ISSN Online 2527-5933
MATH-EDU: Jurnal Ilmu Pendidikan Matematika
Volume 11, Nomor 2, Agustus 2026, pp.150-163

Student Error Analysis of Grade X Students Based on Newman's Stages in Solving Linear Programming Problems in the Context of Tempe Production

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Article Information

Received:
10th July 2026

Accepted:
14th August 2026

Publish:
31st August 2026

Keywords
Error Analysis
Newman's Stages
Linear Programming
Tempe Context

Abstract

This study aims to identify the types of errors and the factors causing errors experienced by grade X students in solving linear programming problems based on the context of tempe production, referring to Newman's stages. The approach used in this study is a descriptive qualitative approach involving three subjects selected based on high, moderate, and low levels of mathematical ability among senior high school students in the city of Palembang. The research instruments consisted of a Student Worksheet (LKPD) focused on the context of tempe production, along with a semi-structured interview guide, with data analysis using the Miles and Huberman model. The findings of this study reveal that the most frequently encountered error was comprehension errors, followed by reading errors and transformation errors, while process errors and encoding errors were not identified independently. The conclusion of this study indicates that students still face significant obstacles in understanding linear programming word problems referring to local context, which is caused by low conceptual understanding and the habit of solving problems procedurally.

How to Cite: Sapitri, T. S. et al. (2026). Student Error Analysis of Grade X Students Based on Newman's Stages in Solving Linear Programming Problems in the Context of Tempe Production. *Math-Edu: Jurnal Ilmu Pendidikan Matematika*, 11 (2), 150-163.

Introduction

Mathematics is a fundamental field of science that plays a strategic role in shaping students' logical, analytical, and systematic thinking skills from elementary to senior high school levels (Ramadhani et al., 2024). In the context of 21st century learning, mathematical problem-solving ability has become an essential competency that students must master, not merely limited to mastery of algorithmic procedures, but also deep conceptual understanding as a foundation for facing real problems (Risky et al., 2022). This is in line with the demands of the national curriculum, which emphasizes context-based learning and higher-order mathematical reasoning. Therefore, the quality of students' understanding in solving contextual mathematics problems becomes an important benchmark in evaluating the success of learning. This ability is becoming increasingly crucial because various studies show that almost all students still make systematic errors when faced with word problems that require deep understanding (Ismaimuza et al., 2024).

One of the senior high school grade X mathematics topics closely related to contextual problem-solving ability is linear programming. This topic requires students to be able to translate real problems into mathematical models in the form of systems of linear inequalities, draw graphs of feasible regions, and determine optimum values through the corner point method (Upu et al., 2022). The complexity of these solution stages makes linear programming one of the topics prone to errors, ranging from the stage of understanding the problem to drawing the final conclusion. Various studies show that student errors in linear programming material are systematic and recurring, so structured identification is needed to determine appropriate learning interventions (Silalahi & Dewi, 2023). A recent study using a Bayesian approach even revealed that students' main errors lie in the omission of constraints and the reversal of inequality signs, indicating a structural misconception (Gunawan, 2025).

The phenomenon of student errors in solving linear programming problems was also found in the field. Based on preliminary observations and interviews with mathematics teachers at a senior high school in Palembang, grade X students showed considerable difficulty in understanding information from linear programming word problems, converting it into a mathematical model, and performing correct calculations (Ismiasih, 2023). These errors have so far only been identified in general terms without being analyzed in depth using a systematic diagnostic approach, so teachers have not been able to determine the most appropriate type of intervention for each student (Silalahi & Dewi, 2023). Other research also confirms that students with low mathematical ability tend to fail earlier at the stage of understanding the problem, while high-ability students still make errors at the calculation and conclusion-drawing stages (Purmanna et al., 2024). This condition reflects a gap between the ideal learning condition, which requires comprehensive conceptual understanding, and the reality in the field, which still shows many errors in the problem-solving process.

One of the error analysis instruments widely used in mathematics education research is the Newman procedure. This procedure classifies errors into five stages, namely reading errors, comprehension errors, transformation errors, process skill errors, and errors in writing the final answer (encoding errors) (Tias & Ismail, 2023). Several previous studies have applied this procedure to linear programming material. Risky et al. (2022) found that transformation errors were the main obstacle for students in solving linear programming problems. Similar findings were presented by Ramadhani et al. (2024), who confirmed the dominance of errors at the transformation and process skill stages. Ismiasih (2023) further revealed that students made errors at all Newman stages, with the main causal factor being low conceptual understanding and the habit of memorizing procedures without understanding their meaning. Basriannor et al. (2023) also added that problem contexts unfamiliar to students contributed to an increased frequency of errors. A recent study by Logistica and Awalludin (2024) on exponentiation material also reinforced the finding that transformation errors dominated (49%) as the cause of student failure, indicating that the main weakness lies in the process of abstraction from text to mathematical symbols. Another study by Wati et al. (2025), specifically on linear programming, found that transformation errors occurred because students used the wrong inequality sign when writing the mathematical model.

Although these studies have made important contributions, a clear gap remains: research specifically analyzing student errors in linear programming based on local wisdom contexts, particularly the context of tempe production as part of Indonesian community culture, is still very limited (Hayannisa, 2025). This is illustrated by Purmanna et al. (2024), who still analyzed linear programming errors using only a general context, even though contexts close to students' daily lives have the potential to increase cognitive engagement and reveal more authentic error patterns (Basriannor et al., 2023). Recent ethnomathematics research shows that local context alone does not guarantee error free problem solving, since students can still struggle to understand problem information and determine solution strategies without adequate conceptual understanding (Masamah & Rakhmandani, 2025), indicating that in-depth investigation of error causes at each Newman stage in such contexts has not been widely conducted.

Based on this gap, this study offers an error analysis approach based on the Newman procedure integrated with the context of tempe production as a representation of local wisdom relevant to students. The novelty of this study lies in the use of local cultural context as a medium for linear programming problems, while also serving as a means to reveal patterns and causes of student errors in a more contextual and in-depth manner. Thus, this study aims to identify the types of errors and the causes of errors made by grade X students in solving linear programming problems based on the context of tempe production according to Newman's stages.

Methods

This study is a descriptive qualitative study, which aims to analyze student errors in solving linear programming problems based on the context of tempe production. The descriptive qualitative method was chosen because this study places greater emphasis on students' thought processes and the types of errors made in solving problems, rather than on the final results expressed quantitatively. The focus of this study is to analyze student errors in solving problems based on Newman's stages. These stages were then developed into error indicators used to analyze student errors at each step of problem solving. The indicators of student errors based on Newman's stages are presented in Table 1 below (Tias & Ismail, 2023).

Table 1. Indicators of Student Errors Based on Newman's Stages

No.	Indicators	Error Criteria
1.	Reading Errors	Errors in reading terms or symbols contained in the linear programming problem.
2.	Comprehension Errors	Errors in determining the information known and asked in the linear programming problem.
3.	Transformation Errors	Errors in converting the linear programming problem into a mathematical model and errors in determining the appropriate strategy or steps for solving the linear programming problem.
4.	Process Errors	Errors in performing mathematical calculation operations during the solving process.
5.	Encoding Errors	Errors in writing the final conclusion of the solution result.

The research subjects were selected based on recommendations from mathematics teachers. Students were chosen based on their mathematics achievement during the learning process and grouped into three categories: high, moderate, and low ability. This grouping was conducted to capture a range of student abilities in identifying errors at each stage of Newman's model. Based on the results of this grouping, the research subjects consisted of NH, NAS, and GPS, who are high school students in Palembang. The study was conducted on Sunday, April 26, 2026.

The research procedure was carried out in three stages, namely the preparation stage, the implementation stage, and the data analysis stage. In the preparation stage, the researcher developed research instruments in the form of a written test and an interview guide, and carried out instrument validation. In the implementation stage, subjects were asked to complete the written test independently, followed by an interview with each subject. Furthermore, the final stage is the data analysis stage, which is the process of organizing the test and interview result data for further analysis.

The data collection technique in this study used a written test in the form of a Student Worksheet (LKPD) based on the context of tempe production and semi-structured interviews. The LKPD was used to obtain written data on student errors in solving linear programming problems based on Newman's stages, while the interviews were used to explore more in-depth information regarding the causes of the errors.

The data obtained were then analyzed using the Miles and Huberman model. The Miles and Huberman data analysis model is a model in qualitative research that emphasizes that the data analysis process is carried out interactively, repeatedly, and continuously, starting from the data collection stage to the drawing of conclusions. The Miles and Huberman analysis model consists of three stages, as follows (Miles et al., 2020).

1. Data reduction, namely the process of selecting, focusing attention, simplifying, and abstracting raw data from field notes as they occur. This process includes summarizing data, coding, tracing themes, and grouping data into certain categories.
2. Data display, namely the process of compiling a set of information so as to allow conclusions to be drawn and decisions to be made. In qualitative research, data can be presented in various forms, such as narrative text, matrices, graphs, networks, or charts.
3. Conclusion drawing or verification, carried out continuously throughout the field research process. From the beginning of data collection, the researcher begins to search for meaning, record patterns of regularity, formulate explanations, identify possible configurations and causal relationships, and formulate tentative findings.

To ensure the validity of the data obtained, this study used a data validity testing technique. Validity testing was carried out so that the analyzed data has a high level of reliability and can be accounted for. In this study, data validity was obtained through triangulation, namely a technique for checking data validity by analyzing it from various aspects. The triangulation used in this study is as follows (Nurfajriani et al., 2024).

1. Source triangulation, used to increase data validity by re examining data obtained from various sources or subjects. Through this technique, the researcher compared interview results from each subject to obtain more accurate conclusions and to ensure the information obtained.
2. Technique triangulation, used to test data validity by re checking the accuracy of data from the same source but using different data collection techniques.

Result and Discussion

Result

This study was conducted with the aim of identifying the errors made by students and their causes in solving linear programming problems based on the context of tempe production. At the instrument validation stage, the researcher carried out a validation process on the LKPD by involving a Mathematics Education lecturer from Universitas Sriwijaya as the validator. Based on the validation results, several suggestions and inputs were obtained regarding the content, language, and presentation of the LKPD. The details of these suggestions and comments can be seen in Table 2.

Table 2. Instrument Validation Results

Comments/Suggestions	Revision Decision
Keep using the tempe context, but the case of local versus imported soybeans needs to be changed	Changing the context from a comparison of local and imported soybeans to the use of plastic wrapped tempe and leaf wrapped tempe
General information needs to be added to the LKPD	Adding general information such as learning objectives, instructions for working on the sheet, grade level, and time allocation
The tempe context has not been explained in general	Adding a general description of tempe as an introduction before the problem
The problem is appropriate, but students still need help in working on it	Adding hints/guidance in several answer boxes
The presentation of the feasible region is not supported by clear visuals	Adding a coordinate axis image (x and y) in the feasible region section

This input was then used as a basis for revising the LKPD so that a suitable instrument was obtained for use in the study. Subsequently, the revised LKPD was used in the implementation stage of the study and tested on the research subjects. The results of the LKPD revision are presented in Figure 1.

Figure 1. Revised LKPD Results

Next, three students with heterogeneous levels of mathematical ability were selected based on the students' report card results, as presented in Table 3 below.

Table 3. Categories of Students' Mathematical Ability Levels

Initial	Ability Category	Student Code
NH	High	S1
GPS	Moderate	S2
NAS	Low	S3

Based on these categories, data collection was carried out by giving students an essay test in the form of an LKPD containing a linear programming problem based on the context of tempe production. Student answers were then reduced and analyzed by examining the errors that emerged based on Newman's stages in working on the LKPD.

From the students' answers, the number of errors that emerged from students in working on the LKPD can be seen in Table 4 below.

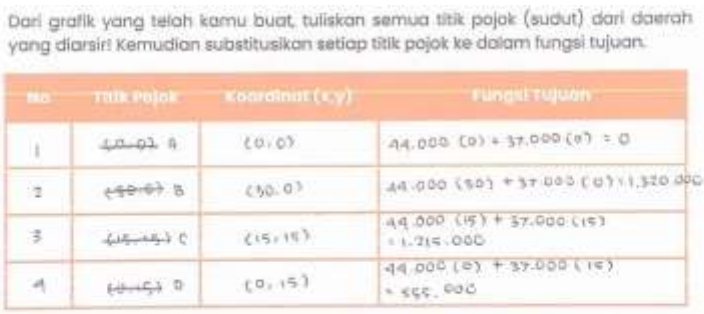
Table 4. Student Errors Based on Newman's Stages

Type of Error	Number of Errors
Reading	1
Comprehension	2
Transformation	1
Process	0
Encoding	0

From the results in Table 4, it can be concluded that the most common type of error among the students who were the subjects of this study is Comprehension Errors, or errors in understanding.

Reading Errors

Based on Figure 2 below, it can be seen that S1 made an error in reading the term corner point by filling in the coordinates from the results previously obtained, then subsequently realized the error and corrected it.



Dari grafik yang telah kamu buat, tuliskan semua titik pojok (sudut) dari daerah yang diarsir! Kemudian substitusikan setiap titik pojok ke dalam fungsi tujuan.

No	Titik Pojok	Koordinat (x,y)	Fungsi Tujuan
1	~~(0,0)~~ A	(0,0)	44.000 (0) + 37.000 (0) = 0
2	~~(30,0)~~ B	(30,0)	44.000 (30) + 37.000 (0) = 1.320.000
3	~~(15,15)~~ C	(15,15)	44.000 (15) + 37.000 (15) = 1.215.000
4	~~(0,15)~~ D	(0,15)	44.000 (0) + 37.000 (15) = 555.000

Figure 2. Reading Error in S1

The following is an excerpt from the interview between the researcher (R) and S1.

R : In the corner point section, you directly wrote the coordinates in the corner point table. Why do you think you wrote it that way?

S1 : I thought I should just write the coordinates, because I usually write the coordinates directly without labeling them first, like A, B, C, and so on.

R : Then why did you change it back from coordinates to A, B, C?

S1 : I only realized it when I reread the table heading, that what needed to be filled in was the name of the corner point that I had labeled A, B, C. So I moved the coordinates to the adjacent column.

The interview results show that the focus remained on solving the problem due to habitual factors, resulting in less attention being paid to the given terms and ultimately filling in the answer in the wrong section.

Comprehension Errors

S3 and S2 experienced the same error, which had quite fatal consequences. The answers show that they were able to read the problem, but failed to grasp the meaning or context of the information given. S3 made an error in interpreting the constraint in the story, as did S2. She considered the information "banana leaf stock only sufficient for 15 kg" as additional available soybeans, when in fact it was a constraint for a specific variable.

The student added the total soybean capacity (30 kg) to the banana leaf stock constraint (15 kg). She saw the figure 30 + 15 = 45 without understanding that 15 kg was part of the total capacity, not an additional new raw material. This misunderstanding at this initial part of the problem caused the answers of S2 and S3 to subsequent problems to become less accurate.

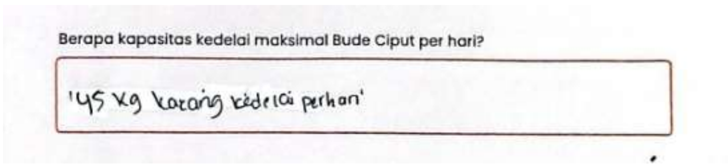


Figure 3. Comprehension Error in S3

The following is an excerpt from the interview between the researcher (R) and S3.

R : Regarding the section on Bude Ciput's maximum soybean capacity per day, why did you get 45 kg?

S1 : It was obtained from 30+15.

R : In the word problem, which part is the 30+15?

S1 : 30 kg is seen from "Bude Ciput bought 1 pack of plastic wrap for Rp30,000, which is sufficient for 30 kg of soybeans," while 15 kg is from the availability of leaf wrapping that can only process a maximum of 15 kg of soybeans per day.

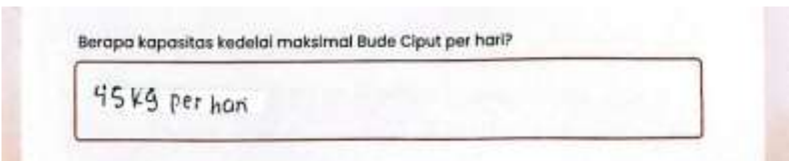


Figure 4. Comprehension Error in S2

The following is an excerpt from the interview between the researcher (R) and S2.

R : How did you conclude that Bude Ciput's maximum soybean capacity per day is 45 kg?

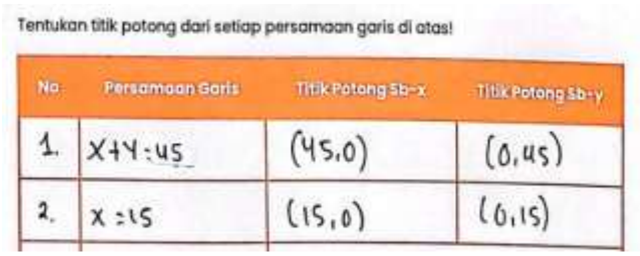
S1 : Well, because 30+15, R.

R : 30+15, which information is that from?

S1 : From 30 kg of plastic wrapped tempe plus 15 kg of leaf wrapped soybeans.

Transformation Errors

Based on Figure 5 below, it can be seen that S2 made an error in determining the second intercept point on the y axis, because the value at the second intercept point on the y axis should not exist, or it is sufficient to only fill in the x axis intercept point.



Tentukan titik potong dari setiap persamaan garis di atas!

No	Persamaan Garis	Titik Potong Sb-x	Titik Potong Sb-y
1.	x+y=45	(45,0)	(0,45)
2.	x =15	(15,0)	(0,15)

Figure 5. Transformation Error in S2

The following is an excerpt from the interview between the researcher (R) and S2 regarding S2's error in determining the intercept point.

R : In the second equation in Activity 2, the line equation is x = 15. Now, why does the y axis intercept point have a value of (0, 15)?

S1 : Because it's just reversed, R.

R : What is reversed?

S1 : Because the x and y values are just reversed.

Based on the interview results above, it can be seen that S2 made an error in determining the intercept point for an equation that only contains one variable. This may also occur due to the factor of the first equation, in which the intercept points were indeed obtained by reversing the variables for each intercept point. This shows that S2 does not yet fully understand how to convert a line equation into intercept point form.

Process Errors

Based on the analysis results of the three subjects, no errors were found at the process errors stage. This is because S2 and S3 had already made errors at the previous stages (comprehension and transformation), so the solving process could not be continued correctly and the resulting answers became incorrect. Meanwhile, in S1's answers, no process errors were found. It can therefore be concluded that process skill errors could not be independently identified in this study.

Encoding Errors

At the encoding errors stage, no errors were also found at this stage for the three subjects. This is because all three subjects wrote their final answers correctly, even though the answers of S2 and S3 were inaccurate. Thus, encoding errors were not identified in this study.

Discussion

The research results show that among the three subjects, the errors identified were comprehension errors experienced by S2 (moderate ability) and S3 (low ability). This is in line with research by Simbolon et al. (2023) and Rosidah et al. (2022), which also found that comprehension errors are the most prevalent type of error in linear programming material, with the primary cause being students' low conceptual understanding of the problem context. Both students misinterpreted the production constraints in the problem, specifically by adding the total soybean capacity (30 kg) to the banana leaf stock (15 kg) to arrive at 45 kg, even though the figure of 15 kg represented a constraint on a specific variable, not an additional raw material. Errors at this stage are critical because they directly impact the entire subsequent problem-solving process. The primary cause is students' low conceptual understanding of the problem context, in which they fail to distinguish information serving as variable constraints from information describing total capacity—particularly in the context of tempeh production, which requires an understanding of the real-world situation before it can be abstracted into a mathematical model.

In addition to comprehension errors, S2 also made a transformation error in the form of a mistake in determining the intercept point of a single variable equation ($x = 15$). She considered the y axis intercept point of this equation to be $(0, 15)$ by "reversing" the x and y values, a procedure she incorrectly applied out of habit from working with two variable equations. This indicates a misconception in the geometric representation of coordinates, in which the student has not yet conceptually understood that a single variable equation only has one intercept point on the corresponding axis. Meanwhile, reading errors were only found in S1 (high ability) and were minor in nature, with the error occurring in filling in the corner point column but being quickly recognized and corrected independently, so this error was more triggered by learning habits than by an inability to read the problem instructions. This error is consistent with research by Simangunsong et al. (2021) and Risky et al. (2022), which found that reading errors in students tend not to be caused by an inability to read, but rather by students' habit of working on problems procedurally, resulting in a lack of attention to the terms and instructions given.

Upon further analysis, it appears that process errors and encoding errors did not occur independently. As found in research by Rofi'ah et al. (2024), process errors and encoding errors are often unable to be identified independently when errors at the previous stage have caused the student's solving process to stop before reaching that stage. This is factually explained by the fact that S2 and S3 had made errors at the previous stage, so the solving process could not be continued correctly, even though they did not make any process errors or encoding errors. Meanwhile, S1, who made no errors at the early stage, was able to complete all the problems accurately, including writing the final conclusion. The patterns observed in the three subjects in this study indicate that students with moderate and low mathematical ability tend to make errors in the early stages of Newman's model, particularly in the comprehension and transformation stages, whereas students with high ability do not make errors in those early stages. However, this study involved only three subjects. Therefore, it does not yet provide sufficient evidence to establish a relationship between students' mathematical ability and the stages of error according to Newman's model. Conversely, these findings provide an indication of how differences in students' mathematical ability may be reflected in the types and stages of errors observed in these specific cases. This is in line with the findings of Putri et al. (2025), who examined student errors in the SPLDV (system of linear equations in two variables) material based on prior mathematical ability, and found that students with moderate to low ability consistently made errors starting from the comprehension and transformation stages, while high ability students only made errors at the final stages of solving, such as calculation and answer writing. Therefore, the findings of this study highlight the importance of structured learning and systematic guidance so that students can more easily understand word problems, particularly in strengthening their understanding of the context of the problems and their ability to convert linear equations into graphical representations.

Conclusion

This study explored the types and possible causal factors of errors made by grade X senior high school students in Palembang in solving linear programming problems based on the context of tempe production, according to Newman's stages. Among the three subjects with different mathematical abilities, three types of errors were identified, namely comprehension errors, reading errors, and transformation errors. Comprehension errors were the main obstacle for subjects with moderate and low ability, who misinterpreted a variable constraint as an addition to raw material capacity, causing the entire subsequent problem solving process to become inaccurate. Transformation errors reflected a misconception in determining the intercept point of a single variable equation, while reading errors in the high ability subject were minor in nature and quickly self corrected. Process errors and encoding errors were not identified independently, as errors at the previous stages had already stopped the solving process at an earlier point. This patterns observed in the three subjects indicate that students with moderate and low mathematical ability in this study tended to make errors in the early stages of Newman's model, which affected their ability to solve subsequent problems. However, this study involved only three subjects and cannot be generalized to establish a broader relationship between mathematical ability and the stages of error according to Newman's model. The errors observed appear to be related to weak conceptual understanding and a habit of solving problems procedurally, which may have been further compounded by the local wisdom context of tempe production that requires an understanding of the real situation before it can be abstracted into a mathematical model.

Based on these findings, mathematics teachers are advised to accustom students to reading problems carefully and discussing the interpretation of information before beginning the solving process, as well as to strengthen students' understanding of the concept of coordinate geometry representation more explicitly. From a research perspective, further studies need to expand the number of subjects and use variations of other local wisdom contexts so that the findings can be more broadly generalized. The development of a more detailed and standardized Newman based diagnostic instrument is also needed to support more targeted learning interventions. In addition, research integrating Newman's stages with specific learning models, such as problem based learning or a realistic mathematics approach, is highly relevant to explore as a concrete form of intervention to address the error patterns found.

Recommendation

Since the three subjects in this study were selected based on report card scores rather than a standardized diagnostic test, future research should use a validated mathematical ability instrument prior to subject selection to ensure that ability categorization more accurately reflects students' actual conceptual grasp of linear programming. Because interviews in this study were conducted only after the written test was completed, subsequent studies could incorporate think aloud protocols during the solving process itself, allowing errors to be traced at the moment they occur rather than reconstructed retrospectively. As this study relied on a single validator during instrument development, involving multiple validators with differing areas of expertise, such as mathematics education and language assessment, would help ensure that contextual word problems are both mathematically sound and linguistically accessible to students. For classroom practice, teachers can use the specific error patterns identified here, particularly the tendency to conflate a constraint with total capacity, as a concrete example when designing formative assessment items that deliberately test this distinction.

Acknowledgments

For their help and support, the authors want to express their sincere gratitude to the lecturers of the Mathematics Education Study Program at Universitas Sriwijaya who served as validators of the research instrument. They also want to thank the senior high school students in Palembang, NH, GPS, and NAS, who volunteered to be the subjects of this study.

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