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***Abstract*—In recent years, traceability has gained interest since some health issues like the mad cow scandal. Able to ensure a follow-up of products through each stage of their life-cycle, traceability provides consumers more visibility and guarantees on the items they buy. However, accessible information about items' origins or content does not meet consumers, associations and regulatory services growing expectations. Furthermore, other concerns like counterfeiting as well as bad headline pressures in case of a product recall, urge firms t o d evelop t heir traceability systems which currently show fragilities. Indeed, today, companies manage traceability in their way which creates silos. Consequently, information flow i s s lowed a nd l imited a long the chain. Based on these, the study discusses the concept of aggregating different companies' traceability management systems into a single one covering all the supply chain. The concept implementation is made possible through collaborative platforms like the Blockchain. In terms of traceability, this technology presents interests in recording transactions in a transparent, reliable and secure ways. However, it first r equires d ata t o be structured before makes it concrete. The contribution of this paper is to provide a meta model as a first g roundwork f or a possible Blockchain implementation for supply chain traceability purposes. Its objective is to i) identify and monitor key traceability information regarded as master, event or transactional data ii) highlight the connections with actors and the sequence of events generated along the product journey. The meta model's behaviour is then, illustrated through a case study from the pharmaceutical industry.**

***Index Terms*—Supply chain, Blockchain, Meta model, Supply chain traceability, Pharmaceutical supply chain**

I. Introduction

During the past 11 years, 7 major food scandals have been revealed in Europe [1]. Among them, the well-known mad cow disease (1996) or more recently, the horse meat scandal (2013) occurred. Such disclosures have weakened consumers' trust and drowned the attention of various actors, from NGOs to governments, to supervise citizen safety [2]. In consequence, market expectations are growing towards a better monitoring of products and more transparency [3]. In this perspective, traceability represents an opportunity to address such demand since, as defined by the International Organization for Standardization [4], it allows "[. . .] tracing the history, application or location of an entity by means of recorded identification". Concretely, traceability core functions are to (i) identify products and actors (ii) label and capture data (iii) record and share information. Consequently, it provides access to master data, transactions and event details related to an entity of the Supply Chain (SC) [5]. Besides, beyond reducing risks and obeying regulations, it presents benefits as it can improve visibility across processes, ensures mistakes to be found quickly and so, restores consumer confidence and avoid bad headlines [6].

Globalisation plus the amount of business trading daily across the globe represent many transactions that need to be recorded and make tracing goods along the chain difficult. Consequently, at a SC level, traceability faces some limits to become completely effective. A first challenge remains in making the association between the physical and the information flow through the SC. Besides, to be useful for analytics, data collected must be accurate, reliable and accessible. Thus, the automation of the traceability systems is a necessity [5]. Secondly, each SC partner has its system to manage traceability and the level needed may differ, due to the strategy or business environment. Another challenge remains in the compatibility between the different systems. Indeed, systems present juridical, geographical and language settings differences. So, as many parties must share and validate documents or data, the flow is slowed by the procedures [7]. Besides, data is the property of the company in charge of tracing its activity and are currently relatively unshared, even within an organisation, which creates traceability silos [8]. For all these main reasons, and not especially in the agri-food sector, the need for developing a new traceability approach able to support the flow multiplication and the data associated, the recording and the sharing with secured means at a global

978-1-7281-1566-5/19/$31.00

scale is crucial.

Traceability has already started to evolve by taking the opportunity of emerging technologies like the Internet Of Things (IoT). As an illustration, Radio Frequency Identification (RFID) shows aptitudes to increase data reliability and speed of processes. Consequently, it is almost replacing barcodes [9]. However, those technologies only deal with data capturing but do not meet the other traceability's core functions. In this perspective, a new concept of SC traceability is emerging. It consists of aggregating companies' traceability management systems into a unique one. This would lead mainly to speed-up the information flow, increase transparency as well as faster error detection and correction [8]. Besides, with the upcoming digital revolution, partners, products and equipment tend to be hyper-connected. In this context of industry 4.0, Blockchain, a new kind of collaborative network which saves and secures transactions [10], is among the best candidates to meet the more and more severe traceability needs. However, before seeing this opportunity applied in concrete, it remains crucial to structure information in line with traceability issues that modern SCs are currently facing. According to this vision, the objective of this article is to provide a meta model (MM) that would serve as a first groundwork for a possible Blockchain implementation. It has been designed in an integrative manner by structuring key traceability data and bounding goods to their associated events and owners over time. The first part of this article is dedicated to the SC traceability stakes and challenges as well as some existing solutions to support such a concept. The second part presents the Blockchain as a potential opportunity to support global traceability challenges. In a third part, a MM proposal is described supporting future development of SC traceability solutions like the Blockchain. The final part shows an instantiation of the MM and a discussion regarding the proposal.

II. BACKGROUND

A. *Supply Chain traceability stakes and challenges*

SC traceability offers the possibility to get a full picture of physical and information flows along the chain. This cartography induces improvement perspectives and identification of critical points. Automatically, the benefits would not only be an increase of process effectiveness but also the capacity to produce [6] Besides, by taking the opportunity of emerging technologies, traceability not only allow back passing history but also offering real-time information [8]. This is essential for taking actions and better managing production and logistics efforts [11]. Companies which would turn to a global traceability system, beyond meeting norms, would mitigate risks and better manage product recalls [12]. Indeed, scandals regularly led to boycotts or claims and may drown their business [6]. Thus, by offering more transparency regarding their processes to consumers, companies would gain in attractiveness, as a competitive advantage, but it requires they engage their responsibility. As a result, global traceability provides a guarantee for consumers a high level of safety products and limits counterfeiting [12]. On the other hand, SCs integrate many partners with different information systems, objectives and regulations. Consequently, connecting information systems regularly often presents interoperability difficulties [13]. SC traceability aims at developing a connection between companies. However, such a concept presents large security considerations in case of hacking [14]. Besides, it requires that SC partners would have to agree and adopt common rules as well as being prepared to share some data [6]. Furthermore, the SC traceability investment can be substantial as it needs robust technologies, a review of processes, time and engagement from all the actors [6]. Finally, small artisanal companies cannot always afford such a system. The risk would be that, in future, consumers only trust in traced products and indirectly turn away from the others whatever the quality [2]. Concretely, these days, products and packing materials are mainly identified by 2D bar codes and scanned at each step of the chain. For one company, in one year, this may represent the recording of 60 million events. At a SC level, the number of operations heightens according to the multiplication of actors, the diversity of products and the densification of the physical flow. The mass makes products tracing difficult and highlights the necessity of an appropriate tool to support the number of data and the monitoring of the product's journey [15]. In this perspective, some emerging solutions are currently available on the market. Among them, collaborative platforms like ZetesOlympus from Zetes Group which collect, save in the cloud and communicate real-time information about events, products or assets to the authorised users (legal service, specific department...) [16]. There is also GS1's solution. This non-governmental association has developed a specific standard: the EPCIS (Electronic Product Code Information Service) to trace products from producers to consumers and also to ensure the interconnection between multiple actors and systems [17]. SC traceability may also take the opportunity of IoT (Internet of Things) systems. Indeed, the Frequentiel group with its Octo+ solution has developed a software-based platform using RFID to accelerate data capturing and able to associate the physical flow to the information one [18]. However, those technologies - platform, bar codes or even sensors - show respective limits linked to the language barrier, the need of readers or the difficulties to exchange data when it is not normed [6]. Besides, the number of transactions is expected to grow considering the increasing number of application users, autonomous objects and the ease to make payments. Consequently, adapted solutions efficient, cost-effective and secured to manage this upcoming massive flow of data is expected. Besides, they would have to overcome interoperability issues, simplify operations and foil hacking attacks. Today, main solutions are limited to support a global traceability system and the need for further developments is waited [6]. In terms of literature also, further global reflections need to be led to provide an offer that could adapt many products and sectors.

B. Blockchain opportunities for SCs

Blockchain is like a distributed register open to anyone who operates without the supervision of a centralised authority and so, limit intermediaries [19]. It aims at making records about asset transactions in a network [7]. As the name emphasis it, it is a chain of blocks that contain information. Once a transaction is performed and approved by the network, a new block is added to the chain and it becomes difficult to revise it [19]. The Blockchain concept shows many possible applications in various sectors like medicine to keep records of patient's medical history, bank transactions or even for traceability [7]. Indeed, the Blockchain as decentralised, transparent and reliable ledger can face current traceability issues. Indeed, the use of Blockchain would allow faster problem origins identification, identifying responsible and product locations to manage more effective recalls. Concretely, each member of the SC would have to record all usual traceability information into the Blockchain. At the end, it would be possible to get a global picture and trace all stages of the product's life. Thus, members would have access to the information available, under authorisation condition, in the Blockchain without tampering possibilities and consumers could verify product history [19]. As a result, and thanks to its three levels of barriers, Blockchain is a very secure system. Besides, the openness this ledger offers may discourage to fraud since detection is faster than with usual systems [33]. However, such promises require some efforts. Indeed, to be effective and beneficial, it is crucial that all the actors adopt the same system [20]. On the other hand, it is also a great opportunity for actors to collaborate even if they do not share the same interests because the technology increases trust between actors and speeds-up the information flow [21]. Since 2017, the number of traceability blockchain-based projects are increasing. This is particularly true in the food sector regarding food safety and adulteration [3]. As an illustration, Walmart, IBM and Beijing Tsinghua University started the development of a model based on Blockchain technology to offer transparency on Chinese pork. The project aims at recording details about origins, breeding conditions or logistics with the use of IoT systems. Walmart in collaboration with IBM again, at the same period, presented results showing a cut down from days to minutes to find out problem origins and the possibility to trace products from stores to farm in 2.2 seconds [27]. Presently, in the available literature, Blockchain perspectives are discussed but some reviews have shown that the technology presents latency, throughput or scaleability issues [22]. Besides, there is relatively little academic work done on the topic [23] and the novelty of the technology requires some additional investigations to fully develop Blockchain potential before large-scale implementations [10]; [22].

C. Research Ambition

Traceability aims at gathering enough and necessary information to determine (possibly retrospectively) the composition of a product and the different steps it has been through. All information generated, along with SC activities, may serve organisational interests but are not necessarily useful for the traceability objectives. The purpose of the research is to support the future development of SC traceability solutions by first identifying the appropriate SC traceability data and secondly, structuring the associated knowledge-based, through a MM. This work is a prerequisite and lay down foundations to future emerging technology implementations like the Blockchain. In this sense, the choice of a MM appeared obvious since, according to [30], it aims at developing an abstract language and framework for applied situations (models). In other words, the research intends to design a conceptual data model to address the following issues SC traceability needs to deal with: i) identify which effective traceability information is generated along the chain and need to be recorded ii) how to structure this data in a logical representation in the perspective of an information system integration.

III. Proposal

A. Traceability Data

In a SC, the physical flow integrates various elements from; different types of products (finished, semi-finished, parts…) to logistics units (pallets, containers, box…). The informational flow represents exchanges of data between supply chain actors or indicates activities' status [32]. Among the information to trace, it is possible to distinguish three main traceability data types: Master Data, Events and Transactional (See "Fig. 3").

Master Data is fixed and consistent information, frequently used across the information system and databases, and shared by different applications, functional areas and business partners. They are core information to describe a customer (name, ID…), a business partner (address, status…), a product (bill of materials, ordering intervals…) or financial aspects (price, transaction type…) [34]. Event Data is dynamic data related to one company's activities (internal traceability). Indeed, the products can be subject to transformations (painted or folded for instance), aggregated or dismantled during a process. Additionally, a process is often an aggregation of diverse activities that are necessary to be recorded to faster error origin identification. There are also other activities that do not directly impact the product and generate event data. Mainly they are logistics operations such as transport, storage or control. For each of them, the bound with the product allows defining the product's moves (departure, arrival), location or condition.

Transactional Data is also dynamic data but related to a transfer of items or information or even a financial operation between business partners (external traceability) [26].

As a reminder, the traceability objective is to be able to find quickly information related to a batch or product thanks to key identification at any moment [26]. Finally, it is the combination of these three types of data: master, events and transactional that allows the necessary and sufficient description of the SC. Indeed, it allows bounding the various steps, actors as well as connecting information to physical elements to enable tracing back the product's journey from "farm to fork".

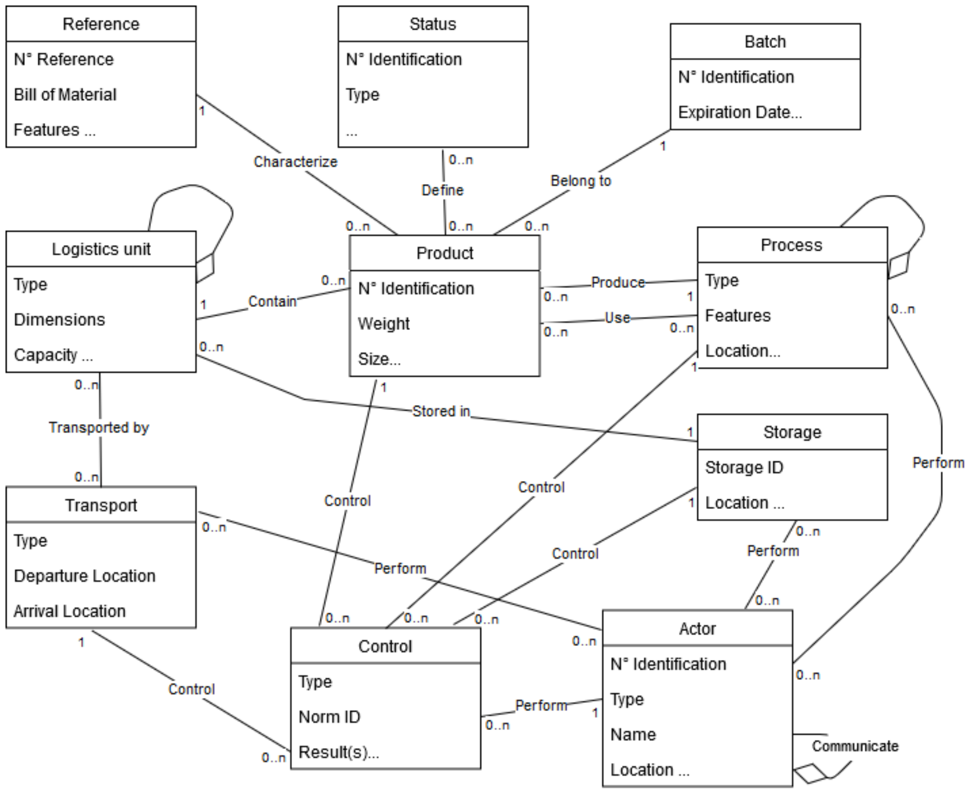

Fig. 1. Meta model for a Blockchain-based supply chain traceability designed in UML modeling language

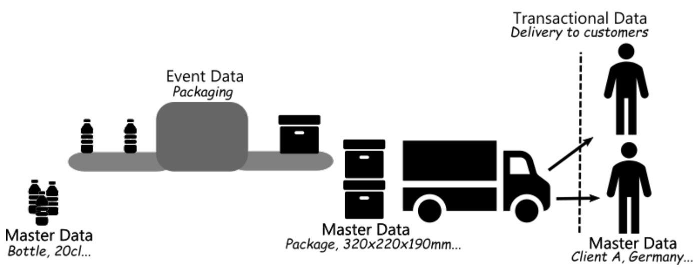

Fig. 2. Illustration of the different traceability data types in a simplified situation of production and delivery

B. Traceability Meta Model

A MM is a generalisation and abstraction of specific cases, called models. As a modelling language, it provides syntax rules and highlights relationships with generic terms. In fact, models are the application of a MM with the use of specific values [24]. In a traceability-centred approach to manage and monitor products, we propose a MM of data needed to cover useful information for managing product traceability throughout their SCs and life cycles (See "Fig. 1"). The approach can be applied whatever the product nature and the SC organisation are.

In a SC, there are two types of physical object to trace; products and logistics units. Products whatever nature (raw materials, parts, finished product…), are characterised with master data (a bill of materials, a name…) which are defined in the 'Reference' class. The class 'Product' concentrates more dynamic data (weight, size…) which may vary for the same product reference. This data is generated as the result of a process and thus are regarded as event data. The class 'Status' gathers information related to the product's position in the chain (in transport, stored, delivered…). The process, which may integrate other processes, has a direct impact on the product. For instance, it can be an aggregation or a dismantle. Specific information, when the process is performed on a batch of products generates data such as the expiry date or the batch number that appears in the 'Batch' class. The 'Process' class collects master data to describe the activity and is essential since it defines the link and change between the input and the output products.

For handling and conservation reasons, products can be contained in different aggregated logistics units (in a package box, then in a pallet…). To be able to trace back a product, for a recall for instance, it is necessary to record the bond between the different logistics units. This is the purpose of the 'logistics unit' class that also concentrates the master data needed to characterise the units. 'Transport' and 'Storage' classes characterised the condition in which the logistics units are transported (transport mean, departure, arrival…) or stored (location, position…). Along the chain, several controls from different nature (custom, quality…) are performed. The 'Control' class describes the control (type, norms, result(s)…) with master data and applies to events like a transport that crosses

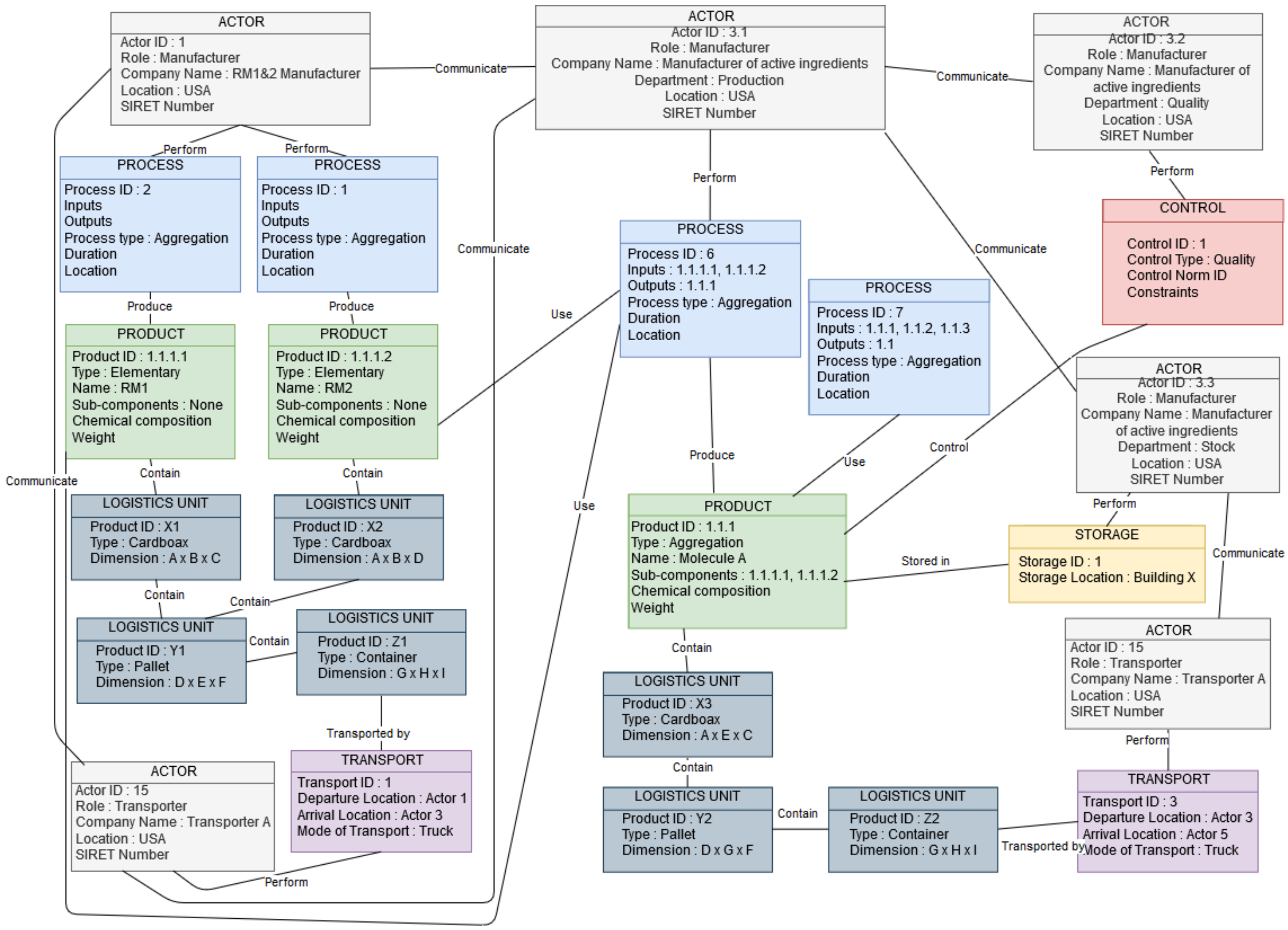

Fig. 3. Meta model instantiation based on the cancer drug supply chain

a border, a quality control within a company, a verification of storage condition or even a process running.

A SC gathers many and various partners: Carrier/Third-party logistics providers (3PL) for the transports, Processors/Manufacturers/Producers for the transformation or production, Retailer/Point of sales/Service operators which are in contact with the consumer, Warehouse/Distribution centre for the handling and storage and finally the authorities that perform controls [26]. Any of them must be defined with master data (a name, address, a type. . .) to create responsibility links. That information as well as the interaction between the partners can be found in the 'Actor' class.

Finally, it does not appear clearly on the MM but for instantiations, each event or transaction will be time-stamped since it is a crucial information for traceability purposes.

The following MM (See "Fig. 1", written in Unified Modelling Language - UML) has been developed using the previously defined elements and characteristics. To illustrate the benefits and limits of this proposal, an instantiation is provided in the following section.

IV. Experiment and Discussion

A. Case Study Presentation

The instantiation of the MM is based on a drug developed by a major French laboratory. Based in France, the company distributes medicines and cosmetics all over the world. To stay competitive and meet new regular standards, the company could gain benefits from a SC traceability system. In this perspective, the MM previously developed has been applied to one of its cancer drugs. Due to confidentiality issues, all names or sensitive information have been replaced by generic values. Basically, the drug's supply chain involves 23 actors. Among them, there are 4 raw material suppliers, 3 manufacturers, 4 handlers, 7 transporters, 2 custom services and 3 distributors. The means of transportation used are trucks and planes. The first part of the drug's process starts from raw material sourcing to the first airline handler and takes place in the USA, the rest is managed in Europe (England, then Ireland, France and to finally distribute clients in Germany, Austria and UK). Basically, the process involves 33 main actions from the set of actors. Eight of them are aggregation processes whereas the rest are logistics operations with 14 transports, 11 storage and 7 control actions (4 quality and 2 customs). To slightly simplify the process, we omitted storage actions at product reception for the manufacturers and the handlers.

B. Instantiation presentation

As the model is massive, only a piece of the process will be described and shown (See "Fig. 3"). This part of the model starts from the sourcing of raw material 1 & 2 and ends when Molecule A is used by the process in charge of producing filled capsules. To improve readability, only the critical storing and control actions appear on the figures. Besides due to confidentiality issues, many attributes remain empty because of a limited access to information but highlights the potentialities.

V. Conclusion and Perspectives

To ensure a proper and effective traceability, solutions like Blockchain can be considered. Nevertheless, they turn ineffective if the input data are inaccurate or unadapted. The point for an effective traceability system is to integrate key traceability information and the link between them. As key data, we mean related to the product composition, change, motion and exchange. Such information can be grouped into three categories : master, events and transactional data. The MM presented in this article, structures those categories in a logical and normed representation in order to offer a robust base for an effective software development like the Blockchain. Besides, it is intended to be generic in the perspective to be used in many situations. However, additional loops between models (in other conditions and sectors) and the MM are expected to make the MM more representative and exhaustive if elements were missing.

Additionally, as illustrated with the model, there are many actors and actions involved before selling the drug. At this point, we can see the huge number of traceability information generated and the connections it induces. This, multiplied by the number of products that may exist and beyond with the number of actors, show the complexity that SC traceability systems would have to deal with.

Acknowledgment

The authors would like to thank the case company and all related participants for the data accessibility and appreciated collaboration.

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