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REVIEW PAPER

A review of RFID –WSN healthcare applications and issues

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Abstract:

Despite the rising implementation of RFID with wireless sensor network technology-based healthcare services, few empirical studies have been conducted to assess the potential of this technology within the healthcare sector. The purpose of this study is to help initiate and direct such empirical research by both conducting a review of the extant literature and using the findings to provide a discussion of current trends and future directions in this domain. In this paper, we develop a conceptual framework that can be used to classify publications on RFID applications and issues in the healthcare industry. We then use this framework to systematically summarize relevant articles. We conclude by highlighting future research directions where the deployment of RFID technology is likely to transform the healthcare sector.

Keywords Radio frequency identification RFID Healthcare Literature review

1. **Introduction**As stated in Indian brand equity foundation (IBEF et al d016,) India is expected to rank among the top three health care marketing in terms of incremental growth by 2020 India was the six largest market globally in terms of 2017 Indian health care sector , one of the fastest growing industry is expected to advance of 22.87 percent during 2017-2020 .There is immense scope for enhancing health service penetration in India, this present sample opportunity for development of health care industryrisingincommonwealth,ageingpopulation,growinghealthawarenessandchangingattitudetowards preventivehealthcareisexpectedtoboosthealthcareservicesdemandinfutThelowcostofmedicalserviceshas resultedinariseinthecountry'smedicaltourism,attractingpatientsfromacrosstheworld.Moreover,Indiahasemergedasahubfor R&Dactivitiesforinternationalplayersduetoitsrelativelylowcostofclinicalresearch conductive policies for encouraging tax benefits. The healthcare industry is one of the largest sectors in many economies. In the United States (US) it represents a "multi-trillion dollar industry" ((Payton et al., 2011). The sectorcreated approximately 14.3 million jobs in 2008, and has thepotential to create an additional 3.2 million jobs by 2018 (United-States-Department-of-Labor, 2010). Currently, this industry faces tremendous challenges, including an increase in operating costs,the high level of medical errors, and the ageing patient population .For example, US healthcare expenses represented about 5% of thecountry's gross national product (GNP) in 1963 (Middleton, 2009),with a potential increase to almost 20% of the GNP by 2017 (Wursteret al., 2009). Likewise, Canada healthcare expenses are in the rise .The country's total public health expenditure in 2000 accounted forabout 6% of the country's GNP, and is expected to increase to nearly7.1% by 2020 (Brimacombe et al., 2001). In Australia, the overall private and public healthcare spending is estimated at about 10% of the country's GDP, or an equivalent of about AUS$ 65,000 million in annual spending (GS1-Australia, 2010). In parallel, approximately1.5 million people in the USA suffer from medication errors each year, and this has brought about extra healthcare costs of roughly$ 2.3 billion in 1993 and $ 3.5 billion in 2006 (National-Academy-of-Sciences, 2007). Many Western societies are ageing ,and analysts argue that the number of older people in the US will increase by 135% between 2000 and 2050 and that the "population Aged 85 and over – probably the group needing health and long-term care services more than any other – should increase by 350%"(Wiener & Tilly, 2002), all of which therefore increasespressure on healthcare expenditure. At the same time, due to theeconomic crisis, several countries are facing critical challenges inproviding healthcare services (Newell, 2011).Despite the rising implementation of RFID technology- WSN basedhealthcare services, few empirical studies have been conducted to assess the potential of this technology within the healthcare sector.

The purpose of this study is to help initiate and direct such empirical research by both conducting a review of the extant literatureand using the findings to provide a discussion of current trendsand future directions in this domain. In this paper, we develop aconceptual framework that can be used to classify publications onRFID applications and issues in the healthcare industry. We thenuse this framework to systematically

summarize relevant articles.This article is organized as follows: Following the description of thecurrent state of the healthcare sector (Section 1) and of information technology (IT)-enabled healthcare opportunities (Section 2),we examine some samples of RFID-enabled healthcare pilot studies in Section 3. Section 4 introduces the research methodology;then Section 5 deals with the classification framework and method,followed by Section 6 which presents our results, while Section 7discusses the implications, limitations and future research directions. Finally, Section 8 serves as the conclusion.

2 Wireless sensor network enabled healthcare transformation: The case of RFID :The health care sectors are currently taking advantage of strong institutional powers and policies for effective use wireless sensor network , which should enable the sectorto better support service delivery (Payton et al., 2011). Indeed,theadoption and effective use of WSNs in the healthcare sectoris "a critical goal of a 21st-century healthcare system" (Menachemi& Brooks, 2008). Information technologies offer manyopportunities for healthcare transformation through business process reengineering. This includes minimizing unproductive dataentry, real-time access of clinicians to patient data for improveddecision making, improving clinical trials which fosters personalized medicine, enhanced monitoring of population in public healthand in real-time research, streamlining processes to increase transparency and reduce administrative overhead (as it happened inother industries), creating new high-technology-based healthcaremarkets and healthcare-related jobs (PCAST, 2010) helping to reduce medical errors, improving on patient safety, facilitatingthe continuity of care, improving on patient—physician communication, enhancing information handoffs and hospital efficiency, aswell as assistance in the overall healthcare management of individuals (Burkhard et al., 2010). Some studies suggest forexample that the adoption and use of interoperable electronic med-ical records systems by U.S. healthcare organizations could lead toimproved efficiency, which may lead to potential safety and savings (Sherer, 2010)More recently, the radio frequency identification (RFID) technology, a wireless automatic identification and data capture technology (FossoWamba et al., 2010), and a disruptive and openinnovation (FossoWamba, et al 2011), has been regarded as the nextwave of WSNinnovation that will widen healthcare transformation (Ngai et al., 2009 Oztekin et al., 2010). For example,RFID technology can facilitate patient identification, tracking, andtracing within the healthcare value chain (Fisher & Monahan,2015). The technology offers an improved means of reducingerrors in patient care, including adverse drug effects, allergies,patient–medication mismatches and medication dosage errors (Thuemmler et al., 2014; Tu et al., 2016). It promotes bettermanagement of critical healthcare assets (e.g., infusion pumps,wheelchairs) by enabling real-time identification, tracking andtracing (Symonds et al., 2007; Bendavid et al., 2010). All these new capabilities enabled by RFID technology have the potentialto facilitate new value creation in healthcare service innovation(Dominguez-Péry et al., 2011). For example, the technology canenable healthcare stakeholders to monitor all steps related to thepatient blood collection and transfusion process, including theidentification of blood bags at the collection point, the trackingand tracing of products from the collection point to the healthcarefacility, and blood transfusion to a dedicated patient (Najera et al.,2016). Also, this technology makes it easier to manage patients withchronic conditions (Cresswell& Sheikh, 2008; Michael et al., 2017).Early studies show that RFID technology represents a viable means of checking, tracking, and tracing pharmaceutical prod-ucts, while allowing a proper management of incident audit trailsbetween the medical equipment and the healthcare staff (Boothet al., 2016). Indeed, counterfeit pharmaceutical products currentlyrepresent a major threat to patient safety for at least a coupleof reasons: (a) they may contain hazardous ingredients (Fuhrer &Guinard, 2009); and (b) they may cause important financial losseto pharmaceutical firms (Dahiya, 2008). Some estimations indicate that in 2010, almost 10% of pharmaceutical products marketedworldwide were counterfeit (Lefebvre et al., 2011), and thereforeaccounted billionin financial losses by the pharmaceutical industry (Dahiya, 2017).

Such a setback recently led themajor US state and regulation (e.g., Food and Drug Administra-tion, California State) to issue adoption mandates, which requirepharmaceutical organizations to adopt a unique identifier (or e-Pedigree) for the tracking and tracing of pharmaceutical products asthey move along the supply chain. As a result of such an action, the healthcare industry experienced a renewed interest in the adoption and use of RFID technology. Some studies have even suggested that "RFID with WSN is an enabling technology that saves lives, prevents errors, saves costs and increases security. It removes tedious procedures and provides patients with more freedom and dignity"(subarmanyam et al 2016).

In short, RFID-WSN healthcare transformation projects could lead to tremendous benefits, including improved patient care, improved patient

security and safety, and finally improved organizational performance (Reyes et al., 2012),thereby enabling "new work practices to develop higher order capabilities for improving cost management, enhancing patient safety, and enabling regulatory compliance in hospital settings" (Lewis et al., 2009).The high operational and strategic potential of the technology is effective in the healthcare market, as the value of the RFID market rose from about $ 5.63 billion in 2010 to almost $ 5.84 billion in 2011 (Das &Harrop, 2011). Consequently, the global market turnover for RFID readers and RFID tags alone is expected to reach the impressive amount of $ 8.9 billion by 2015 (MarketResearch.com, 2011).In 2016, almost 150 million RFID tags were in use in the healthcaresupply chain (Pleshek et al 2016), and the forecasts show the sales of RFID tags and systems will reach almost $ 1.43 billion in 2019, up from the nearly $ 94.6 million of 2012 Such a jump will be mainly due to the widespread of RFID-WSN healthcare applications, including the item-level tagging of drugs and various medical disposables , real-time locating systems for healthcare staff, patient sand assets for improved efficiency and reduced losses, the compliance with safety requirements, and the availability of assets (Harrop et al., 2015).

However, the principle behind RFID technology is not that complicated. A basic RFID system includes RFID tags (active, passive, or semi-passive), which are also called RFID chips or transponders ,serving as a digital data store that can be embedded or attached to a physical item to be identified and tracked. RFID readers or interrogators communicate with the tags and retrieve the information to be sent to a host computer or RFID middleware to ensure communication between the RFID infrastructure and the different intra- and inter-organizational systems. This process initiates and supports business transactions (Asif&Mandviwalla, 2017).When compared to similar AIDC technologies (e.g., bar-coding),RFID technology presents a vast range of advantages including a unique item/product level identification, no need for line ofsight, multiple tags reading, more data storage capability and dataread/write capabilities (Asif&Mandviwalla, 2017).

However, thehigh implementation costs of the technology remains a majorinhibitor for its widespread adoption and use, as well as the substantial gap between the technology implementation costs and the RFID-WSN benefits (Bensel et al., 2008). Furthermore, the lack of common standard and the low operational performance level of RFID in a harsh environment continue to hamper its adoption.

2 RFID-WSN healthcare:

Recently, several studies have been conducted to assess the real potential of RFID-WSN healthcare. For example, the Seoul National University Bundang Hospital is using RFID technology to enhance the workflow for better patient management (Kim et al., 2015). As for the Texas Health Presbyterian Hospital in Dallas, its current use of RFID is to track and trace over 7000 items (including IV poles, wheelchairs, and hospital beds) throughout the hospital, and this is generating tremendous benefits such as the nurses saving about 15% of their time for searching for critical assets, as well as about $ 30,000 of monthly savings from rental equipment (Pleshek, et al 2011). The Royal Wolverhampton Hospitals National Health Service Trust in England is also using a realtime RFID-enabled location system to manage three different functions throughout its facility: tracking the movements of patients and staff members, managing the locations of tagged assets, and ensuring hand-hygiene compliance. The hospital is planning to use the solution to track patients as they are registered, moved through various wards and then dis-charged, to improve the level of staff utilization by better directing staff members as to which services each patient requires next, and so forth . Similarly, the Toronto University Health Network is currently testing an real-time RFID-enabled location system in order to prevent the transmission and spread of new infections, and control any existing infections, by tracking equipment, patients and employees . Another user of RFID technology is the University Hospital of Jena.

The only 200-year-old university clinic in the German state of Thuringia is using the technology in combination with a SAP NetWeaver plat-form to identify, track and match medication accurately and in real time from the hospital's pharmacy to the patients. Undoubtedly, this leads to improved treatment process, increased service quality in medical care, and improved safety of patients (e.g., reduction of undesired medication effects) Nevertheless, despite this high operational and strategic potential of RFID technology-wireless sensor network healthcare transformation, few empirical studies have been conducted to assess the potential of this technology within the sector. For example, a review by Ngai et al. (2016) on RFID technology shows that only 3.6% of the papers dealt with applications and issues related to the healthcare sector, while almost 17.8%, the highest frequency of peer-reviewed articles on RFID technology, tackled application and issues related to the retail sector.

In addition, even if there is currently a real emergence of literature reviews on RFID technology (Ngai et al., 2010), RFID technology in the supply chain (Sarac et al., 2010) and RFID-enabled healthcare (review within a single journal) (FossoWamba et al, 2012), a comprehensive review of articles dealing with RFID applications and issues in the healthcare is still to come.

More specifically, this study draws on prior studies on RFID technology research agendas (Curtin et al., 2015; Ngai et al., 2016), as well as on the extant literature on RFID technology to achieve the following objectives:

(1) Develop a conceptual framework for the classification of articles dealing with RFID applications and issues in the healthcare
(2) . Use the conceptual framework to classify and summarize all relevant articles.
(3) Develop future research directions where the deployment and use of RFID technology is likely to transform the business processes in the healthcare sector.

3 *Classification framework:*

For this study, a classification framework was developed based on early studies on RFID technology (FossoWamba& Chatfield, 2009) in general, with a focus on this technology in the health-care industry (Van Oranje et al., 2009; FossoWamba&Ngai, 2011) (Fig. 2). According to FossoWamba and Chatfield (2009), the level of RFID-enabled business value realization depends on several factors, one of the most important being the costs (e.g., costs associated to the level of electronic integration and organizational integration, human resource training costs, RFID infrastructure costs). FossoWamba and Ngai (2011) demonstrate that RFID has the tremendous potential of transforming patient management-related processes, in line with Van Oranje et al. (2009) for whom the same technology is capable of transforming not only patient management-related applications, but also asset management and staff management-related applications. Drawing on Van Oranje et al. (2009), FossoWamba and Ngai (2011), FossoWamba and Chatfield (2009), we developed a classification framework that identifies three broad categories of RFID-enabled applications that influence the creation of benefits by means of RFID technology in the healthcare sector: asset management, patient management, and staff management-related applications. This model posits that the realization of the benefits from RFID-enabled healthcare applications is moderated by key RFID issues (e.g., technological, data management, security and privacy, and organizational and financing issues) (Van Oranje et al., 2009). We argue that when exploring RFID-enabled applica-tions, the firms that are increasingly become aware of RFID-enabled issues and are taking proper actions to deal with them will be the greatest recipients of benefits related to these applications. For example, we suggest that the greater amount of RFID-enabled ben-efits will fall in the hand of the firms that will have carried out proper management changes in the course of the RFID project. Similarly, the firms which will have adequately trained their staff to support emerging RFID-enabled healthcare applications will come out with great benefits

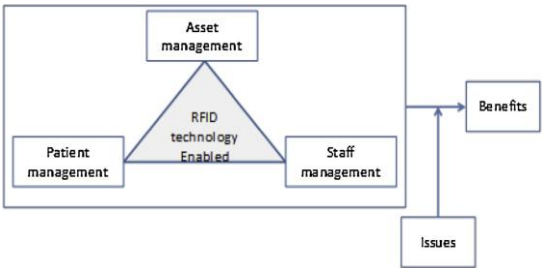

Figure 1-***Classification framework***

Table 1 RFID-enabled healthcare asset management applications.

Asset identification	Asset tracking and tracing for access control and inventory shrinkage decrease	Asset tracking and tracing for expiration date and restocking
Blood bags identification in hospitals to ensure blood type matching	Detection of tampered or unacceptable drugs	Asset tracking and tracing to avoid procedure delays
Proper equipment servicing	Inventory utilization	Inventory management
Materials tracking to avoid left-ins	Real-time inventory counting	Maintenance of medical equipment
Medicine tracking	Provision of e-Pedigree	Location tracking and tissue bank operations

a. RFID-WSN patient management :

RFID-WSN technology holds tremendous potential in terms ofimproving the management of patients within the healthcare sup-ply chain. The technology is regarded as a viable means to eliminate various inefficiencies related to patient management, such as medication errors. For example, by using an RFID-enabled electronicpatient identification where all patient history is stored, health-care stakeholders can in real time recover patient information anddiscover potential drugs incompatibilities, which will enable themto avoid adverse drug effects which constitute a major problem inthe healthcare sector (Lieshout et al., 20017). healthcare provider on grounds relatedto adverse drug effects (The-Commonwealth-Fund, 2011). Moreprecisely, RFID-enabled patient management covers the followingapplications

(Van Oranje et al., 2010) accurate patient identification for medication safety, critical information to the patient,dementia outpatients tracking and tracing, elimination of wrongprocedure for patient surgery, RFID-driven medical record, infanthospitals identification to avoid mismatching, tracking and tracingof infant hospitals for security against theft, intelligent medicationmonitoring for the elderly at home, automated care interventionpathways, procedures for audit management, monitoring of patientlocation tracing, patient identification for blood transfusion, patientidentification to avoid wrong drug dose, time procedure, trackingand tracing of hospitals for patient flow monitoring, patient track-ing to ensure safety access and control dementia psych, portable,current and comprehensive health records, provision of real-timeinformation on health indicators and vital signs (by means of RFID), and tracking of drugs supplies and procedures performed on each patient.

b. RFID-WSN health care issues

The emerging literature on RFID-enabled healthcare applications enables the identification of three categories of issues:technological, data management, security and privacy, and organizational and financial issues (Van Oranje et al., 2009) .•Technological issues: These are issues such as the lack of requiredwireless infrastructure within healthcare facilities to supportRFID-enabled healthcare projects, the potential interference ofRFID systems with medical equipment, the difficulty to clearlydefine the scope of RFID-enabled healthcare projects, and thetechnical realization of such projects (e.g., integration of RFIDsystems with healthcare infrastructure, identification of commonstandards) (Van Oranje et al., 2009).
•Data management, security and privacy issues: They cover issuessuch as security and privacy issues, RFID data integrity and reli-ability, management of huge amounts of data generated by RFIDsystems, RFID-enabled business intelligence (Van Oranje et al.,2009).•Organizational and financing issues: They cover issues such thedifficulty to conduct a cost-benefit analysis of RFID-enabledhealthcare projects, the cost of RFID system, change management,training, skills to support emerging RFID-enabled healthcareprocesses, integration of RFID with healthcare organizationalcomplexity, culture and norms (Van Oranje et al., 2009)

c. RFID-WSN healthcare transformation benefits :

The adoption and effective use of RFID technology in the health-care sector has the potential to provide tremendous benefits interms of efficiency, quality and management (Van Oranje et al.,2009) Efficiency gains: Cover the following benefits: capital expensereduction, inventory reduction, operating cost reduction, labourcost savings, increased patient management..Quality gains: Cover all benefits related to the improvement ofpatient care quality (e.g., elimination of wrong patient and wrongmedication errors, elimination of wrong patient and wrongprocedure errors), improved coordination between healthcarestakeholders, improved patient satisfaction, improved infectioncontrol capacity, improved asset preventive and corrective maintenance ..Management gains: Cover all benefits related to the capacity ofhealthcare stakeholders to comply with various regulations, thereduction of insurance premiums, the improvement of processand event audit capacity as well as of forecasting capacity

5 . Results

We now present and discuss the results of the review of pastpeer-reviewed articles dealing with RFID-WSN healthcare. Inthe first place, we highlight the distribution of articles by year, topic,benefits, issues, approach and journal. Based on the literature we reviewed, . , One of the reasons may be the fact that the retail giant Wal-Mart issued an adoption man-date in 2017 thereby triggering more interest for RFID technology. Clearly, the amount of publications on RFID-WSN healthcare has exploded since the first review by (Ngai et al., 2016)

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6 future work

There are a plethora of opportunities for future studies in this area. Future research needs to focus on how the management of these new RFID-enabled healthcare capabilities should be realized to enhance healthcare performance. Indeed, prior research on WSN-enabled firm performance suggests that "the role and articulation of 'the underlying mechanisms' through which WSN capabilities improve firm performance remain unclear"(Mithas et al., 2011). In the context of logistics and manufacturing (FossoWamba& Chatfield, 2009) found that business value creation and realization from RFID projects were contingent to strong leadership, second-order organizational learning, resources commitment, and organizational transformation.

Future research needs to investigate the extent to which these contingency factors still exist in the healthcare sector, given that "the healthcare context provides high levels of complexity and nuance that can support information systems (IS) theory extension and innovation" (LeRouge et al., 2007). Also, future research needs to investigate technological, organizational and environmental factors that may have an impact on the adoption and use of RFID-enabled healthcare applications by applying current dominant IS adoption theories (Fichman, 2000), and develop new theories when required. Other areas for future research regarding the use of RFID in the healthcare value chain include: assessing the business value of RFID-enabled item level tagging within the healthcare value chain in order to evaluate the impact of this item level tagging on the healthcare outcome and costs. Indeed, one of the key challenges of the healthcare sector is the difficulty of measuring the exact healthcare delivery costs to each patient, which allows a compari-son of the costs with the outcomes. In this context, some scholars believe that technologies such as RFID may play an important role in resolving these challenges (Kaplan & Porter, 2011) Furthermore, to understand the influence of different healthcare stakeholders on their peers, it would be interesting to examine the business value from the co-adoption of RFID technology and other healthcare ISs (e.g., ERP, electronic medical records (EMR) sys-tems, computerized clinical decision support (CCDS), computerized physician order entry (CPOE), picture archiving and communica-tion system (PACS), automated dispensing machines (ADM) and electronic materials management (EMM)), and applying new theories (e.g., social network theory).Indeed, a recent study by Sykes et al. (2009) shows that social network theory and social network constructs may improve our "understanding of employees' sys-tem use", by going beyond behavioral intention and capturing the informal interactions that complement the formal infrastructure . Prior studies on IT adoption (Riggins &Mukhopadhyay, 1994) show a positive correlation between the level of business process reengineering and the use of and value gained from ITs. This trend was noticed in the emerging literature on RFID adoption in logistics and manufacturing (FossoWamba& Chatfield, 2009).

Therefore, additional research is needed to empirically investigate how to reengineer healthcare-related processes (patient, asset and staff) to achieve higher levels of business value from RFID-enabled healthcare projects. For example, Najera et al. (2011)) found that RFID technological issues (e.g., RFID tags reading accuracy and performance) have a negative impact on RFID-enabled patient management applications. And Michael et al. (2008) found that privacy and security issues are among key inhibitors of RFID-enabled healthcare applications. Future research should also look at better strategies to incorporate RFID into healthcare processes and operations. Future studies need for example to identify the scope of the RFID-enabled healthcare project, then assess the potential impact of the technology in terms of incremental and/or process transformation. This assessment should also include the cascade effect that can be created by applying RFID at certain parts of the organization and/or operations. For example, McNulty and Ferlie (2004), when studying the implementation of business process reengineering in a UK National Health Service hospital, discovered that the impact of "reengineering within a UK hospital was limited by managers and clinicians operating within an organizational form that embraced new public management (NPM) and vertical principles of organizing and which made it difficult to adopt a coherent process-based logic of organization" (Therefore, exploring the importance of key healthcare stakeholdersin facilitating or inhibiting the execution of RFID-WSN health-care projects should be included into future research. Developing a holistic performance measurement and management system to assess the value generated by RFID-WSN healthcare operations should be also included into future research. Indeed, within health-care settings, "performance measurement and management takes place around distinct units which report up the line" thus lacking the holistic view of the impacts of transformational initiatives within the sector.

Also, early studies from FossoWamba (2012), FossoWamba et al. (2010) showed that the impacts of RFID are not only incremental and/or transformational, but may include new emerging processes called "smart or intelligent" processes (that are triggered without any human intervention). Assessing the impacts of such processes within the healthcare settings should be included into future research.

Limitations In addition to the diverse implications of this study, we should mention some of its limitations. We utilized nine major databases and followed a published methodology to conduct our literature review; however, the search was not exhaustive. Another limitation is that only articles written in English were included in this review. Future research should consider expanding the size of databases and

include non-English speaking journal articles. Finally, although we employed a systematic approach to classify the articles, the inclusion of articles into our final selection was based on our subjective judgment. Future studies should be conducted to corroborate our classifications.

Conclusion

This paper presents a comprehensive review of articles dealing with RFID applications and issues in the healthcare. More specifically, we developed and implemented a classification framework with three categories of RFID-enabled applications influencing benefits creation from RFID technology in the healthcare sector: asset management, patient management, and staff management-related applications. This study analyzes the extant literature to high-light the usefulness and relevance of the proposed framework. This study also posits that the realization of the full business benefits from RFID-enabled healthcare applications will depend on three categories of issues, namely: technological, data management, security and privacy, and organizational and financing issues. The framework we developed and the analysis we con-ducted provide an overview of extant literature in the healthcare RFID domain. This review also highlights several avenues for future research on healthcare RFID. Based on the results of this study, we posit that there is a need for more healthcare RFID .

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