Original Research Article
DOI: https://www.doi.org/10.62418/ijvph.11.1.2025.67-74

Mapping the Pork Value Chain in Meghalaya: Stakeholder Survey for Tracking Stock Movement and Disease Control

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(Received: 11th April 2025 | Accepted: 7th June 2025)

Abstract

Meghalaya, a northeastern Indian state characterized by its mountainous terrain and substantial tribal population, exhibits a high reliance on porcine products as a primary dietary component. Despite widespread domestic swine husbandry, the state's demand necessitates significant inter-state importation, thereby elevating the potential for disease and vector introduction. This study investigates the porcine and pork supply chain within Meghalaya, delineating key stakeholders and mapping livestock movement. Employing a combined convenience and chain-referral sampling strategy, data were collected from 105 stakeholders across four geographically diverse districts. Participants were categorized based on their roles within the supply chain, encompassing primary producers, intermediaries, wholesalers, processors, and retailers. The study revealed that National Highway Six serves as a critical conduit for the entrance of swine from external states, posing a substantial risk for the dissemination of transboundary animal diseases and foodborne pathogens. The prevailing informal and unregulated nature of piggery commerce and processing amplifies the vulnerability to epizootic events. This research underscores the imperative for the implementation of a robust traceability system to facilitate comprehensive monitoring of pig movement and effective disease containment, thereby enhancing food safety and safeguarding public health within Meghalaya. Furthermore, future investigations should evaluate stakeholder receptivity to participation in surveillance programs focused on foodborne and zoonotic diseases detectable at the point of slaughter. Additionally, integrating these stakeholders into transboundary animal disease control strategies through targeted education, awareness campaigns, and capacity-building initiatives will enable the effective application of a One Health approach.

Keywords: Pork, Value chain, Transboundary animal diseases, Meghalaya

Introduction:

Meghalaya is a hilly state which is occupied mostly by tribal population and their food habits are governed by their customs and traditions (Govindasamy et al., 2018). It forms one of the eight sisters of North East India with the other members being Assam, Manipur, Mizoram, Arunachal Pradesh, Tripura, Nagaland and Sikkim (Shadap et al., 2016). The Northeast region is often vulnerable to transboundary animal diseases, which severely affect the food security of the region, inflicting a negative public health outcome. Being bounded by neighbouring countries such as China, Myanmar, Bhutan, Nepal and Bangladesh, along with the porous nature of the borders allowing free flow of livestock as well as wild population further adds to the vulnerable status of the region. Incidentally, the northeast region served as the portal of entry of transboundary animal diseases into India in the earlier years reporting the first cases of Porcine Reproductive and Respiratory Syndrome (PRRS) in 2013 (Rajkhowa et al., 2015) and African Swine Fever (ASF) in 2020 (Rajkumar et al., 2021). Moreover, various reports indicate the presence of various foodborne pathogens including bacteria, virus and tissue dwelling parasites that can be transmitted to humans via pork consumption, which is an integral component of the culinary palette of the people of Meghalaya (Das et al., 2014; 2020; Shakuntala et al., 2020; Milton et al., 2023; 2024). In order to meet the demand, pig rearing is followed by 47.84% of the households and imports an additional 11.25% of total pigs sourced from outside the state which accounts for 8.46% of pork availability to the state (Government of Meghalaya, 2022). There is still a significant deficit of pork in the state. The state harbours 7.8% (7,06,364) of the total pig population in the country with 4,17,870 animals slaughtered annually producing 19,520 metric tons of meat (BAHS, 2024). Marketing of pigs is performed by various marketing channels as identified by previous studies (Sunil et al., 2021; Suchiang et al., 2017). The marketing channels involved the roles of producers, local trader, wholesaler, retailer and consumer. Based on this understanding and the need to tackle the spread of transboundary animal diseases, the present study aimed at identifying various stakeholders

and tracing the movement of pigs and pork into and across the state of Meghalaya, which can be used in the future for establishing a traceability system to curtail the spread of both foodborne diseases as well as transboundary animal diseases.

Materials and Methods:

Study Design and Period

This cross-sectional study was conducted between January 2023 and October 2024.

Sampling Strategy and Participant Selection

A total of 105 stakeholders involved in the porcine/pork supply chain were selected from four districts of Meghalaya: Ri Bhoi, Eastern West Khasi Hills, West Khasi Hills, and West Jaintia Hills. Participants were selected using a combination of convenience and chain-referral sampling techniques. Participant in an area was randomly chosen and the next person was referred by the previous person in order to follow the value chain of the pig and pork in the four districts chosen.

Data Collection

Structured, in-person interviews were administered to each participant to gather data regarding their specific role within the porcine supply chain in Meghalaya. The interviews focused on identifying the origin of incoming livestock and the destination of outgoing stock.

Participant Classification

Participants were categorized based on their primary function within the supply chain:

Primary Producers (Farmers): Individuals engaged in the rearing of swine.

Intermediaries: Individuals facilitating the transfer of livestock from primary producers to wholesalers, processors, or retailers.

Wholesalers: Individuals involved in the large-scale distribution of livestock or pork products.

Processors (Butchers): Individuals engaged in the slaughter and processing of swine.

Retailers: Individuals involved in the direct sale of pork products to consumers.

Data Management and Analysis

Collected data were compiled and managed using Advanced Microsoft Excel. Data visualization was performed using Advanced Microsoft Publisher. Preliminary social networking analysis (SNA) was performed using R Studio v2015.05.0 Build 496 (R language v4.4.1) employing the packages “readxl”, “igraph”, “tidygraph”, “ggraph”, “ggrepel”, “dplyr” and “tidyr”.

Results and Discussion:

Meghalaya, a mountainous state in Northeast India, exhibits a substantial reliance on domestic swine husbandry to meet the demand for porcine products, a dietary staple within its predominantly tribal population. However, the state's domestic production remains insufficient, necessitating the importation of live animals from extra-regional sources. The prevalence of informal marketing channels, coupled with the practice of multi-species slaughter within shared facilities, contributes to unregulated trade and elevates the risk of transmitting foodborne pathogens and transboundary animal diseases.

Participant Categorization and Distribution

Participants were classified into one or more of five predefined categories: primary producers, intermediaries, wholesalers, processors, and retailers. The distribution of roles demonstrated a predominance of retailers (n=78), followed by processors (n=48), primary producers (n=22), intermediaries (n=6), and a single wholesaler (n=1). Due to the multi-functional nature of stakeholder roles within the supply chain, participants were further classified into mutually exclusive categories. The most prevalent mutually exclusive categories were retailers (31/105, 29.52%), primary producers (20/105, 19.05%), intermediaries (4/105, 3.81%), processors (3/105, 2.86%), primary producer-processor-retailers (2/105, 1.90%), intermediary-processor-retailers (1/105, 0.95%), intermediary-retailers (1/105, 0.95%), and wholesaler-retailers (1/105, 0.95%). The utilization of convenience and chain-referral sampling, employing a bottom-up approach, resulted in a disproportionately large representation of retailers within the respondent pool. While previous investigations have documented the predominance of live swine transactions between primary producers, wholesalers, and consumers (Suchiang et al., 2017; Sunil et al., 2021), the present study encountered a limited number of wholesalers. This discrepancy may be attributed to methodological variations in sampling strategies and geographical foci, underscoring the heterogeneity of marketing channels operating within Meghalaya.

Primary Producer Supply Chain

The primary producer cohort was concentrated in the villages of Umsaw, Nongpoh, Umsning, Khweng, Umden, and Tyrso within the Ri Bhoi district. The majority of primary producers (excluding two) maintained on-farm breeding populations, utilizing either natural or artificial insemination. One primary producer (RB57) in Umden sourced livestock from Bhoirymbong (Ri Bhoi). The primary producer-processor-retailer

respondents (RB8 and RB33) supplemented on-farm production with livestock procured from local farms or processed meat from other local processors (e.g., RB32). Livestock were distributed to local processors within the same or neighbouring villages.

Intermediary Network

Six intermediaries were identified, with three based in Sumer (Ri Bhoi), two in Umsning (Ri Bhoi), and one in Mairang (Eastern West Khasi Hills). Intermediaries in Umsning (RB18 and RB29) facilitated livestock transfer from local farms to processor/retail outlets in Umsaw and Umsning. The intermediary in Mairang (EWKH12) sourced livestock from Assam for distribution within the Mairang market. Intermediaries in Sumer (RB60, RB61, RB62) played a critical role in the importation of livestock from extra-regional sources, including Haryana, Punjab, Karnataka, and Rajasthan. Livestock transported via trailers was distributed across Ri Bhoi, East Khasi Hills, East Jaintia Hills, and West Jaintia Hills districts. The movement of livestock was subject to disruption during African swine fever outbreaks. National Highway 6 (NH6) served as the primary entry point for extra-regional livestock into eastern Meghalaya (Figure 1). A significant influx of livestock from extra-regional sources was observed via National Highway 6 (NH6). Intermediaries based in Sumer functioned as temporary holding facilities for incoming livestock, facilitating subsequent distribution to stakeholders across eastern Meghalaya. Furthermore, Byrnihat, located on the Assam-Meghalaya border along NH6, was identified as a major livestock sourcing hub. This route served as a primary conduit for augmenting the state's slaughter-bound swine population until the onset of African swine fever outbreaks, which prompted a state-imposed cessation of livestock movement. Subsequently, processors and retailers shifted their procurement strategies towards locally sourced livestock.

The return transport of livestock vehicles from extra-regional sources without adequate sanitation poses a potential risk for the dissemination of pathogens from Northeast India to other regions (Rotluangkimi et al., 2025). In the Ri Bhoi district of Meghalaya, stakeholders rely on both NH6-mediated and locally sourced livestock. In Mairang, a significant proportion of stakeholders depend on an intermediary who sources livestock from Assam and local farms. Although previous research has suggested a limited role for local traders/intermediaries in the porcine value chain (Sunil et al., 2021), alternative studies have indicated their prominence (Suchiang et al., 2017). Furthermore, the producer-retailer-consumer pattern observed in Nongstoin and Jowai aligns with findings from earlier studies in Meghalaya (Suchiang et al., 2017).

Processor Procurement and Distribution

Processors were located in various villages across Ri Bhoi, Eastern West Khasi Hills, West Khasi Hills, and West Jaintia Hills districts. Processors in Nongpoh sourced livestock from local farms and Byrnihat. Processors in Quinine, Umran, Umsning, Umsaw, Khweng, Sumer, Umbir, and Khapmara primarily procured livestock from local farms and distributed processed meat within their respective villages. Ten processors in Mairang sourced livestock from diverse locations, including Mairang, Byrnihat, Assam, Ri Bhoi, Patharkhmah, Jirang, and Umsning. Processors in Nongstoin procured livestock from Sohiong, Mawngap, Mairang, Shillong, Ri Bhoi, and Assam. Processors in Jowai handled livestock from Mukhap, Mukhla, Wahiajer, Shangpung, Mowkaiaw, Nongbah, and Jowai (Figure 1).

Wholesaler Operations

A single wholesaler (RB25) operating in Umsning (Ri Bhoi) functioned as a wholesaler-retailer. Processed meat was procured from local processors and distributed in wholesale and retail quantities within the Umsning market.

Retailer Sourcing and Distribution

Retailers procured processed meat or live animals for slaughter from local sources. Processed meat was sold in the marketplaces within their respective localities. Diverse porcine and pork supply chains were identified within Meghalaya (Figure 2).

Social Networking analysis

Preliminary social networking analysis indicated the presence of 66 nodes operating with 64 edges (Figure 3). The network density was found to be 0.0149 which indicated the sparseness of the network, whereas diameter value of 3 indicated the limited steps to travel from one end of the node to the other (Table 1). The average path length value was 1.5536 which indicated efficient connectivity and close clustering of nodes despite the network being disconnected *i.e.* separated into 8 separate sub-networks (Table 1). While accessing the node centrality statistics, the in-degree values were highest for Mairang market (in-degree value: 9) followed by Jowai old market (in-degree value: 8) and Nongstoin market (in-degree value: 7) whereas, the out-degree values were highest for Umsning, Bhoirymbong and Sumer (out-degree values: 4) (Table 2). These central nodes serve as key aggregation points which could hold epidemiological significance in terms of control of foodborne and transboundary diseases. Other centrality parameters indicated that Umsning and Sumer were influential in the animal flow with high eigenvector (1.00) and high betweenness value (29), respectively (Table 2). These

influential cut-points serve as major conduits in the network and also possess epidemiological significance (Dube et al., 2009). Though Byrnihat was considered as a major hub for supply of animals in the Northeast India, Sumer was identified as a major hub through which most of the animals available in Meghalaya pass through. However, the analysis had some limitations due to non-uniformity of stakeholder data regarding the geographical point involved in the animal trade. This limitation was also reported by a previous study based on movement of animals in Sweden (Lindstrom et al., 2009).

The present study, in conjunction with existing literature, highlights the variability in marketing channel preferences across different districts within Meghalaya. The limited geographical scope of this study, encompassing a subset of districts, constitutes a limitation that warrants consideration in future investigations.

Conclusions:

In conclusion, this study has successfully delineated the principal nodes and stakeholder roles within the porcine and pork supply chain of Meghalaya. The identification of key nodes such as Umsning, Sumer, and major markets in Mairang, Jowai, and Nongstoin as central to animal movement underscores their strategic importance for targeted surveillance and exercising intervention strategies. Preliminary social network analysis, although constrained by data limitations, offers valuable insight into the structure and vulnerabilities of the existing supply network. Establishing a robust traceability system tailored to the socio-economic and logistical context of Meghalaya, informed by such empirical mapping, is imperative for enhancing animal health governance, public health safety, and regional biosecurity.

Conflict of Interest:

The authors have no conflict of interest.

Data Availability:

Data set generated during research will be made available from the corresponding author on reasonable request.

Ethical Statement:

Not applicable

Author's Contributions:

Samir Das - concept, analysis, original draft and review; Srinivas Kandhan - Field data collection, writing original draft; Pranab Jyoti Das - concept, review, A. Arun Prince Milton - ideation, review, John Pynhun Lamare - Field data collection, Sandeep Ghatak - data analysis, review; Sourabh Deori - data analysis, review

Acknowledgements:

The authors are thankful to ICAR NASF for providing the necessary funds (NASF/PA-9025/2022-23). We are also thankful to the Director, of ICAR Research Complex for providing infrastructure and facilities.

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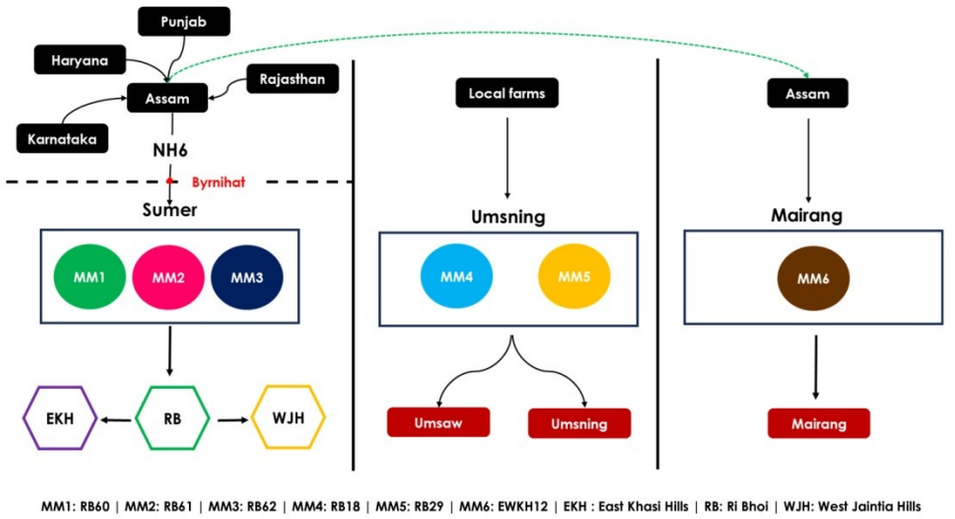

Figure 1: Flow of pigs through middleman
MM: Middleman | RB: Ri Bhoi | EKH: East Khasi Hills | EWKH: Eastern West Khasi Hills | WJH: West Jaintia Hills

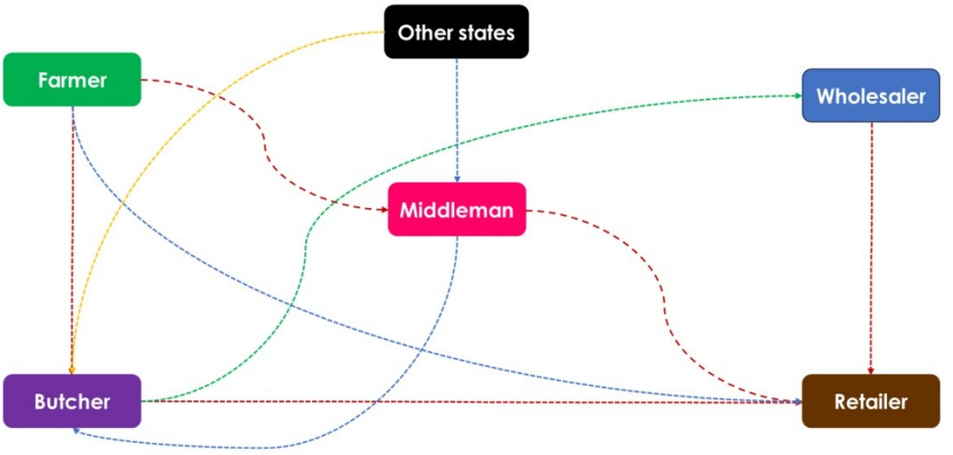

Figure 2: Probable channel of movement of pigs and pork among various stakeholders

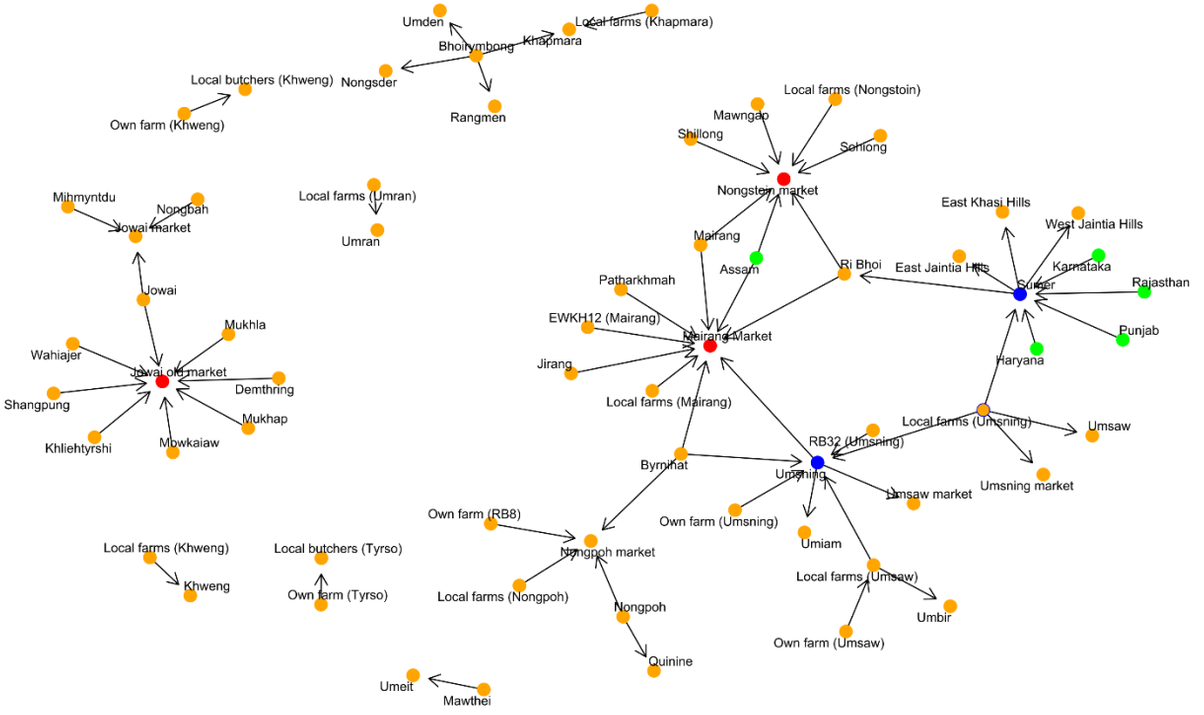

Figure 3: Social networking analysis of pig and pork flow in Meghalaya

Table 1: Network summary statistics

Number of Nodes	Number of Edges	Network Density	Diameter	Average Path Length	Number of Components
66	64	0.0149	3	1.5536	8

Table 2: Node centrality parameters

Node	Degree	In_Degree	Out_Degree	Betweenness	Closeness	Eigenvector
Umsning	10	6	4	17	0.0115	1
Own farm (Umsaw)	1	0	1	0	0.0065	0
Bhoirymbong	4	0	4	0	0.1667	0
Mawthei	1	0	1	0	1	0
Byrnihat	3	0	3	0	0.01	0
Local farms (Nongpoh)	1	0	1	0	0.0061	0
Own farm (RB8)	1	0	1	0	0.0061	0
Nongpoh	2	0	2	0	0.0062	0
Local farms (Umran)	1	0	1	0	1	0
Umran	3	2	1	0	1	0.2851
Local farms (Umsning)	4	0	4	0	0.0103	0
Own farm (Umsning)	1	0	1	0	0.0081	0
RB32 (Umsning)	1	0	1	0	0.0081	0
Local farms (Umsaw)	3	1	2	5	0.0084	0
Local farms (Khapmara)	1	0	1	0	0.0833	0
Own farm (Khweng)	1	0	1	0	1	0
Local farms (Khweng)	1	0	1	0	1	0
Own farm (Tyrso)	1	0	1	0	1	0
Haryana	1	0	1	0	0.0074	0
Punjab	1	0	1	0	0.0074	0
Sumer	9	5	4	29	0.01	0
Karnataka	1	0	1	0	0.0074	0
Rajasthan	1	0	1	0	0.0074	0
Mairang	2	0	2	0	0.009	0
Assam	2	0	2	0	0.009	0
EWKH12 (Mairang)	1	0	1	0	0.0083	0
Local farms (Mairang)	1	0	1	0	0.0083	0
Ri Bhoi	3	1	2	11	0.0109	0
Patharkhmah	1	0	1	0	0.0083	0
Jirang	1	0	1	0	0.0083	0
Sohiong	1	0	1	0	0.0066	0
Mawngap	1	0	1	0	0.0066	0
Local farms (Nongstoin)	1	0	1	0	0.0066	0
Shillong	1	0	1	0	0.0066	0
Jowai	2	0	2	0	0.05	0
Wahiajer	1	0	1	0	0.0385	0
Shangpung	1	0	1	0	0.0385	0
Khliehtyrshi	1	0	1	0	0.0385	0
Mukhap	1	0	1	0	0.0385	0
Mukhla	1	0	1	0	0.0385	0
Demthring	1	0	1	0	0.0385	0
Mowkaiaw	1	0	1	0	0.0385	0
Nongbah	1	0	1	0	0.0278	0
Mihmyntdu	1	0	1	0	0.0278	0
Umsaw market	1	1	0	0	0.0081	1
Umiam	1	1	0	0	0.0081	1
Rangmen	1	1	0	0	0.1	0
Umeit	1	1	0	0	1	0
Nongpoh market	4	4	0	0	0.0078	0
Quinine	1	1	0	0	0.0051	0
Umsning market	1	1	0	0	0.0075	0

Umsaw	1	1	0	0	0.0075	0
Umbir	1	1	0	0	0.0065	0
Khapmara	2	2	0	0	0.125	0
Local butchers (Khweng)	1	1	0	0	1	0
Khweng	1	1	0	0	1	0
Umden	1	1	0	0	0.1	0
Nongsder	1	1	0	0	0.1	0
Local butchers (Tyrso)	1	1	0	0	1	0
East Jaintia Hills	1	1	0	0	0.0074	0
West Jaintia Hills	1	1	0	0	0.0074	0
East Khasi Hills	1	1	0	0	0.0074	0
Mairang Market	9	9	0	0	0.0118	1
Nongstoin market	7	7	0	0	0.0086	0
Jowai old market	8	8	0	0	0.0625	0
Jowai market	3	3	0	0	0.0385	0

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Citation: Das S, Srinivas K, Das PJ, Milton AAP, Lamare JP, Ghatak S, Deori S. Mapping the Pork Value Chain in Meghalaya: Stakeholder Survey for Tracking Stock Movement and Disease Control. Indian Journal of Veterinary Public Health. 2025; 11(1): 67-74.

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