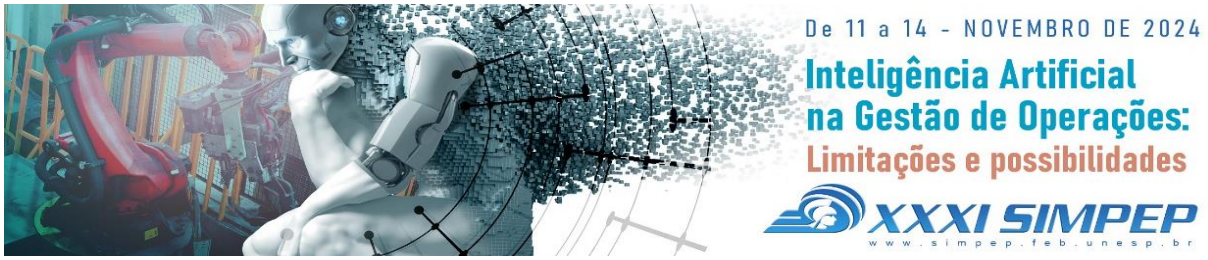

CONTRIBUTION OF INFORMATION AND COMMUNICATION TECHNOLOGIES OF INDUSTRY 4.0 IN A WASTEWATER COLLECTION AND TREATMENT PROCESSES

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ÁREA: *06. ENGENHARIA ORGANIZACIONAL*
SUBÁREA: *6.7 - GESTÃO DA TECNOLOGIA*

RESUMO: *INDUSTRY 4.0 COMBINES TECHNOLOGIES FOR PRODUCTION PROCESSES WITH INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT). IN BRAZIL, SEWAGE DISPOSAL AND WATER TREATMENT ARE NOT AVAILABLE FOR ALL. ICT CAN CONTRIBUTE TO DATA ACCURACY, TRACEABILITY, AND INTEGRATION, WHICH LEADS TO A FASTER RESPONSE TO EVENTS AND DISRUPTIONS IN THIS SECTOR. THIS PAPER AIMS TO ANALYZE THE CONTRIBUTION OF ICT FROM INDUSTRY 4.0 IN A BRAZILIAN COMPANY IN THE WASTEWATER COLLECTION AND TREATMENT PROCESSES SECTOR. THE RESEARCH METHOD USED IS MULTIPLE CASE STUDIES WITH A QUALITATIVE APPROACH. FOR DATA COLLECTION, THERE IS A RESEARCH INSTRUMENT COMPOSED OF OPEN AND CLOSED QUESTIONS BASED ON THE LITERATURE REVIEW. FOUR SEMI-STRUCTURED INTERVIEWS WERE CARRIED OUT WITH EMPLOYEES OF MANAGERIAL AND STRATEGIC LEVELS IN A PERSON. THE ICTS ADOPTED BY THE COMPANY ARE BIG DATA, INTERNET OF THINGS (IOT), AND ENTERPRISE RESOURCE PLANNING (ERP). IOT AND ERP HAVE THE SAME ADVANTAGE FOR CONSUMERS SUCH AS USE OF DATA, INTERPRETATION, PATTERN OF CONSUMPTION, AND DATA USE. THE DISADVANTAGE WAS THE HIGH COST OF DEPLOYMENT. THE ICT THAT MOST CONTRIBUTED WAS THE INTERNET OF THINGS (IOT), MAINLY WITH AGILITY, AND BIG DATA CONTRIBUTED LESS. THE MOST CONTRIBUTION FROM THESE ICT WAS IN REAL-TIME INVENTORY MONITORING.*
PALAVRAS-CHAVE: *INDUSTRY 4.0; INFORMATION TECHNOLOGY; WASTERWATER COLLECTION AND TREATMENT COMPANY.*

1. INTRODUCTION

According to the World Health Organization (WHO), Brazil ranks 117th in the world in terms of the percentage of the population with access to wastewater collection and treatment. Furthermore, if the country continues in the same way, National Basic Sanitation Plan (Plansab) goal will only be reached in 2043, being necessary a contribution of R$443.5 billion over 20 years for all Brazilians to start receiving this service (BRK AMBIENTAL, 2020).

The country presents a disparity between the capitals among the different regions. Within 27 Brazilian capitals only nine have at least 99% of the total water supply. Regarding the sewage collection, only six capitals have an index of more than 90%. As for sewage treatment, although six capitals have at least 80% of sewage treatment, two of them collect at least 90% of the sewage produced (TRATABRASIL, 2022).

Technologies can help technically in water quality and, in a managerial way, accelerate processes through the elimination of errors, control, and tracking of information. Considering the technical form, such as devices that present online sensors connected to a display, it is possible to obtain valuable information about the water, including temperature, salt concentration, color, turbidity, pH, and residual chlorine, among others (BRK AMBIENTAL, 2018). Related to the managerial aspect, processes improve through Information and Communication Technologies (ICT) adoption, such as Enterprise Resource Planning (ERP), Internet of Things (IoT), Blockchain, Big Data etc. This paper will focus on these ICT which are related to the managerial processes. The paper aims to analyze the contribution of ICT from industry 4.0 in a Brazilian company in the wastewater collection and treatment processes sector. The article contributes joining the Management of Information Technology topic with the wastewater collection and treatment sector, whose results in search of articles published between 2019 and 2023 have just 26 articles published in journals indexed on the Scopus and Web of Science databasis. Therefore, papers focus on microbiology, chromatography, and other technical subjects, which are not in Production Management stream of research.

2. LITERATURE REVIEW

2.1 Advantages and disadvantages of ICTs

Industry 4.0 combines technologies applied to manufacturing with intelligent systems.

These technologies added to Information and Communication Technologies (ICT) and other manufacturing technologies already in use allow information flows and physical processes to be available when and where they need to be along the supply chain, from various industries and sizes (WAN et al., 2017). One of the factors that drove this new trend was, mainly, the automating of labor in developed countries (COPPOLA et al., 2022).

In the literature consulted, some ICTs were identified, such as Blockchain, Artificial Intelligence (AI), IoT, Robotics, 3D/4D Printing, Big Data, the Green Light Optimal Speed Advisory System, Digital Dismissibility Identities (DDI), Modular Construction Integrated, and Enterprise Resource Planning (ERP). Some of these ICTs contribute to the service sector allowing direct communication with companies' information systems through software and hardware for problem-solving and decision-making (LUTHRA, 2018). In this paper, the ICT studied will be ERP, Big Data, and IoT.

Considering that ICTs generally contribute to the service sector, including improving customer relations, technological revolutions contribute continuously to the evolution of business management relationships, more specifically in this sector (GÁLVEZ-ALBARRACIN; PÉREZ-BONFANTE; GUERRERO, 2021).

Some advantages are reducing the time related to the flow of information, flexibility and speed in processes, greater control over objectives, allowing a higher quality of the final good or service (GUERRA-ZUBIAGA, 2021). Besides, ICT improve the optimization of customer service and support, the development of AI and the expansion of cloud storage capacity. However, they have disadvantages, such as dependence on technology, the growth of online fraud, specific platforms that can represent a source of distraction, high maintenance costs, less physical contact between individuals, qualification of job candidates for the sector, and cyber threats (WAN et al., 2017; GÁLVEZ-ALBARRACIN; PÉREZ-BONFANTE; GUERRERO, 2021; AKHTAR et al. 2021). Table 1 summarizes the advantages and disadvantages of selected ICT:

TABLE 1 - ICT advantages and disadvantages (theory).

ICT	Advantages	Disadvantages	Sources
ERP	Acts in real-time Allows for greater inventory control	High demand for other ICTs and high cost of implementation	Peksa (2021) Akhtar (2021)
Big Data	Evaluates the performance of a service	Great complexity Reliance on an adaptive	Bramakan, Faregh, & Zareravasan (2021)

	supply chain	network to evaluate services	
IoT	Raises productivity A high degree of optimization Increased security	Absence of encryption for data control High investment	Silva et al. (2018)

Source: Done by authors (2024).

2.2 ICT contributions: criteria

Because ICT presents specific criteria according to the specificities of each one, the differences between them, and based on the contributions they can generate for organizations. For this paper, the search step and literature review provide a set of criteria for the analysis of ICT contribution measurement presented in Table 2.

TABLE 2 - Criteria for measure ICT contributions

Criteria	**Sources**
Safety	Rannenberg (1993); Jiang et al. (2021)
Real-time inventory monitoring	Mardegan, Azevedo and Oliveira (2014)
Relationships with registered suppliers	Swan (2015)
Agility	Karlson (2004)
Reliability (commercial transactions)	Nakamoto (2008); Saberi et al. (2019)
Cost reduction	Skerlic and Muha (2016)
Selection of suppliers	Fazlollahtabar (2021); Wang (2019)
Integration	Nakamoto (2008)

Source: Done by authors (2024).

3. METHOD

This paper is one of the results of Santana's (2022) work. It has four steps. The first step was the papers' searching and selection after defining the aim of the paper. The search was done by Scopus and Web of Science databases, using some strings related to the theme, and filters. The strings were "ICT and industry 4.0", "ICT and advantages", "ICT and disadvantages", "ICT contributions", and "ICT criteria". The filters were period (2017-2021), type of document (article), and language (Portuguese and English). After that, one researcher read the titles and selected the papers with more adherence to the theme of the paper. In the next step, he read the abstracts and selected papers related to the main subjects. The second

step was the literature review and the questionnaire, while some contacts were done in the company where the field research was developed. The third step was the interviews, where four employees contributed to the paper in the Company named in this paper as 'Company X'. All semistructured interviews were made in person and spent around one hour, from April to June 2022. There was a direct observation by the researcher who was an intern at the Company X during the research. Table 3 shows the interviewees' profiles:

TABLE 3 - The interviewees' profiles.

Interviewers' data	**Interviewer 1 (I1)**	**Interviewer 2 (I2)**	**Interviewer 3 (I3)**	**Interviewer 4 (I4)**
Level of education	Bachelor	Bachelor	Bachelor	Bachelor
Major	Electric Engineering	Production Engineering	System Analyst (Data Processing)	Mathematics
Position	IT Consultant	Supply Analyst	IT Superintendent	Technology Management
Time in the company	3 months	2 years and 6 months	4 years and 6 months	3 years
Time in the office	3 months	4 months	4 years and 6 months	3 years

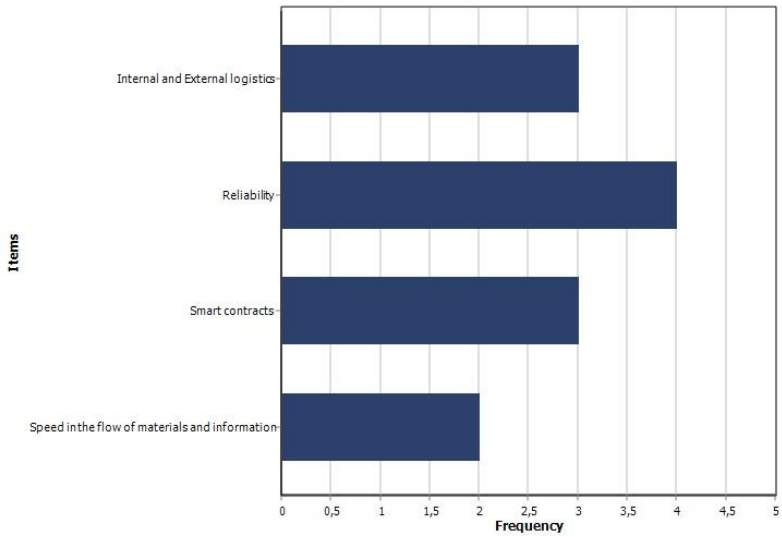
Source: Done by authors (2024).

The fourth step was the data analysis by a scale (agree/disagree) for advantagens and disadvantages. For ICT contributions the scale was a type o Likert (1=very low; 2=low; 3=medium; 4=high; 5=very high). Therefore, there was a QDA Miner Lite version (Provalis Research, 2022) software to support the content analysis, showing the benefits of ICT in this Company, the advantages, and the disadvantages. The ICT analyzed were based on the technologies adopted by Company X.

4. RESULTS

The Group of which Company X is part is a leader in the sector of private concessions providing water supply, sewage collection, and treatment services in Brazil since 1998. It has more than 3,000 employees and 13 concessionaires, present in 15 cities. According to the interviewees, the benefits of ICT in Company X are presented in Figure 1:

FIGURE 1 - Benefits of ICT in Company X.



Source: QDA Miner (Provalis Research, 2024).

Company X offers an essential service, so information produced and received demands Reliability. One problem in the flow of information could lead to a disruption in wastewater treatment, which would be chaos in cities. Information reliability is a requisite of this kind of organization. ERP contributes to the flow of information, which allows the organization of materials (i.e., for emergencies for maintenance) in internal and external logistic activities. Table 4 and Figure 2 show the ICT advantages in Company X, according to interviewees:

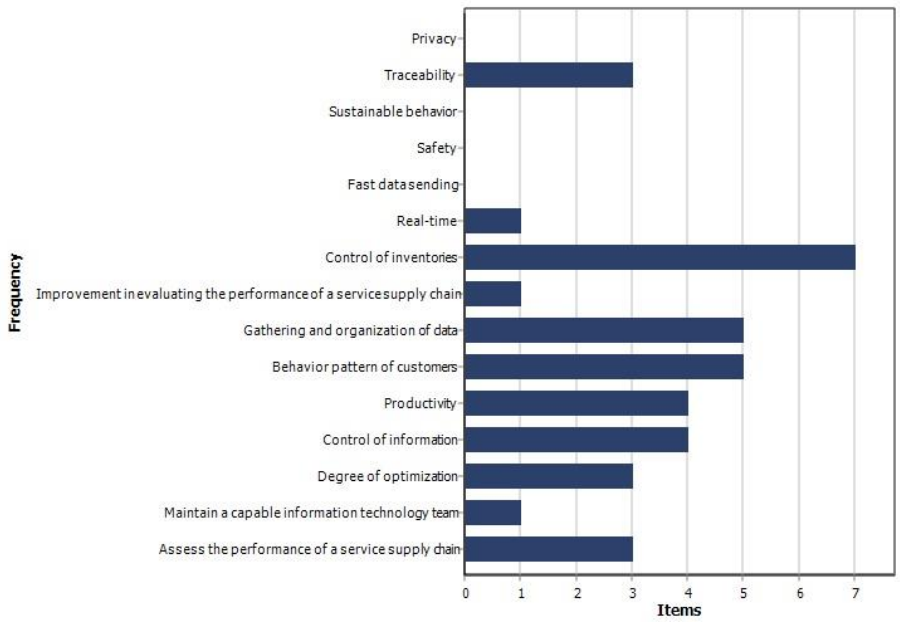
TABLE 4- ICT advantages in Company X.

ICT	Advantages	Sources	Interviewees
ERP	Acts in real-time	Peksa (2021); Kapetanopoulou & Kouroutzi (2021)	I1- Disagree I2- Agree I3 – Disagree I4 –Agree
ERP	Allows for greater inventory control	Marinho et al. (2021)	I1-Agree I2- Agree I3 –Agree I4 – Agree
Big Data	Improvement of service sectors	Bramakan, Faregh, & Zareravasan (2021)	I1 – Disagree I2 – Agree I3- Agree I4 – Disagree

Big Data	Evaluates the performance of a service supply chain	Bramakan, Faregh, & Zareravasan (2021)	I1 – Agree I2 – Agree I3- Agree I4 – Disagree
Big Data	Extends the use of unstructured data	Bramakan, Faregh, & Zareravasan (2021)	I1 – Disagree I2 – Disagree I3- Agree I4 – Disagree
IoT	Analyze customer behavior patterns	Silva et al. (2021)	I1 – Agree I2 – Disagree I3- Disagree I4 –Agree
IoT	A high degree of optimization	Silva et al. (2021)	I1 – Agree I2 –Agree I3- Disagree I4 –Agree
IoT	Greater control of information	The authors	I1 – Disagree I2 –Agree I3 – Disagree I4 –Agree

Source: Done by authors (2024).

FIGURE 2 - ICT advantages in Company X.



Source: QDA Miner (Provalis Research, 2024).

Regarding the control of inventories (Table 4 and Figure 2), all interviewees agreed on this ERP's advantage, with its adoption being a decisive strategy for the company's success. Therefore, most interviewees agreed with the independence of this ICT comparing with others, but the opinion was divided when asked about the real-time advantage.

As for Big Data, this ICT evaluates the performance of a service supply chain, understanding the data generated in large volumes, which brings more benefits to the company (most interviewees agreed with this advantage). The impact of Big Data on certain activities in some areas demonstrates that companies have already understood its function and, consequently, when implementing it, they will obtain a large part of the expected result, mainly with more specific tools. Most interviewees disagreed with the advantage related to this ICT to expand the use of unstructured data (BRAMAKAN; FAREGH; ZARERAVASAN, 2021).

According to the interviewees, the Internet of Things (IoT) allows a greater integration, which leads Company X to a greater effectiveness linked to productivity and the degree of process optimization. However, two interviewees reported the problem related to the high investment demanded to adopt this technology. E3 had three of the four answers contrary to the other interviewees in this ICT. Regarding the disadvantages of ICTs, Table 5 presents interviewees' opinions:

TABLE 5 - ICT disadvantages in Company X.

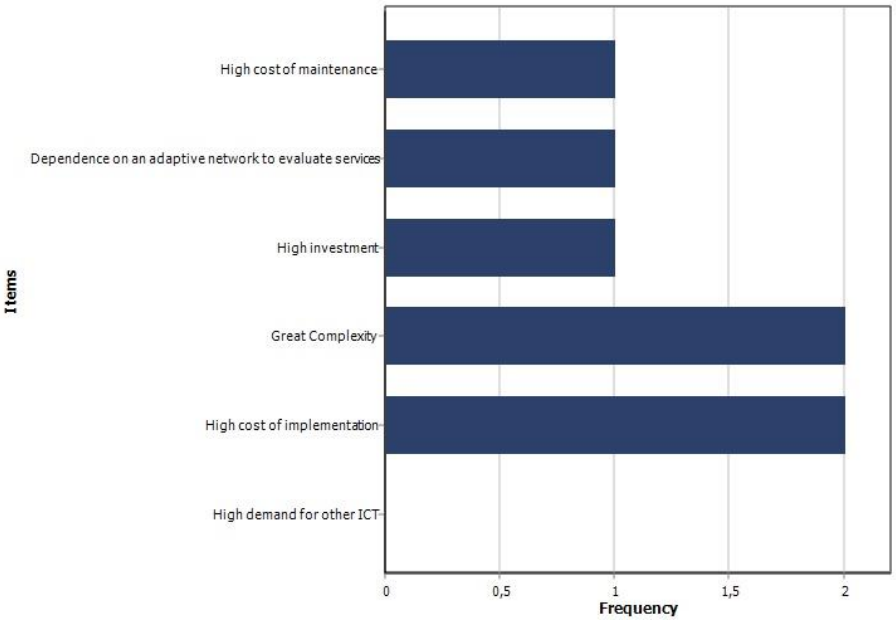
ICT	Disadvantages	Sources	Interviewees
ERP	High demand for other ICTs	Peksa (2021), Akhtar (2021)	I1- Disagree I2- Agree I3 – Disagree I4 – Disagree
ERP	High deployment cost	Marinho et al. (2021)	I1-Agree I2- Agree I3 –Disagree I4 – Disagree
Big Data	Great complexity	Bramakan, Faregh, & Zareravasan (2021)	I1 – Agree I2 – Disagree I3- Agree I4 – Disagree
Big Data	Reliance on an adaptive network to evaluate services	Bramakan, Faregh, & Zareravasan (2021)	I1 – Disagree I2 – Agree I3- Disagree

			I4 – Disagree
IoT	Absence of encryption	Silva et al. (2021)	I1 – Agree
			I2 – Disagree
			I3- Disagree
			I4 – Disagree
IoT	High investment	Silva et al. (2021)	I1 – Disagree
			I2 – Disagree
			I3 –Agree
			I4 –Agree

Source: Done by authors (2024).

Figure 3 shows the results from the QDA Miner analisys related to ICT disadvantages:

FIGURE 3 - ICT disadvantages in Company X.



Source: QDA Miner (Provalis Research, 2024).

Regarding the disadvantages of ICTs for the company, it was observed when analyzing Table 5 that, about ERP technology, most interviewees confirm the high cost of implementing such innovation in the organization and refute the greater need for demand for other ICTs. Big Data technology, according to most of the interviewees, is very complex in its application, and is not being dependent on an adaptive network to evaluate services. Therefore, most interviewees considered that there is a demand for high investment to IoT implementation. ERP and IoT impact the opinions about ICT disadvantages in Company X,

mainly concerning to high costs of implementation. Related to the contribution, Table 6 presents the scores.

TABLE 6 - ICT contribution to Company X.

ICT	Criteria	I1	I2	I3	I4	Total
ERP	Safety	4	4	5	4	17
	Real-time inventory monitoring	5	4	5	4	18
	Relationships with registered suppliers	1	1	5	1	8
	Agility	3	2	3	4	12
	Reliability (commercial transactions)	4	4	4	4	16
	Cost reduction	2	3	3	3	11
	Selection of suppliers	2	2	4	1	9
	Integration	4	4	5	4	17
	Total	25	24	34	25	108
Big Data	Safety	4	4	5	NR	13
	Real-time inventory monitoring	4	4	1	NR	9
	Relationships with registered suppliers	2	2	1	NR	5
	Agility	4	3	4	NR	11
	Reliability (commercial transactions)	3	4	5	NR	12
	Cost reduction	3	3	2	NR	8
	Selection of suppliers	2	3	1	NR	6
	Integration	4	4	2	NR	10
	Total	26	27	21	-	74
IoT	Safety	4	3	3	2	12
	Real-time inventory monitoring	5	4	5	5	19
	Relationships with registered suppliers	1	3	1	NR	5
	Agility	5	5	5	5	20
	Reliability (commercial transactions)	4	3	5	3	15
	Cost reduction	5	4	5	4	18
	Selection of suppliers	1	NR	1	NR	2

Integration	5	4	4	5	18
Total	30	26	29	24	109

Source: Done by authors (2024).

NR = No response

By analyzing Table 6 (by sum per ICT/criterion and interviewee), we can understand the contribution of ICT through certain criteria, by interviewees scores. Thus, it is possible to conclude, such as the high contribution of Big Data technology in the Safety criterion. ERP contributed more to the Real-time inventory monitoring criterion and less to Relationships with registered suppliers. Finally, IoT stands out as the only technology to contribute more to the Agility criterion.

Interviewees, in general, perceived a higher contribution from IoT. Individually, it contributed more to Agility and less to Selection of suppliers. It occurs because it has a more operational function, while the other ICT are closer to strategic decisions.

Big Data contributed the least among all. In the individual analysis, its highest contribution was in the Safety criterion, and the lowest contribution was in Relationships with registered suppliers.

Interviewees 1 and 3 perceived a broad contribution from ERP to the Real-time inventory monitoring criterion. This occurs because I3 is the IT superintendent in the IT sector of Company X, obtaining a broader view of the company and IT processes. I1 gave the highest score to IoT and I3 to ERP, which was the highest of each ICT.

Related to I2, he observed the highest contribution of Big Data in the criteria because he works in the supply sector, being the only interviewee from a client area in the Company X of the IT sector. Hence, I2 has a less critical view comparing to Interviewees who work in the IT supplier sector. The Interviewee who saw the highest contribution (5) was I3, mainly in IoT. On the other side, I4 notice less contribution to the Company, mainly from Big Data.

IoT was the one that received the highest amount of 'very high' score (5), contributing more to Agility. The Real-time inventory monitoring criterion was the one that obtained the highest contribution from ICT.

5. CONCLUSION

We can see that the benefits of ICT's adoption in Company X result in the integration of services, accurate management of inventory and demands, speed of flows, intelligent connections in services, and automated integration of various operations.

The advantages of adopting ICT in Company X allowed data generated in large volumes to obtain a more accurate interpretation, increased productivity, and high degree of process optimization. However, the disadvantages were the high cost of ICT implementation and its high complexity. In addition, new digital threats have been a concern for Company X due to the need for information secrecy.

A trade-off appears related to the fact that while companies deploy ICT to increase security, the problems related to it appear in the supply chain increase either. It happens because the systems integration and the exchanges from the growing number of supply chain partners lead more supply chain agents to access data.

The most contribution was from IoT, supporting Company X in Agility criterion, and, in general, ICT contributed with Real-time inventory monitoring criterion. These two criteria were the most expected, considering that the devices present online sensors, lead to a better operation control and faster data exchange. In this sector, where there are many cities with many connections for water and sewage from millions of commercial buildings, apartments, and houses, control and speed are criteria that provide many benefits to a population in a country which demands more quality in this kind of necessary service.

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