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The causal loop diagram model of traceability system rental equipment in oil and gas supporting companies

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ABSTRACT

Traceability in equipment rental systems enhances security, reliability, and operational transparency by providing the ability to accurately track leased equipment. Challenges in implementing traceability include difficulties in collecting accurate data, the absence of standardized recording practices, and the complexities of integrating technology to ensure complete tracking. This research aims to identify variables affecting the traceability system thinking to improve its efficiency in ongoing business processes. A qualitative descriptive approach is used to offer comprehensive insights into implementing traceability in equipment rental systems, focusing on oil and gas support companies. The study employs the causal loop diagram (CLD) method to dynamically map and identify traceability process variables. Findings show that traceability enables more precise tracking of equipment movement and usage, enhancing inventory management and streamlining maintenance. The CLD method reveals the dynamic relationships between system variables such as equipment availability, maintenance needs, and customer satisfaction, which guide continuous improvement. These results provide stakeholders with valuable insights for optimizing efficiency and service quality in equipment rental operations, particularly in oil and gas support companies. Enhanced traceability can significantly boost operational effectiveness and customer satisfaction.

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1. INTRODUCTION

The developments in the industry pose challenges for companies active within it. To survive and succeed in competition, companies must devise analyses that turn challenges into business systems [1]. Every company in the industrial sector competes to attract customers and market their products or services. The oil and gas industry, being a major contributor to the country's foreign exchange reserves, has a wide scope from upstream to downstream. Efforts to enhance customer satisfaction in this industry are centered around maintaining service quality standards [2]. The development of outsourcing management strategy in the oil and gas industry is gaining increasing attention due to its potential and recently has become one of the most popular alternatives [3]. The strategy aims to address several issues in the oil and gas industry, which have expanded in scope, ranging from resource sharing to the need for advanced technology [4]. In the past, implementing outsourcing in the oil and gas industry was considered risky due to its critical and strategic nature. However, it has become easier now with the availability of numerous supporting companies or services in the market. Supporting service companies in the oil and gas industry operate in activities that support both upstream and downstream operations. They provide construction and non-construction services related to the oil and gas industry’s operational activities. The integrated system is made to manage sales and expand its market share [5].

In the construction process of oil and gas projects, equipment availability is crucial for executing construction projects or maintenance at project sites. Typically, oil and gas companies either utilize equipment owned by contractors or opt to rent equipment from contracting service companies. The utilization of equipment rental services brings various challenges for both lessee and lessor companies. While the rental equipment business holds significant potential and opportunities, it cannot be overlooked that initiating such a business requires substantial initial investment and significant capital. To address various challenges in the rental equipment business, the rapid development of technology brings new business opportunities the use of information technology such as traceability systems becomes paramount for companies. This system enables the tracking of equipment from before the rental process begins, throughout the rental process, until the rental is completed, to enhance security and effectiveness in the equipment rental process. With a robust traceability system, the risk of poor-quality and unsafe materials in the supply chain can be minimized [6]. The success of traceability systems heavily relies on accurate record-keeping. An efficient mechanism is required to collect and authenticate information promptly, ensuring that the information can be updated and shared effectively across the entire supply chain [7].

Implementing traceability in rental systems presents several challenges. One major issue is the difficulty in gathering accurate data due to varied sources and poorly coordinated data collection processes. The lack of consistent information recording standards across companies or industries further complicates data comparison and integration. Additionally, ensuring the completeness and accuracy of leased equipment tracking through technology is challenging, given the dispersed nature of rental equipment and differing conditions. A rental traceability system involves tracking and managing rental equipment, so it requires an improvement route for distribution solutions because it aims to increase efficiency in the supply chain [8]. To address these challenges, efforts must focus on enhancing stakeholder coordination, developing uniform recording standards, and adopting advanced technological solutions. Understanding and addressing these complex relationships can be effectively facilitated through the use of causal loop diagrams (CLDs).

The analysis using CLDs in the context of traceability research within rental equipment systems is crucial because CLDs enable a profound understanding of the dynamic relationships among various variables in the system. With CLDs, researchers can visually identify and depict how variables influence each other over the long term [9]. This enables for the identification of behavioral patterns that may occur, as well as the impact of changes in one variable on other variables [10]. Therefore, utilizing CLD analysis can aid in formulating more effective strategies and policies to enhance the performance and efficiency of rental equipment systems. Additionally, it helps anticipate and address the impacts of various environmental changes or external conditions that may arise [11], [12].

This study assumes a causal relationship between the level of traceability in rental equipment systems and customer satisfaction. Improving traceability is expected to reduce the risk of loss or damage to equipment. Furthermore, integrating advanced traceability technology should enhance operational efficiency in managing rental equipment. The research aims to address key questions related to the system, such as identifying relevant variables, analyzing the interrelationships between these variables as causes and effects, and determining the primary factors that can improve efficiency.

2. METHOD

To analyze the issues, a system thinking approach is employed, focusing on three vital elements: characteristics (elements), interconnections (relationships between characteristics providing feedback), and the system’s goals or functions. The objectives or ultimate goals of the system, often unseen, frequently serve as primary determinants of the system’s behavior. While not all systems have clear or measurable goals, the system thinking concept acknowledges the importance of this aspect in understanding and improving the system’s performance [13]. Building a strong and integrated information system really supports the implementation of a systems thinking approach in selecting suppliers and environmentally friendly rental issues [14]. Moreover, system thinking also aids in identifying complex patterns in interactions among system elements, comprehending the impacts of decisions made on the entire system, and designing more effective strategies to achieve desired objectives [15], it is utilized to comprehend the complexity of systems, analyze interactions among elements within the system, and develop solutions aligned with desired objectives [16]. This modeling is utilized to formulate an understanding of the structure of a system and to demonstrate how changes in one area can impact the entire system and all its components at different points in time [17]. In this study, it is

important to acknowledge several limitations that influence the depth and scope of the analysis regarding traceability in rental equipment. The limitations of this research are as follows:
– The scope of available data is limited to information obtained from rental equipment providers and lessees.
– Limited access to historical data or specific internal data from related companies.
– Technical constraints in modeling the complexity of relationships among variables in the system using CLD, especially if the available data is limited or incomplete.
– Limited time and resources for in-depth research, potentially resulting in some aspects or dimensions of traceability in rental equipment not being thoroughly studied.

In the research methodology, CLD analysis is used as the main tool to identify and understand the relationship between variables related to traceability in the rental equipment system. The research methodology process flow is shown in Figure 1 as follows:

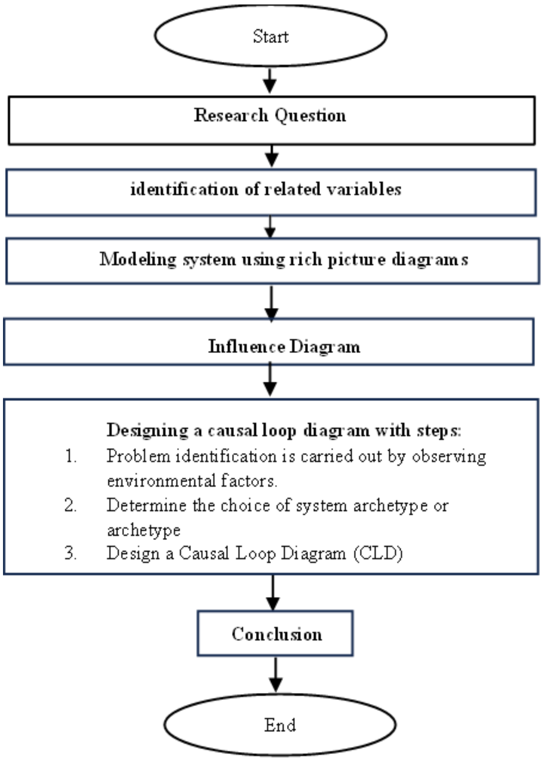

Figure 1. Flowchart

a. Research question

In the initial stage of this research, identifying stakeholders with interests in traceability in rental equipment becomes the main focus. The system stakeholders involved in this research are:
– Problem owner: company owners
– Problem solver: project managers, IT development team
– Problem customer: MIGAS companies
– Problem user: operational departments, technicians, equipment users (customers)

b. Identification of related variables

Entities and variables related to this research include oil and gas support companies, customers (oil and gas companies), project managers, workshops, maintenance, warehouses, customer warehouses, and work locations. The variables affecting traceability include rental duration, quantity and types of equipment, technical specifications, rental costs, availability of technicians or operators, location and logistics, maintenance, request for quotation, purchase costs, number of customers, number of complaints, lost equipment data, reliability, tangibles, responsiveness, internet of things (IoT) integration, technological development, efficiency, customer needs, implementation of a rental traceability system, and increase of safety and quality. After identifying the system variables, a system diagram can be created to explain the system from input to output [18]. The system diagram in this study can be seen in Figure 2 as follows:

c. Modeling system using rich picture diagram (RPD)

The design of a RPD aims to informally capture the main entities, structures, and perspectives involved in a particular situation or process. This includes the known issues as well as the potential within that situation [19].

d. Influence diagram

The design of an influence diagram aims to illustrate the relationships and impacts among the components involved in a system in more detail and granularity [20]. This includes a visual representation depicting how each component influences one another and how their influence affects the overall outcome of the system [21].

e. Designing A CLD

The CLD model is widely used in problem-solving with a systems approach, considering the dynamic complexity of systems or to support dynamic systems thinking [22], [23]. The CLD model emphasizes its focus on the cause-and-effect relationships among components or factors influenced within a diagram, represented by curved lines ending with arrows connecting the system components to each other [24]. Data analysis using CLDs involves the following process [25]:

– Identification of the problem is conducted by observing environmental factors that directly or indirectly influence the ongoing business processes.
– Determination of the basic system pattern or archetype, such as the archetype of limit to success (growth), considering that the business process at some point will encounter growth constraints due to various reasons.
– Designing the CLD. After establishing the interconnections among various variables affecting the company’s service quality, the loop diagram is constructed using the Vensim PLE v.32 (Vensim32) application program as a tool for depicting CLDs.

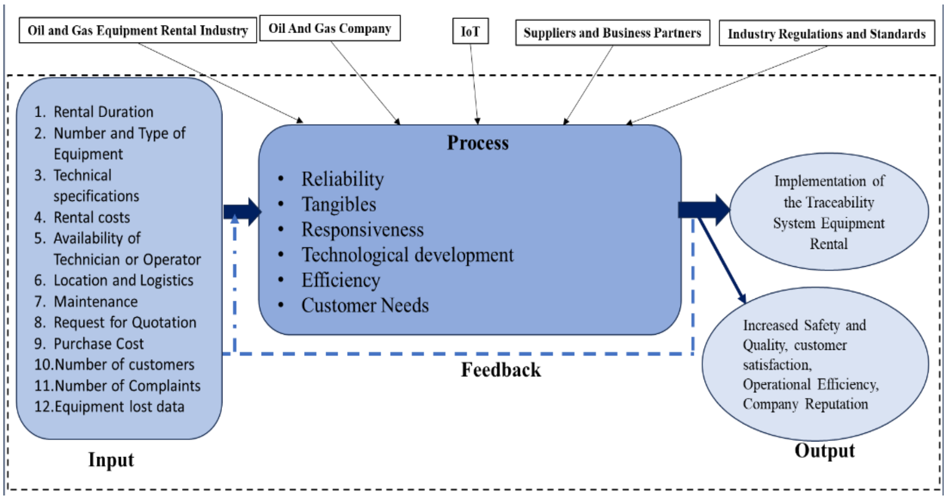

Figure 2. System diagram

3. RESULTS AND DISCUSSION

3.1. Rich picture diagram

The analysis of the RPD represents a complex but structured traceability system, ensuring all tools used in a project are properly monitored from the request stage to delivery and use in the field, and helps in identifying potential areas of concern in traceability research. The RPD in this study can be seen in Figure 3. RPD in the study of rental equipment traceability will involve a visual representation of the main entities, and dynamics involved in the system:

– Main entities: rental equipment provider company, renting company, technicians or maintenance personnel, leased equipment, customers or end users of the equipment, and IT system or information technology for tracking and monitoring.
– Dynamics: influence of changes in equipment demand on availability and maintenance, impact of equipment reliability on customer satisfaction, the influence of operational efficiency on company costs and profitability, and external factors such as regulatory changes or market conditions on business operations.

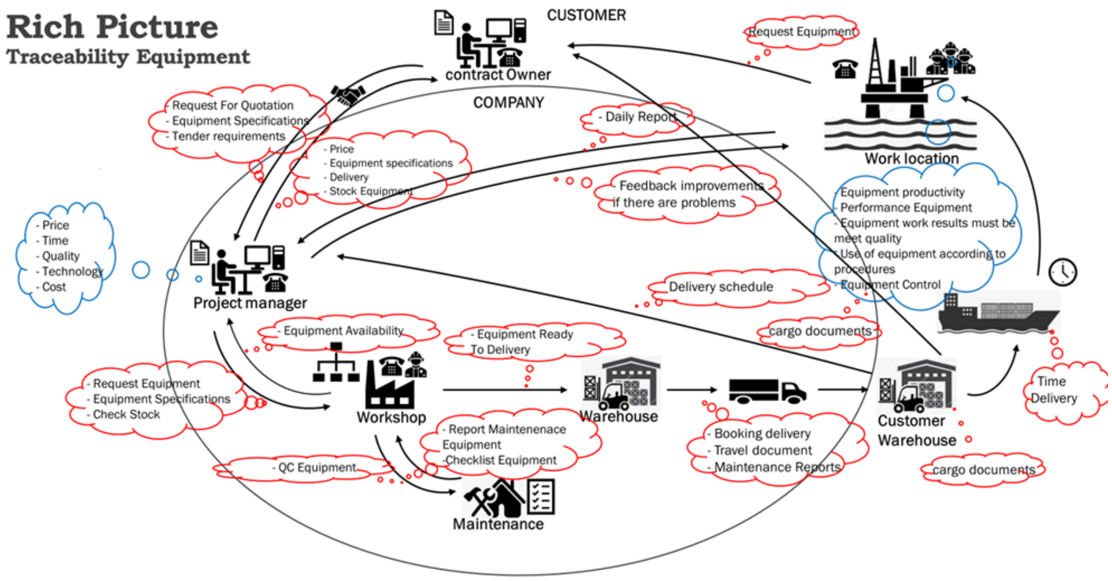

Figure 3. RPD

3.2. Influence diagram

In the context of rental equipment systems, analyzing the influence of interrelated variables becomes crucial to understanding the dynamics and interactions among these elements. The influence diagram can be seen in Figure 4. From the designed influence diagram, it can be observed that:

a. Rental duration influences rental cost, longer rental durations tend to increase rental costs, affects customer needs, longer rental durations can fulfill the needs of customers requiring equipment for longer periods, and impacts complaints number, longer rental durations may increase the risk of complaints related to equipment performance or technical issues during the rental period.
b. Quantity and types of equipment affects rental cost, the availability of a greater variety of equipment can increase rental costs, impacts technical specifications, the quantity and types of available equipment will affect the technical specifications required by customers, and influences customer needs, availability of various equipment can meet different customer needs.
c. Technical specifications influence rental cost, equipment with higher technical specifications may have higher rental costs. Affects customer needs, appropriate technical specifications can meet specific customer requirements. Influences reliability, good technical specifications can enhance equipment reliability.
d. Rental cost influenced by rental duration, quantity and types of equipment, and technical specifications: longer rental durations, greater quantity and complexity of rented equipment, and higher technical specifications will increase rental costs.
e. Availability of technicians or operators affects maintenance, adequate availability of technicians or operators ensures timely and quality maintenance. Impacts responsiveness, availability of technicians or operators can improve responsiveness in addressing customer requests and issues.
f. Location and logistics affect rental cost, difficult or remote locations from distribution centers may increase logistics and equipment delivery costs. Influences customer needs strategic locations can efficiently meet customer needs.
g. Maintenance influences reliability, regular and quality maintenance can enhance equipment reliability. Impacts complaints number, poor maintenance can lead to decreased equipment performance and increased risk of customer complaints.
h. Request for quotation: influences purchase cost, high demand for quotations may increase equipment purchase costs. Affects customer number: high demand for quotations can attract more customers to use equipment rental services.
i. Purchase cost influenced by request for quotation and technological development, high demand for quotations and rapid technological development can influence equipment purchase costs.
j. Customer number influences customer needs, the more customers there are, the greater their needs are fulfilled. Affects complaints number, however, a high number of customers can also increase the number of complaints if the service is inadequate.

k. Complaints number influenced by rental duration, maintenance, and customer number longer rental durations, poor maintenance, and a high customer number can increase complaints.
l. Lost equipment data influenced by responsiveness and security, the level of responsiveness in addressing lost equipment and storage security can affect the amount of lost equipment data.
m. Reliability influences customer trust, equipment reliability can enhance customer trust in rental equipment services.
n. Tangibles affects responsiveness, physical aspects of services (tangibles) can influence responsiveness in addressing customer requests.
o. Responsiveness influences customer needs, high responsiveness in addressing customer requests can better meet their needs.
p. IoT impacts implementation of rental tool traceability system, IoT technology can be used to enhance the traceability system in rental equipment.
q. Technological development influences purchase cost and implementation of rental tool traceability system, rapid technological development can affect equipment purchase costs and facilitate traceability system implementation.
r. Efficiency affects rental cost and responsiveness, improved operational efficiency can reduce rental costs and enhance responsiveness in service.
s. Customer needs influences service provision, customer needs and preferences must be met to maintain their satisfaction.
t. Implementation of traceability rental equipment Influences incerasedof security and quality, implementation of a traceability system can enhance the security, quality, and efficiency of rental equipment services.
u. Incerased of security and quality influences customer trust, enhanced security and quality can increase customer trust in rental equipment services.

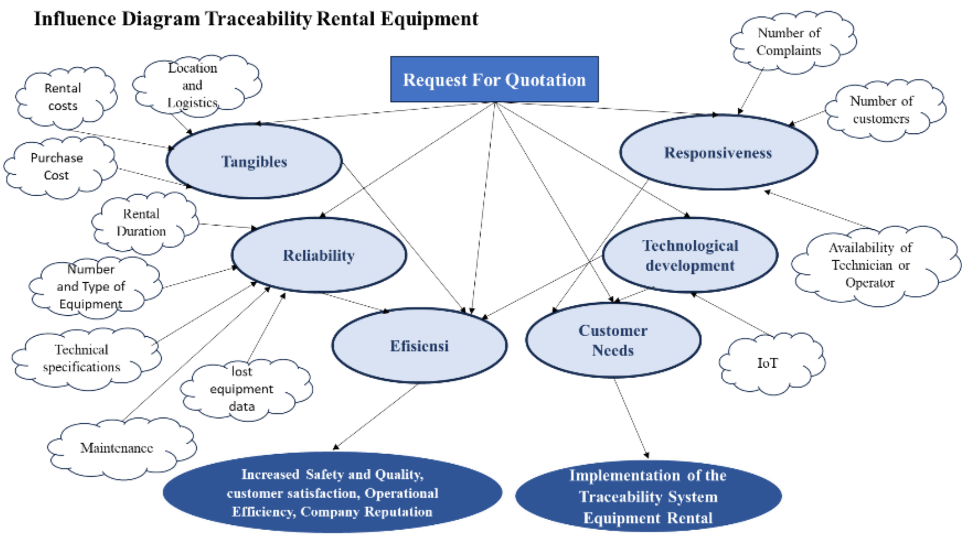

Figure 4. Influence diagram

3.3. Causal loop diagram

CLD modeling utilizes the software program Vensim PLE v.32 (Vensim32) as a tool to illustrate CLDs. The process involves the following steps:

a. Identify the variables for the CLD

Based on the environmental observation depicted in the findings, it can be concluded that there are 21 variables in the system.

b. Determination of the basic system pattern or archetype limit to success (growth)

From the variables, one reinforcing loop and one balancing loop can be depicted. The basic patterns can be observed as follows in the Figure 5, the higher the request for quotation, the higher the level of customer satisfaction. The higher the request for quotation, the higher the demand for efficiency. However, with the weakness of efficiency, it leads to a decrease and even a reduction in the request for quotation provided. This condition becomes a balancing loop, which limits the growth process.

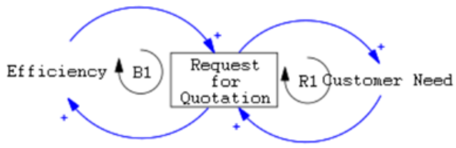

Figure 5. Archetype pattern

c. CLD

Based on the basic pattern and selected variables, the CLD modeling is as follows: after understanding the cause-and-effect relationships from the CLD, here is the cause-and-effect Table 1 based on factors or variables related to rental equipment. Table 1 summarizes the cause-and-effect relationships among various factors involved in rental equipment systems. The analysis of factors in the equipment rental system shows that reliability, responsiveness, and efficiency are greatly influenced by various variables. Factors such as rental duration, types and quantities of equipment, and technical specifications contribute positively to equipment reliability. On the other hand, rental costs and purchase costs can affect the physical quality of services (tangibles). The availability of technicians or operators and the number of customers positively impact system responsiveness, while location and logistics can enhance the physical quality of services. These factors are interrelated in influencing operational efficiency, customer satisfaction, and company reputation in the equipment rental industry. The CLD can be seen in Figure 6.

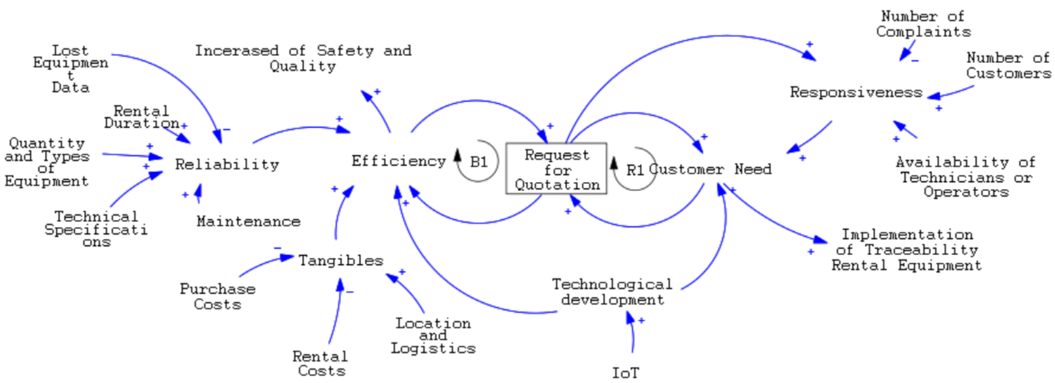

Figure 6. CLD

Tabel 1. Table of cause and effect

No	Factors	Cause and effect
1	Rental duration	Positive impact on increased reliability
2	Quantity and types of equipment	Positive impact on increased reliability
3	Technical specifications	Positive impact on increased reliability
4	Rental costs	Negative impact on tangibles
5	Availability of technicians or operators	Positive impact on increased responsiveness
6	Location and logistics	Positive impact on increased tangibles
7	Maintenance	Positive impact on increased reliability
8	Request for quotation	Positive impact on increased tangibles, reliability, efficiency, customer needs, technological advancement, and responsiveness
9	Purchase costs	Negative impact on tangibles
10	Number of customers	Positive impact on increased responsiveness
11	Number of complaints	Negative impact on increased responsiveness
12	Lost equipment data	Negative impact on increased reliability
13	Reliability	Positive impact on increased efficiency
14	Tangibles	Positive impact on increased efficiency
15	Responsiveness	Positive impact on increased customer needs
16	IoT	Positive impact on increased technological development
17	Technological development	Positive impact on increased efficiency and technological development
18	Efficiency	Positive impact on increased security and quality, customer satisfaction, operational efficiency, and company reputation
19	Customer needs	Positive impact on increased implementation of traceability rental equipment
20	Implementation of traceability rental equipment	Positive impact on customer needs
21	Incerasedcof safety and quality	Positive impact on efficiency

4. CONCLUSION

From this study, it can be concluded that the CLD model has provided a clear overview of the dynamic factors influencing the traceability system in rental equipment. Based on the initial hypothesis, it is evident that an increase in the traceability level within the rental equipment system has the potential to reduce the risk of loss or damage to equipment. Additionally, the integration of more advanced traceability technology has been shown to enhance operational efficiency in equipment rental management. This study not only successfully identified the variables associated with the system but also analyzed the interrelated relationships among variables as causes and effects. Furthermore, this research determined key factors that can enhance efficiency within the rental equipment system. Thus, the findings of this study contribute significantly to the understanding and development of traceability systems in rental equipment, with a focus on improving customer satisfaction and operational efficiency.

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