of general skills and is world-widely used for university career education. University education also provide general skill training programs such as Program for Leading Graduate Schools [3] emphasizing on the links to industry. These contents, however, are often not practical and missing direct link to research activities; so, the students who want to devote themselves into research are sometimes reluctant to participate in these activities.

The authors believe that Value Engineering (VE) and Theory of Inventive Problem Solving (TRIZ) are practical methodologies for fostering general skills that has direct link to research activities. Function Analysis in VE allows us to objectively analyze the functions in a system and systematically discover its problems [4]. In addition, TRIZ attributes the concept of "positive" and "negative" on these functions, then instruct to define a problem as a conflict of a pair of positive and negative functions. The invention patterns that has been derived by analyzing millions of patents direct us into proper solution to the conflict [5]. Both the processes, which have significant connection to the general skills, are also essential in research activities; one may expect that students equipped with VE and TRIZ will contribute not only to research achievements in university but also to the performance as employees in industry after their graduation.

So far, the first author, having opportunity to organize workshop related to general skills such as journal paper writing support and interdisciplinary academic exchange, has provided contents that include VE and TRIZ. In the interdisciplinary academic exchange, for example, students from various fields collaboratively define problems and suggest solutions through group working [6]. Although the students show strong interest on creativity and problem solving, which are included in VE and TRIZ, they are reluctant to proactively utilize them in their research activities. It may be because VE and TRIZ are mainly used for business improvement and product development in industry, and not popular in university education. In addition, researchers, especially who are not seeking commercial benefit but purely universal truth, may mentally conflict with some of the concepts of VE and TRIZ.

This paper aims to propose an application of value engineering (VE) and theory of inventive problem solving (TRIZ) to universal research supervision across various engineering fields in university education. The following sections firstly introduce the knowledge gained experience through journal paper writing support and interview survey on engineering students; then, discusses how VE and TRIZ could be reorganized for research supervision in engineering fields.

2. Problems observed through journal paper writing support

The first author has provided journal paper writing support for engineering students since several years ago, where many of the students seemed to be struggling with problems related to the general skills. Some students cannot clearly explain their research contents even in their native language, Japanese. Other students, which may be more serious situation, seemed to be performing their research activities without clear understanding of research backgrounds. One may, here, recognize the importance of general skills for defining a problem and organizing information, which may be a part of problem solving and communication skills, in addition to popular language training.

Then, the first author has proposed Fig.1 as a general recognition of a problem to be solved through their research with respect to the concept of problem definition in TRIZ [5]. One can clearly define a

problem to be solved through research by specifying information elements of "Research System", "Positive State", and "Negative State" [7].

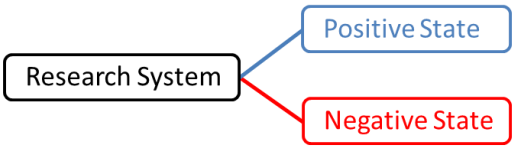

Fig. 1 Illustration of a problem to be solved through research

Here, as shown in Fig.2, a “System” is composed by a plurality of components, which may be “things”, “concepts” or “objects”, and generate certain behaviors as the results of interactions among the components. The behaviors are actions on components outside the system, and the recognitions of “positive” and “negative” on them determines the "Positive State" and the "Negative State" respectively.

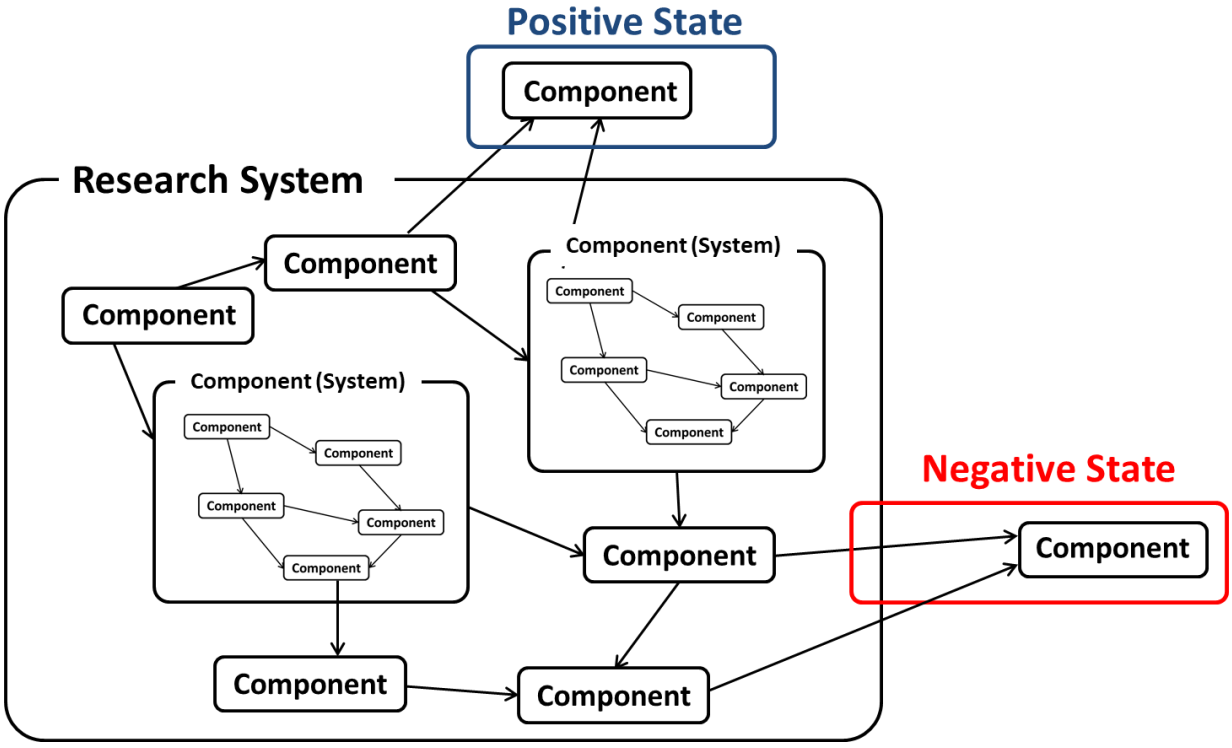

Fig. 2 Detail of “Research System” with “Positive State” and “Negative State”

The first author analyzed and categorized research outlines, which were submitted by the participants in the journal paper writing support, with respect to the problem definition in Fig.1 [8]. Although the research outlines contained many technical terms, so the contents are difficult to be fully understood, their research objectives seemed to be categorized into the following two types: (a) Clarifying the Generation Mechanism of “Negative State” and (b) Proposing New Methodology to Reduce “Negative State”.

The concepts introduced above, the problem definition and the two categorization of research types, have enabled the first author and the students to cooperatively define research objectives through smooth communication, resulting in more practical journal paper writing support across various engineering fields.

3. Interview survey on engineering students

In addition to above, an interview survey was conducted to grasp more specific problems faced by the students in their research activities. The answer to the question, "What is/was problems and concerns in your research activity?" were corrected from 20 engineering students; many of them were participants of the journal paper writing support. In the interview, the first author and students talked interactively as much as time allows and the average time duration spent for the interview each was about 10 to 20 minutes.

The survey results indicated that the concerns faced by the engineering students are roughly categorized into two groups: difficulties in the process of defining research topics and technical problems faced in research activities. The former group includes the answers such as “My problem perception does not agree with that of my supervisor.”, “I do not understand the meaning of this research.”, “I do not know how and from where I can start my research.”. The latter group is represented by the answer, “No one can support me when implementing suggestions given by supervisor.” and other technical troubles related to operations of experiment apparatus including simulation software.

4. How VE and TRIZ can be applied to research support?

Based on the experience through the research paper writing support and the results of the interview survey, one may conclude that VE and TRIZ can solve only limited number of students who are exposed to problems in university research activity. The methodologies in VE and TRIZ are designed for business improvement and product development; so, only the students who are challenging on idea generation for the research type, (b) Proposing New Methodology to Reduce “Negative State”, can directly utilize the method.

This is because more than half of research topics challenged by the students are the type (a), Clarifying the Generation Mechanism of "Negative State". In addition, most of the topics are transfers from previous works that has been always challenged for a long time in laboratory.

Of course, VE and TRIZ may encourage students to generate ideas related to the type (a), but, in such case, they need to intentionally stand on another viewpoint that is different from the product development process. In addition, although the students obviously can use VE and TRIZ for any technical problems faced in research activities, they often insufficiently understand their research backgrounds, where one may not expect much contribution to research achievements even with VE and TRIZ.

4.1 Application of VE and TRIZ for five phases in research activity

The authors, here, propose a research support strategy by applying VE and TRIZ as a solution to the problems. We firstly divide a research, in which “Publishing Paper” is a temporal goal, into five phases: (1) Defining Research Problem, (2) Defining Approach toward Problem Solving, (3) Obtaining Data, (4) Deriving Knowledge Based on Obtained Data, and (5) Information Sophistication. The following specifically introduces the application tactics of VE and TRIZ at the phases each.

1) Defining Research Problem

Defining a proper research topic may be the most important factor to smoothly progress on the following research activities. At this phase, then, one may apply the problem definition strategy, which has been introduced above with Fig.1, to clearly determine a problem to be solved through the research.

2) Defining Approach toward Problem Solving

One needs to specify an approach to solve the problem defined in the phase (1). As mentioned in section 2, the approach should be one of the two types, (a) Clarifying the Generation Mechanism of “Negative State” or (b) Proposing New Methodology to Reduce “Negative State”. Here, the authors propose to use functional analysis for both "Positive State" and "Negative State" for further specifying tasks to be performed in the following research activities. Although one may attempt to analyze a problem with a diagram like in Fig. 1, such description limits the number of components and interactions, while the function analysis, which enlists the template of a function, “Component (Subject)” “Action (Verb)”

“Component (Object)”, allows us to describe and analyze unlimited number of components and interactions.

The research type, (a) or (b), determines how the function analysis should be used as shown in Fig.3. Those who are engaged in the type (a) should select functions that seems to require further investigation on "Negative State" and further analyze the function based on own hypothesis. In this case, the tasks in experiments and investigations, which is phase (3), should aim to prove the hypothesis. Those who are engaged in the type (b) may pick up a conflicting pair from the functions that composes the "Positive State" and the "Negative State”, then modify the components engaged in them with respect to the TRIZ methods; Substance and Field Analysis, 40 Invention Principles and 76 Inventive Standards; to reduce the "Negative State". In this case, the tasks in phase (3) should aim to verify of the improved performance of the modified components.

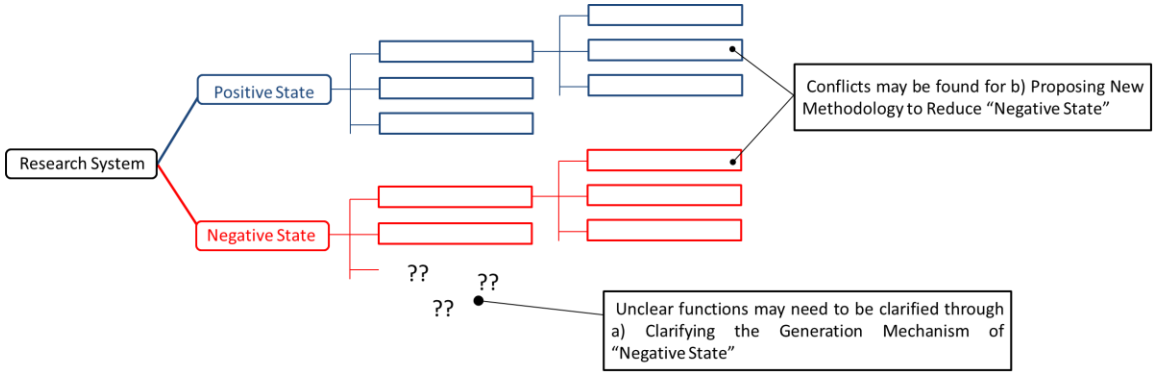

Fig. 3 Function analysis for defining approach toward problem solving

3) Obtaining Data

Students normally spend a lot of time on phase (3), where they perform experiment and other investigations to obtain data and problems faced in this phase can be progressed with strategies similar to those introduced in phase (1) and (2). According to the interview survey introduced above, the students face various problems at this phase, and they are required to solve the problems by their own. Therefore, VE and TRIZ may significantly influence on the students at this phase with proper research direction ensured through the phase (1) and (2).

Fig.4 shows the illustration of how experiments and other investigations are performed. In experiments and other investigations, a researcher observes that a component, which is defined as “Component 1”, is acting on another component, which is defined as “Component 2”, regardless of the research types, (a) and (b). Then, the researcher needs to control the “Component 1” with and measure its influence on “Component 2” with “Control and Measurement System”. The “Control and Measurement System” may be experiment apparatus and other operations for obtaining data. Here, one may assume that problems faced in phase (3) is troubles related to the “Control and Measurement System”.

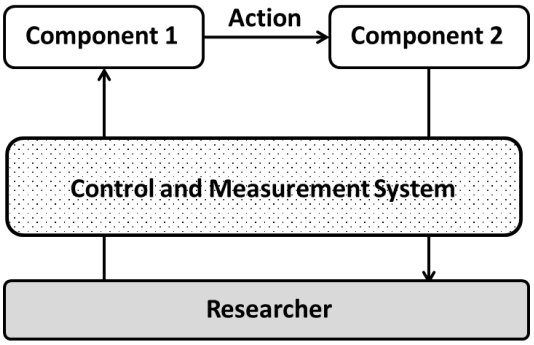

Fig. 4 “Control and Measurement System” for Obtaining Data

We can, now, define “Positive State” and “Negative State” of the “Control and Measurement System” as shown in Fig.5. The "Positive State" is, “It successfully observe the state, “Component 1” is acting on “Component 2”, while "Negative State" is, “It unsuccessfully observe the state, “Component 1” is acting on “Component 2”.

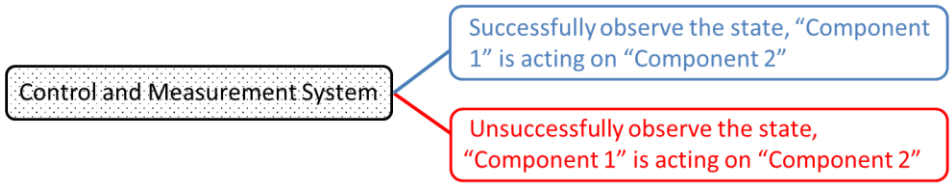

Fig. 5 “Positive State” and “Negative State” of the “Control and Measurement System”

As shown in Fig.6, the “Positive State” can be broken down into, “Control and Measurement System” controls “Component 1” and “Control and Measurement System” measures “Component 2”, while and the “Negative State”, “Control and Measurement System” insufficiently controls “Component 1” and “Control and Measurement System” insufficiently measures “Component 2”, followed by further function analysis on these functions. Then, one may proceed with possible approaches, (a) Clarifying the Generation Mechanism of “Negative State”, or (b) Proposing New Methodology to Reduce “Negative State”, for solving these problems, which are processes similar to phase (1) and (2).

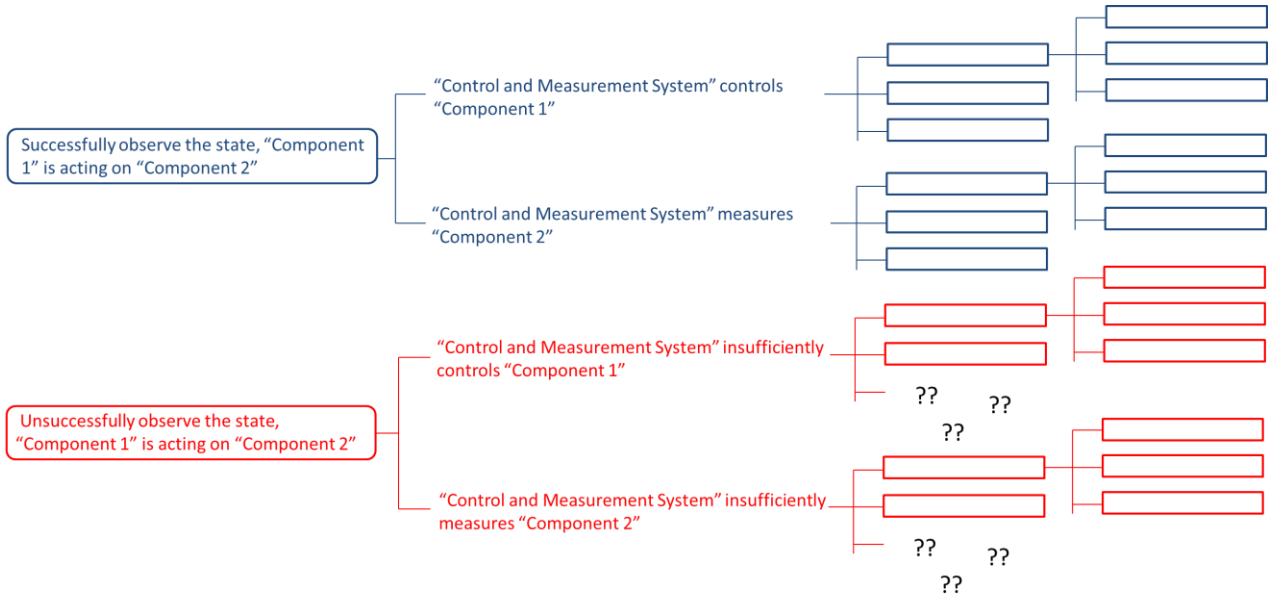

Fig. 6 Function analysis on “Control and Measurement System”

We now consider an example situation where a researcher observes a situation, “a motor consumes a battery”. Here “motor” and “battery” are “Component 1” and “Component 2” respectively. This operation may be a part of research type (a) when its purpose is to show a hypothesis that the motor more consumes the battery in certain condition than usual. This operation may also be a part of research type (b), when its purpose is to verify the higher performance of a newly developed motor. In both cases, proper control of the motor and proper measurement of its influence on the battery remaining are required to successfully complete this operation, in which any troubles encountered here are recognized as the "Negative State".

4) Deriving Knowledge Based on Obtained Data

One may organize information obtained through phase (1)-(3) with respect to the following items as the achievement candidates. The items, (A) and (B), are direct achievements of the research type (a) and (b) respectively; the results obtained through the process for the achievements may enable to present other items including (C). In addition, the items (D) and (E) possibly remains after going through whole process of a research for research type (a) and (b) respectively.

(A) Generation mechanism of “Negative State” has been clarified.
(B) New methodology reduces “Negative State”.
(C) New methodology to reduce “Negative State” has been proposed.
(D) Some generation mechanism of “Negative State” has not been clarified.
(E) New methodology generates new “Negative State”.

5) Sophisticating Information

The argument above may enable to further sophisticate information obtained through research by using the template shown below. One may insert information elements into the template to systematically develop a draft for upcoming research presentations.

“Research System” generates “Positive State”, however, it also generates “Negative State. Previous research has clarified that the “Negative State” is generated because *Explain how “Negative State” is generated*, (while *Explain unknown parts of how “Negative State” is generated* has not been clarified). This research aims to *Explain research objective with respect to one of the following two research type, a) Clarifying the Generation Mechanism of “Negative State”, b) Proposing New Methodology to Reduce “Negative State”.*. In this research, it has been observed that “Component (Subject)” “Acts on (Verb)” “Component (Objective)”. The parameter of “Component (Subject)” was controlled by using the control system, which *Explain the control system*, then, the parameter of “Component (Object)” was measured by using the measurement system, which *Explain the measurement system*. The observation result indicated that *Explain what were observed.*. Therefore we concluded that *Explain what you can conclude with respect to one or some of the followings. i)Generation mechanism of “Negative State” has been clarified. ii)New methodology reduces “Negative State” iii)New methodology to reduce “Negative State” has been proposed.*. However, *Explain the remaining problems to be solved in future works with respect to the followings. iv)Some generation mechanism of “Negative State” has not been clarified. v)New methodology generates new “Negative State”* remained as future challenges.

Fig.5 Template for Sophisticating Information

4.2 Future prospects

University, in its long history, has played an important role in creating and transmitting advanced knowledge through lectures and research supervisions by expert faculties in specific fields. However, recent rapid development of information technology has enabled everyone to instantaneously access to information all around the world, which is rapidly lowering the value of advanced knowledge owned by the expert faculties. In addition, new discoveries, which is the achievements of research activities, tend to expire in shorter time than before; so, university students currently cannot get job only with expert

knowledge and experience obtained through their university lives.

Instantaneous access to a large amount of information sometimes confuses students and their supervisors when proceeding with research activities. The students often access overly particular information, which may not be fully understood even by their supervisors, for solving problems confronted. The supervisors, in such situation, may wrongly lead the students into deep maze where the students are isolated and lose the sight of meanings of their tasks. Although one may limit the research topics only within the field that the supervisor can fully control to avoid this situation, it inevitably narrows the possibility of education and research activities.

The authors are ultimately aiming at establishing a universal research support methodology shared across all disciplines by extending VE and TRIZ. Such methodology will allow university faculties to concentrate on research support fully using their expertise and share research support know-hows across various fields. In the era, as described above, VE and TRIZ will have increasing importance as a proactive way to foster students' creativity across disciplinary boundary.

5. Conclusion

This paper has presented how VE and TRIZ, which are mainly used for business improvement and product development, can be applied to research support in university based on the experience through journal paper writing support and interview survey conducted on engineering students. Students often lose the sight of direction in their research activities for various reasons. Then, the strategic utilization of VE and TRIZ at 5 phases in research activities have been specified. As future prospects, it has been stressed that the traditional role of university education, knowledge transmission, is currently losing its meaning due to the development of information technology, and contents in VE and TRIZ, which has been introduced in this paper, may become more significant in future university education.

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