

A PC-based Decision Support System for Optimal Cutting of Logs in Veneers Production

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We report on a user-friendly decision support system (DSS) for solving specific cutting stock problem from a smaller wood-processing company. A prototype DSS is developed for use in veneers production and is designed to aid managers in create or improving existing tailoring of logs using their experience and preferences. The results of testing a typical cutting-stock problem are shown to point out how such DSS, which utilizes linear and mixed-integer programming, can reduce inventory costs and improves the exploitation of input material.

Povzetek: V prispevku je prikazan odločevalni informacijski sistem (OIS) za reševanje problema razreza hlodov na podhlode v proizvodnji furnirja.

1 Introduction

Decision Support Systems (DSS) have emerged as the computer-based system to assist decision makers address semi structured problems by allowing them to access and use data and analytic models. Such systems have the following characteristics: they are interactive computer-based systems; they are aimed at semi-structured problems. They utilize models with internal and external databases, and they emphasize flexibility, effectiveness, and adaptability. These characteristics have guided much of the research in the DSS area, but the potential benefits of DSS in the business environment have not been fully realized [1, 2, 3].

Although the definition of the DSS concept has been elusive, the field has flourished with the development of computer technology. Keen [8] reviewed the decade of DSS development and concluded that there is a need for balance between each of the three DSS elements: decision, support and systems. To achieve the mission of DSS - helping people make better decisions - Keen stressed the need for an active supporting role for decisions that really matter. This paper focuses on the decision component of the DSS.

PC technologies are becoming accepted and incorporated into organizations and our personal lives. PC-based systems have the potential to improve both individual and organizational performance. As decision makers recognize the potential benefits, many companies are investing in information technology. PC-based systems have been generally hailed as a revolution that will change the nature of professional work and transform the way people work. It is expected that almost all knowledgeable workers are likely to have

their own PC to perform both stand-alone tasks and network services.

Despite the proliferation of microprocessor-based systems, the potential benefits of these systems, as aids to managerial decision making, may not be fully realized due to poor design and low acceptance by users. It is recognized that individuals are sometimes unwilling to use these systems, even if the system may increase their productivity. While some of these systems may have an impact on individuals and organizations, the adoption and acceptance of these systems among decision-makers has been limited. This may be due to the inflexibility in the systems as well as their narrow design. Therefore, it is important to understand the environment of the decision makers and the type of support they need in order to make effective decisions, and to examine the models appropriate for addressing their problems [1, 5].

In this paper we describe a PC-based DSS which addresses the optimal cutting of logs in the manufacturing of veneers. The development of DSS is proposed on generalized prototyping approach [2, 3] that leads to more efficient and simpler use of such systems. The effectiveness of the DSS is shown by relatively simple example which utilizes the pattern-oriented LP-based methods for solving one-dimensional cutting stock problem. The results of testing show that the application of such managerial DSS enhances problem solving capability for achieving greater competitiveness of an organization.

In the first part of the paper, we present a description of the major operations in the production of veneers focusing on the process of efficient longitudinal tailoring of logs. The second part of the paper describes

design and development of a DSS for this environment. Finally, we illustrate how the DSS can be used in practice to improve existing intuitive tailoring of logs.

2 The application problem

The application problem that is considered in this case study was identified in a small-to-medium size Slovenian veneers factory. The factory belongs to a group of connected wood-processing enterprises that have successfully passed the process of economical restructuring in the past few years. The factory is producing steamed and sliced veneers from domestic and imported wood species. It has been operating since 1926 and is famous all over Europe particularly for its top-quality steamed beech veneers. On one side, this reputation is a result of a long tradition. On the other side, the management is continuously striving to improve the competitive position of the enterprise by gradual automation of production facilities as well as by introducing modern information systems and advanced information technology.

In this sense, a particular challenge for the manager of the company in recent years has been a better integration of production and business processes by means of various DSS. Such integration became a necessity due to a change in market conditions. In previous decades of successful operation for the largely unsaturated market, their production relied on the so-called "make-to-stock" strategy. With recent economy trends, such as: loss of the market share in the countries of the former Yugoslavia, privatization and restructuring of the Slovenian national economy, as well as further globalization of trade, the management has been forced to switch over to the strategy of "make to order". In such a situation, we would define the problem as follows.

While the partially intuitive planning, assisted with simple calculations, was enough to manage the previous strategy, the new production planning strategy requires more sophisticated information systems. Due to very tight resources in terms of available time, qualified people and investment money, the management currently cannot deal satisfactorily with these problems. In this situation, our research group decided to perform some exploratory work, with the aim to develop a suitable DSS for a specific Mathematical Programming (MP) application.

2.1 Analyzing the decision-making process

The essential operation to be discussed in this paper is longitudinal tailoring of logs. It is done by cutting the selected logs in the transversal direction to a pre-determined number of sub-logs. The tailoring plan is prepared in advance according to the actual purchasing orders, as it is explained later. The aim of this operation is to get proper initial length of sub-logs before slicing them to veneer sheets that have the same length as sub-logs. In terms of optimal wood exploitation, this operation has the greatest potential for achieving substantial cost savings. Therefore this operation was chosen to receive the main attention in the presented case study.

Primary analysis of the decision-making process applied to the management of the veneers production operations described in a paper [3] reveals a number of decision-making situations. One of the relevant problems in this regard, such as determination the optimal log-cutting strategy and the quantity of logs to be purchased, is related to optimal exploitation of input material (logs). This situation is shown in Fig. 1.

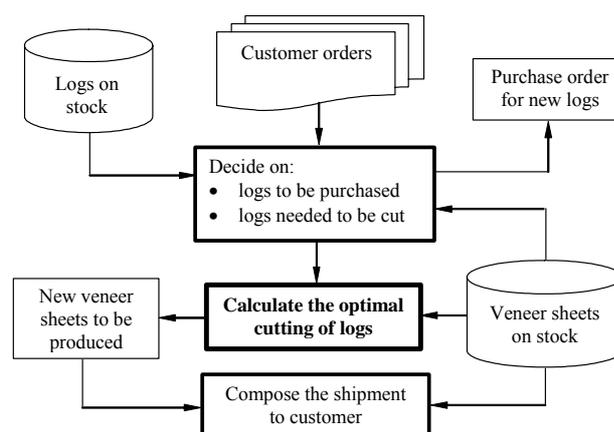


Fig. 1: The decision-making process in the production of veneers.

The discussion is focused to the indicated initial decision-making problem from Fig. 1, i.e. the optimal cutting of logs. The current decision-making model in the production of veneers is based on obtainable data

samples about logs and related veneer sheets that have been produced in several periods (see Table 1).

Up to the present, the **longitudinal tailoring** was performed by an intuitive "rule of thumb". Thereby, the

goal of the operations manager is to establish a “reasonable minimum” of the edge-waste remainders of logs which, unfortunately, does not take into account the end-waste remainders of logs. This simple approach to log cutting causes gradual accumulation of an undesired inventory of veneer sheets in the warehouse which

significantly increases inventory costs. Thus the idea is to improve the existing decision-making process using scientific approach to minimize at the same time both, the edge waste as well as the end waste from cutting the logs.

Table 1: Typical data samples about the logs and the veneer sheets

	Log ID number	Length (cm)	Volume (m ³)		Log ID number	Length of sheets (cm)	Area (m ²)
Log 1	1234	563	1,19505	Packet 1	1234	220	13,024
Log 2	1535	657	2,047	Packet 2	1535	182	8,91072
Log 3	1623	446	0,741	Packet 3	1623	151	6,2816
Log 4	1854	721	1,904	Packet 4	1854	193	12,4678
Log 5	1910	512	0,701	Packet 5	1910	112	2,0608

2.2 The problem-solving paradigm

The problem of optimal cutting of logs in veneer production is called *one-dimensional cutting stock problem* (1d-CSP). This problem consists of determining the smallest number of logs of length L_p , ($p = 1, 2, \dots, s$) that are available in sufficiently large quantity and have to be cut in order to satisfy the required number b_i sub-logs of lengths l_i ($i = 1, 2, \dots, m$). The lengths of sub-logs l_i are determined by the required length of ordered veneer sheets. On the other hand, the required number of sub-logs (b_i) can be calculated from the required area and thickness of ordered veneer sheets taking into account the diameter and quality of logs to be cut. A combination of required sub-logs lengths in the log of length L_p is called cutting pattern. For each log length L_p , the number n_p ($p = 1, 2, \dots, s$) of all different cutting-patterns can be determined with regard to the particular sub-log length l_i . The element a_{ijp} of matrix A that describes each cutting pattern, represents the number of sub-logs of length l_i obtained in cutting pattern j related to log length L_p . The number of logs of length L_p to be cut according to cutting pattern j is denoted by a decision variable x_{jp} .

In this problem situation, the objective is to minimize the number of logs (x_{jp}) of length L_p , that have to be cut according to the j -th pattern. Thus, our 1d-CSP represents a pure integer programming (IP) problem that can be modeled as follows:

$$\min \sum_{p=1}^s \sum_{j=1}^{n_p} L_p x_{jp} \tag{1}$$

subject to

$$\sum_{p=1}^s \sum_{j=1}^{n_p} a_{ijp} x_{jp} \geq b_i, \quad i = 1, \dots, m$$

(2)

where

$$x_{jp} \geq 0 \text{ and integer, } j = 1, \dots, n_p; \quad p = 1, \dots, s$$

For cutting pattern to be valid:

$$\sum_{i=1}^m a_{ijp} l_i \leq L_p \tag{3}$$

$$a_{ijp} \geq 0 \text{ and integer, } j = 1, \dots, n_p; \\ p = 1, \dots, s$$

The IP problem described above can be solved using different LP-based methods [3, 4, 9]. In practice, most IP problems can be solved by the technique of Branch-and-Bound (BB).

In actual situation, the ordered number of different veneer sheet lengths and the number of different log lengths that are available for cutting at the same time is usually small; that means: ($m < 5$ and $s < 3$). Therefore, the number of all possible log-cutting patterns that can be enumerated is not large. Because of this property, a normally good solution for many real log cutting problems can be obtained by using the BB method of selected DSS development software.

In the case of larger number of different veneer sheets lengths (large-scale 1d-CSP) the use of the BB method is impractical, because the number of all possible cutting patterns (columns) can be very large. As a result, the IP will be too large to even formulate and difficult or impossible to solve. To tackle this problem, the "delayed column generation approach" can also be included into DSS [6, 7].

2.3 Selecting the DSS development

2.3.1 Software

Criteria for the evaluation of DSS software have been dealt with by some authors (e.g. Buede, 1992). For the purpose of our selection, the process of setting up requirements for a proper software tool was considered from three different viewpoints: (1) broad viewpoint of the enterprise, (2) viewpoint of the OR expert (developer) and (3) pragmatic viewpoint of the user (i. e. manager). Results of preliminary selection

Table 2: List of commercial DSS software development tools selected as closer candidates

Name	Short description	Supplier
LINDO	linear programming (LP) solver	LINDO Systems
LINGO	linear, non-linear programming (NLP) and integer programming (IP) solver with specific mathematical language	
What's Best	spreadsheet (EXCEL) add-in for solving LP, NLP and IP problems	
ILOG	resource optimization suite (includes CPLEX)	ILOG, Inc.
MS EXCEL	standard solver, Frontline solvers for EXCEL for solving LP, IP and NLP problems	Microsoft Inc., Frontline Systems Inc.
CPLEX optimizer	general large-scale MP software and services for resource optimization	CPLEX division of ILOG, Inc.
SAS/OR module	software tools for MP, scheduling, decision analysis, project management, statistical analysis	SAS Institute, Inc.

based on these criteria, and at the same time taking into account local preferences, have shown that a couple of OR or general-purpose software candidates (see Table 2) are remarkable for further consideration.

If compared on the basis of requirements given previously, all commercial MP software systems given in Table 2 have favorable features as candidates to be selected for further development of a manager-friendly DSS in our specific circumstances. They appear to have an almost equal rank from the viewpoint of the OR expert. Therefore, the choice of the basic DSS development software may depend largely on the particular needs and circumstances of the enterprise where the new DSS will be used.

A general argument for SAS/OR software selection was the fact that the SAS System offers to the user enterprise a wider selection of software tools and technology, not only for MP [9, 10, 11, 12]. In the context of a production enterprise, such as that of veneers production, the software tools for forecasting (the SAS/ETS module), for statistical analysis (the SAS/STAT module) and quality control (the SAS/QC module) are of particular interest. In this way, the benefit of this selection for the company is to have a single software provider, the same source of technical support and a truly integrated information delivery system with similar user interfaces.

Another important argument for having selected the SAS System is the possibility of effective exploitation of modern technologies for effective development and implementation of end-user oriented DSS such as: Data Warehousing and On-Line Analytical Processing (OLAP), object-oriented programming concepts (the SAS/AF software) with powerful Screen Control Language (SCL), and interfaces that provide easily and timely access to data

from SAS-format and outside databases (the SAS/ACCESS software).

The other two arguments that have led to the selection of the SAS/OR software are bounded to the circumstances that are important for the enterprises in Slovenia. In particular, the SAS System provides data-exchange interfaces for ERP systems used in a number of important Slovenian enterprises (specifically the SAP R/3). Finally, the local SAS office in the capital of Slovenia, Ljubljana, has a good reputation for their technical support of SAS products and training courses in the Slovenian language.

3 The system design, development and testing

A specific DSS was built to assist the operations manager during his tasks of log cutting in production of veneers, such that the system: (1) is based on the mental model of the user; (2) does not require any special MP knowledge for operating it; (3) can be used through simple point-and-click commands; (4) has simple data-input and data-output procedures; (5) can be operated from a standard personal computer running the Microsoft Windows operating system; (6) exploits as much as possible the features and functions of the selected SAS/OR software; (7) is flexible and easy to modify as well as to maintain. During the initial development steps of the reported DSS it was confirmed that the above requirements can be satisfied by the SAS software.

The DSS includes four components: the user-interface, the modeling base, the database and solution techniques. The integration of the four components of the DSS, i.e., the structure of our DSS, is presented in Fig. 2.

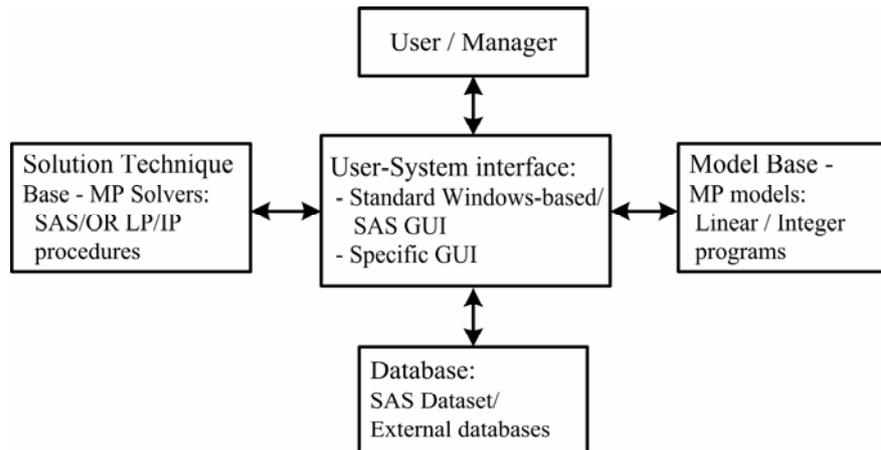


Fig. 2: The structure of a decision support system

However, the standard SAS/OR graphical user interface provides a specific programming language that was not considered appropriate for an operations manager. Therefore, development was focused around building a special window-based graphical user interface (GUI) allowing easier use of related solution

technique. The graphical user interface was developed specifically for this application by means of the SAS/AF software. The application is started from standard SAS GUI screen by clicking to the application-specific "PROC" icon (see Fig.3).



Fig. 3: Basic data-definition screen

3.1 Test case

A typical test case is described here for illustrating an ordinary production task in log cutting that can be solved by the developed DSS. Let suppose that a customer orders three different quantities of veneers of equal thicknesses and of three different sheets lengths: $l_1 = 182$ cm and total area A_1 m²; $l_2 = 151$ cm and total area A_2 m²; $l_3 = 112$ cm and total area A_3 m². In this situation it is calculated that the 350 sub-logs (b_1) of length l_1 , 250 sub-logs (b_2) of length l_2 and 400 sub-logs (b_3) of length l_3 are needed if the original logs of tree

type 3 with length of 446 cm is used. All possible cutting patterns that can be created from selected log of length 446 cm are determined. Results of this step are given in Table 3.

The operations manager has to input data into the DSS, according to the Table 3. Input data relate to the computation objective (min or max), to the number of constraints and decision variables and to the file name (existing or new). Fig. 3 and the upper-left/central part of Fig. 4 illustrate how the test data can be fed into the new DSS by means of the two data-input GUI screens.

Table 3: Possible cutting patterns for a log of length $L_l = 446$ cm, $j = 1, 2, \dots, 12$, $p = 1$

Cutting patterns (j)	182-cm sublogs	151-cm sublogs	112-cm sublogs	Edge waste (cm)
Pat. 1 - x1	1	0	0	264
Pat. 2 - x2	2	0	0	82
Pat. 3 - x3	1	1	0	113
Pat. 4 - x4	1	1	1	1
Pat. 5 - x5	1	0	1	152
Pat. 6 - x6	1	0	2	40
Pat. 7 - x7	0	1	0	295
Pat. 8 - x8	0	2	0	144
Pat. 9 - x9	0	2	1	32
Pat. 10 - x10	0	0	1	334
Pat. 11 - x11	0	0	2	222
Pat. 12 - x12	0	0	3	110
Req.nb. of sublogs	350	250	400	

After performing data input, the presented test case brings the operations manager to the results of the SAS "PROC LP" optimization procedure. To get them, he has to click on the "SOLVE" button shown in Fig. 4. The results of the optimal solution appear in the left-bottom part of the same (main data input/output) screen. In this solution, the values of decision variables (X_1, X_2, \dots, X_{12}) practically represents the number of 446

cm logs that have to be cut according to twelve ($n_l = 12$) cutting patterns given in Tab. 1. In this case, the minimally required number of original logs to fulfill this customer order is **338**. Optional sensitivity analysis is available by clicking either to the "RANGE/PRICE" or to the "RANGE/RHS" button. Recalling Fig. 4, the user can combine input data from other databases by clicking the "ACCESS" button.

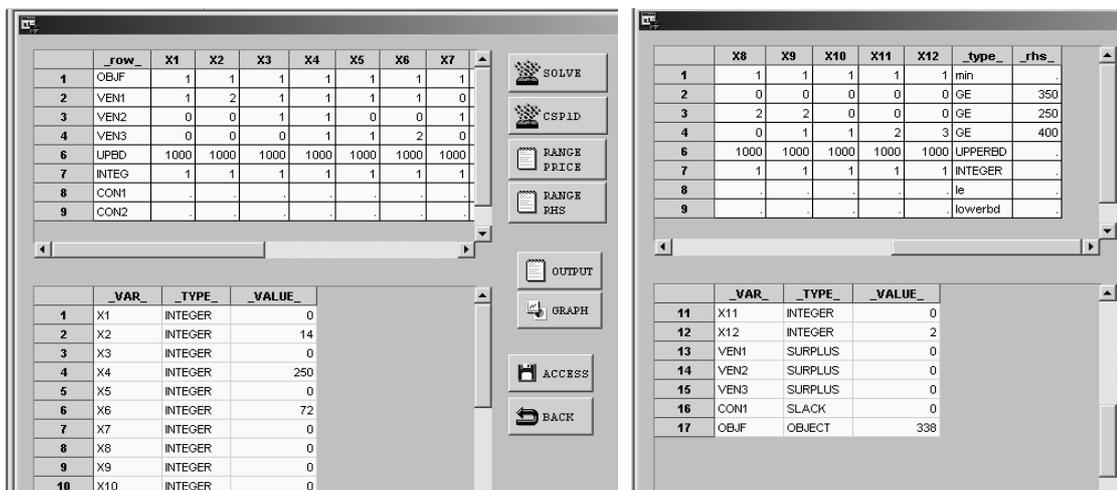


Fig. 4: Main data I/O screen: input test data and the results of optimal solution

4 Analysis and discussion

The approach to DSS development used in this paper represents an attempt to make the implementation and use of DSS in industry and other smaller businesses more efficient. It recognizes the fact that effective DSS are aimed at semi-structured problems, utilize models with internal and external databases, and emphasize flexibility, effectiveness and adaptability. Introduction of such systems in the business environment requires to solve a range of non-technical and people-related problems, e.g. limited resources, low level of IT and MP knowledge, open organizational issues, sometimes

resistance to use quantitative models for decision making, etc. In this situation, the approach recommends to take full advantage of commercially available MP software and modern information-processing facilities, i.e. personal computers, mostly affordable to or available even in smaller firms, respectively.

Looking at the case study from the practical viewpoint, let us discuss the benefits of using the new DSS, in comparison to the intuitive decision-making used in the veneers manufacturing firm to date. For this purpose, we will look closer to the test case given in Table 3. First, let us look how the operations manager solves the problem by his ad-hoc approach. He may intuitively decide to cut one original 446 cm log directly

into the required lengths of sub-logs of 182, 151 and 112 cm, leaving an edge-waste of 1 cm. This requires to cut 400 original 446 cm logs and gives a total **edge waste of 4 m** only, a total **end waste of 317,5 m**. In this situation total length of original logs required for cutting is 1784 m.

One reason is that the manager is looking only on reducing edge waste and is not used to care about end waste. This was acceptable before, as the over-production of veneer sheets and the consequent inventory costs were not problematic because the additional veneers packets could be sold at a later date. The next reason is that the manager is not enough skilled now to create intuitively different cutting patterns and/or to choose the best one. Thus, the simplest way for him is to cut the logs as the above example shows.

On the other hand, the optimal solution that is generated by the DSS results in total 338 original logs required for cutting, where **total edge waste is 44,98 m** that is much greater than 4 m, but **total end waste is zero** and the consumption of original logs is reduced to 1507,48 m.

There are also some other possibilities in the same production process where this DSS can be used, such as:

- Help in ordering new logs.
- Log cutting optimization with consideration of logs on stock.
- Consideration of cutting-machine setup costs.
- Consideration of a greater number of different sub-log lengths using the delayed column generation method.
- Broader use of DSS for similar decision-making situations in other types of production.
- Optimization in the same organization, such as product-mix problems, blending problems and transportation problems.

The GUI is the essence of the new DSS which is built around the original SAS/OR software. Actually, it works with four data input/output screens having a relatively simple layout. Developing a DSS application directly from the original SAS/OR software requires from the user knowing the SAS high-level programming language and some basic computer knowledge.

On the other hand, this new GUI is an user-friendly interactive windowing point-and-click application that gives a user quick, easy access to desired information. For using the new GUI efficiently, the user has to understand: the goal and the basic assumptions, the principles of LP, the 1d-CSP formulation in LP terms, the structure of the screens, the meaning of command options and the contents of data-input/output windows. Once instructed about the procedure of using the DSS for solving the log-cutting problem, the user can get information that will help him at more appropriate decision making.

When comparing the use of this DSS with the procedure of using the original SAS GUI for solving the

same 1d-CSP, it turns out that the main advantage of such a DSS is the fact that the user does not need to formulate the LP model in the specific SAS language. The other advantage is the possibility of using the other SAS optimization procedures [9] for solving other types of optimization problems. The DSS prototype that includes the PROC LP of the SAS/OR software is not very case-specific. This means that it is useful for solving other types of LP and MIP problems and can also be used for training the users about the new approach to operational decision-making.

5 Conclusion

Through a case study from the production of veneers, the paper presents a pragmatic approach to the development of a DSS, to be used by the operations managers. The basic idea of the proposed approach is to choose a good commercially available OR software and then upgrade it with a user-friendly graphical interface. The feasibility of the approach is illustrated by a simple prototype DSS for optimal cutting of logs in the manufacturing of veneers.

By choosing to test the DSS which utilizes the *pattern-oriented* LP-based Methods for solving the standard 1d-CSP, it was attempted to show that the power of OR can be more successfully presented to the industrial practitioners when the underlying theory is relatively straightforward. The results of testing a typical cutting-stock problem with actual production data indicate that such a user-oriented DSS can indeed improve the competitiveness of a (small) organization. It does this by supporting the operations manager to process customer orders more efficiently and, at the same time, by helping him (her) to keep the inventory of finished goods as low as possible. Therefore, it is considered that the challenge mentioned at the beginning of this paper can be met satisfactorily by using the prototyping approach even for solving of more complex OR problems.

By taking together the cumulative benefits from all these possible future DSS applications, it can be imagined that a significant financial/economic/commercial benefit for the firm can be expected. Of course, only a detailed cost-benefit analysis, based on real production data, can give a proper basis for investing in this direction of further DSS development.

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