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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Internet of things and smart cities and communities – Services, applications, computation and data processing

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Requirements and capabilities of a digital twin system for smart cities

Recommendation ITU-T Y.4600

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Recommendation ITU-T Y.4600

Requirements and capabilities of a digital twin system for smart cities

Summary

Recommendation ITU-T Y.4600 identifies requirements and capabilities of a smart city digital twin system which may be used to analyse use cases and case studies, develop strategies and identify optimal parameters to achieve a specific goal of a city by conducting simulations on a digital replica of the city (virtual cities).

A digital twin is a digital representation of an object of interest and may require different capabilities according to the specific domain of application, such as synchronization between a physical thing and its digital representation, and real-time support.

A smart city digital twin can be defined as a digital twin for a smart city that can be used to develop strategies to achieve specific goals for a smart city by conducting simulations and to increase visibility of human-infrastructure-strategy interactions.

A smart city digital twin allows the simulation of plans before implementing them, exposing problems before they become a reality. In other words, it is possible to conduct simulations on a digital replica of the city (virtual cities) before actually implementing the strategy on the real city.

In this way, it is also possible to find the best strategies to achieve a specific goal or strategies that have similar effects while minimizing budget and resource usage. Therefore, a smart city digital twin is a tool for improving urban operations, efficiencies and resilience of a city.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.4600	2022-08-29	20	11.1002/1000/15073

Keywords

Digital twin, simulation, smart cities and communities, strategy.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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Requirements and capabilities of a digital twin system for smart cities

1 Scope

This Recommendation identifies requirements and capabilities of a smart city digital twin system which may be used to analyse use cases and case studies, develop strategies and identify optimal parameters to achieve a specific goal of a city by conducting simulations on a digital replica of the city (virtual cities).

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

None.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following term defined elsewhere:

3.1.1 thing [b-ITU-T Y.4000]: With regard to the Internet of things, this is an object of the physical world (physical things) or the information world (virtual things), which is capable of being identified and integrated into communication networks.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 digital twin: A digital representation of an object of interest.

NOTE – A digital twin may require different capabilities (e.g., synchronization, real-time support) according to the specific domain of application.

3.2.2 smart city digital twin: A digital twin for a smart city.

NOTE – This can be used to develop strategies to achieve specific goals of smart cities by conducting simulations before actually implementing the strategies.

4 Abbreviations and acronyms

None.

5 Conventions

In this Recommendation:

The keywords "**is required to**" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keywords "**is recommended**" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

The keywords "**can optionally**" and "**may**" indicate an optional requirement which is permissible, without implying any sense of being recommended. These terms are not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

6 Concept of digital twin system for smart cities

A digital twin is a digital representation of an object of interest. It may require different capabilities according to the specific domain of application, such as synchronization between a physical thing and its digital representation, and real-time support.

A smart city digital twin can be used to develop strategies to achieve specific goals of a smart city by conducting simulations and to increase visibility of human-infrastructure-strategy interactions.

A smart city digital twin allows the simulation of plans before implementing them, exposing problems before they become a reality. In other words, it is possible to conduct simulations on a digital replica of the city (virtual city) before actually implementing the strategies on the real city.

In this way, it is also possible to find the best strategies to achieve a specific goal or strategies that have similar effects, while also minimizing budget and resource usage. Therefore, a smart city digital twin is a tool for improving urban operations, efficiencies and resilience of a city.

Figure 1 depicts the concept of a smart city digital twin system.

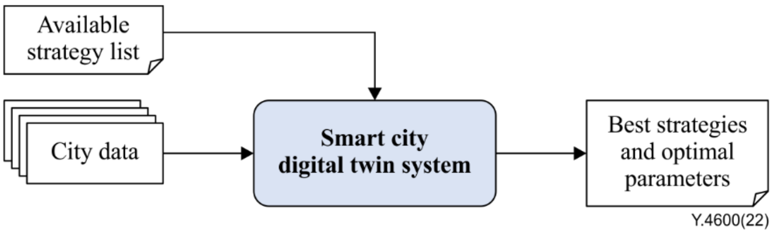

Figure 1 – Concept of smart city digital twin system

Figure 2 shows the concept of simulations to find best strategies and optimal parameters from the available strategy list. City officers will survey available strategies based on their past experience and previous research, and this list is given to the smart city digital twin system as input. The smart city digital twin system conducts simulations on the virtual city to find the best strategy, or best combination of strategies, and optimal parameters of the chosen strategies.

NOTE – The number of chosen strategies can be less than or equal to the number of available strategies.

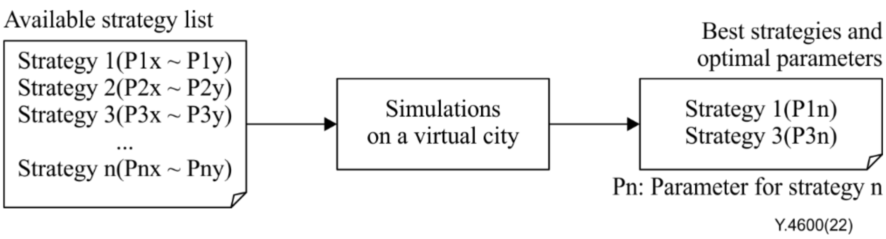

Figure 2 – Concept of simulations to find best strategies and optimal parameters

For these kinds of simulations on virtual cities, the smart city digital twin needs to accurately represent not only static (or passive) objects of the city, such as land, geographical area, streets, buildings and public spaces, but also moving (or active) objects, such as citizens, buses and bicycles. A smart city digital twin system builds a virtual city based on the city data as depicted in Figure 1. Figure 3 shows an example of digital representation of a city.

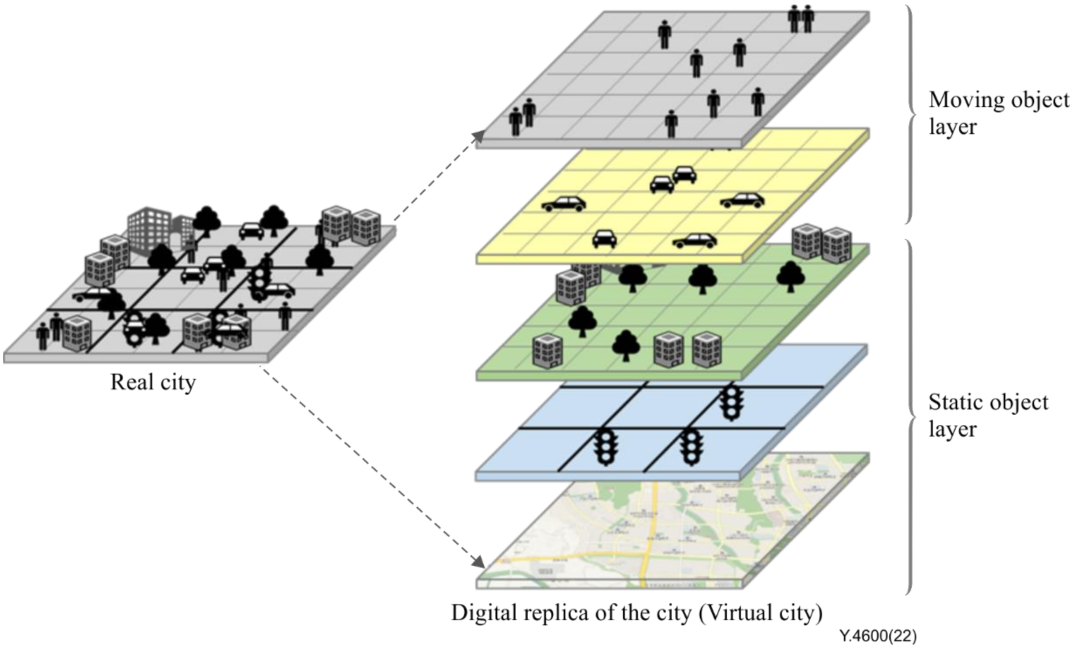

Figure 3 – Example of digital representation of a city

7 Requirements for a smart city digital twin system

7.1 Data collecting and processing requirements

The following are the data collecting and processing requirements for a smart city digital twin system:

– It is required to support collecting city administration data such as the number of citizens and households that make up the city.

– It is required to support collecting urban spatial data such as those related to parks, bridges, roads and buildings that are present in the city.

– It is required to support collecting movement data such as those related to citizens, public transport, shared vehicles, etc.

– It is required that individual persons cannot be identified based on data collected or processed. This includes de-identification of personal information when collecting and processing data.

– It is required to support the security of the data collected, processed, used and shared with external systems.

– It is recommended to share data with external systems through open interfaces.

7.2 Modelling and simulation requirements

The following are the modelling and simulation requirements for a smart city digital twin system:

– It is required to support the creation and recreation of a model based on city data for the simulation of strategy combinations.

– It is required to support the modelling of various phenomena such as movement of urban population, consumption behaviour and transportation usage patterns.

– It is required to support the modelling of moving objects such as citizens, buses and bicycles.

– It is required to support the modelling of static objects such as land, geographical area, streets, buildings, public spaces, etc.
– It is required to support large-scale agent-based simulation, not only in terms of number of simulated agents but also of their complexity. In particular, a smart city digital twin system needs to simulate many agents which model people.
– It is required to support the simulation on strategy combinations.
– It is required to support the configuration and management of a virtual simulation space to reflect the real city.
– It is required to support expanding or reducing the size of the simulation space (e.g., part of city or entire city).

7.3 Visualization requirements

The following are the visualization requirements for a smart city digital twin system:

– It is required to support searching for and recommending for strategies and optimal strategy parameters to achieve a specific goal.
– It is required to support analysis of the impact of each identified strategy on the specific goal.
– It is required to support analysis of the impact of each strategy created by a specific combination of strategy parameters on the specific goal.
– It is required to support the visualization of agents using a graphical user interface.
– It is required to support the visualization of the properties of the agent.
– It is required to support the visualization of simulation results according to the strategy combination.
– It is required to support the visualization of the impact of a strategy change.
– It is recommended to support the visualization of the movement of agents and change of properties of agents according to the progress of the simulation.

8 Capabilities of smart city digital twin systems

8.1 Capability framework of the smart city digital twin system

The capability framework of a smart city digital twin system is composed of the capabilities shown in Figure 4 as identified by the requirements in clause 7.

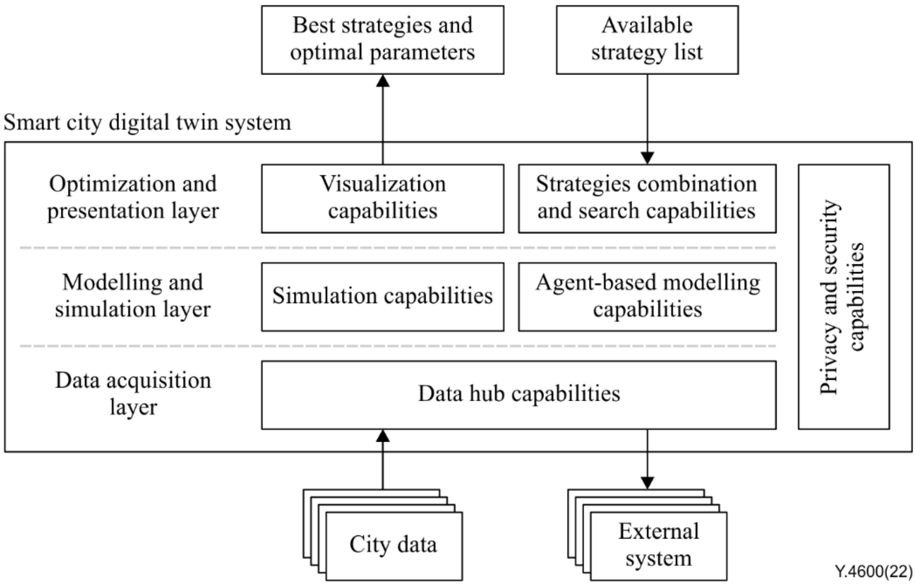

Figure 4 – Capability framework of smart city digital twin system

It is composed of three layers: optimization and presentation layer, modelling and simulation layer and data acquisition layer.

The optimization and presentation layer consists of the visualization capabilities and the strategies combination and search capabilities. The modelling and simulation layer consists of the simulation capabilities and the agent-based modelling capabilities. The data acquisition layer consists of the data hub capabilities. The privacy and security capabilities are commonly implemented in each layer.

8.2 Data hub capabilities

The data hub capabilities include the following abilities in accordance with clause 7.1:

NOTE – All collected data which may contain personal information are de-identified by using the privacy and security capabilities as described in clause 8.7.

– The ability to collect city administration data from external data systems.
– The ability to collect urban spatial data from external data systems.
– The ability to collect movement data from external data systems.
– The ability to collect personal consumption expenditures of the citizens from external data systems.
– The ability to share data with external systems through open interfaces.

8.3 Strategies combination and searching capabilities

The strategies combination and searching capabilities include the following abilities in accordance with clause 7.3:

– The ability to search for and recommend strategies and optimal strategy parameters to achieve a specific goal.
– The ability to analyse the impact of each identified strategy on a specific goal.

8.4 Agent-based modelling capabilities

The agent-based modelling capabilities include the following abilities in accordance with clause 7.2:

NOTE – In agent-based modelling, a system is modelled as a collection of autonomous decision-making entities called agents.

– The ability to create and recreate a model based on city data.

– The ability to make models of various phenomena.

– The ability to make models of the urban infrastructure.

8.5 Simulation capabilities

The simulation capabilities include the following abilities in accordance with clause 7.2:

– The ability to support large-scale agent-based simulation.

– The ability to configure and manage a virtual simulation space to reflect the real city.

8.6 Visualization capabilities

The visualization capabilities include the following abilities in accordance with clause 7.3:

– The ability to visualize the agents using a graphical user interface.

– The ability to visualize the properties of the agents.

– The ability to visualize the movement of agents and the change of properties of agents according to the progress of the simulation.

– The ability to visualize the simulation results according to the strategy combination.

– The ability to visualize the impact of a strategy change.

8.7 Privacy and security capabilities

The privacy and security capabilities include the following abilities in accordance with clause 7.1:

– The ability to support de-identification of personal information.

– The ability to support security of the data collected, transmitted and used.

Appendix I

Use case of smart city digital twin system

(This appendix does not form an integral part of this Recommendation.)

Compared to traditional modelling approaches which treat employees, customers, products and equipment as passive objects, a smart city digital twin is based on the agent-based modelling approach which focuses on individual objects, their behaviour and their interaction. An agent-based simulation model is a set of interacting objects that reflect relationships in the real world, which makes it possible to understand and manage the complexity of today's business and social systems.

NOTE 1 – The agent-based modelling is for simulating the actions and interactions of autonomous agents (both individual or collective entities such as organizations or groups) to assess their effects on the system as a whole as shown in Figure I.1.

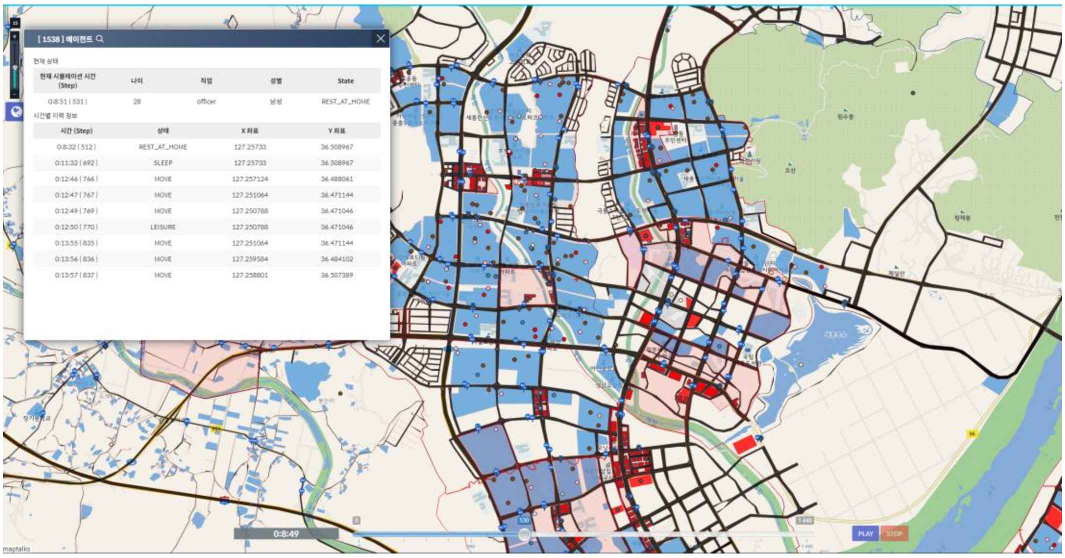

Figure I.1 – Simulation on individual citizen (agent-based modelling)

The following example shows simulation results on a virtual city to find the best strategies and optimal parameters to achieve a 17% increase in sales within a given budget in Sejong city. For this simulation, the change rate of the floating population (a group of people who frequently move from place to place) in each town of Sejong city and the capacity and location of new parking areas shown in Figure I.2 are used. In general, the increase in sales in certain commercial areas is proportional to the floating population and accessibility-related factors, such as parking area, which affect the floating population.

NOTE 2 – If the floating population is increased to 1,100 from 1,000 then the change rate of floating population is 10%.

For this simulation, all the necessary statistical data (e.g., population, sales information, ratio of commuting population) and static data (e.g., road, location of buildings) are initially provided as input.

Figure I.2 – New parking area candidate site in Sejong city

After 11 repetitive searches, the smart city digital twin system finds optimal parameters satisfying the goal (17% increase in sales) as shown in Figure I.3.

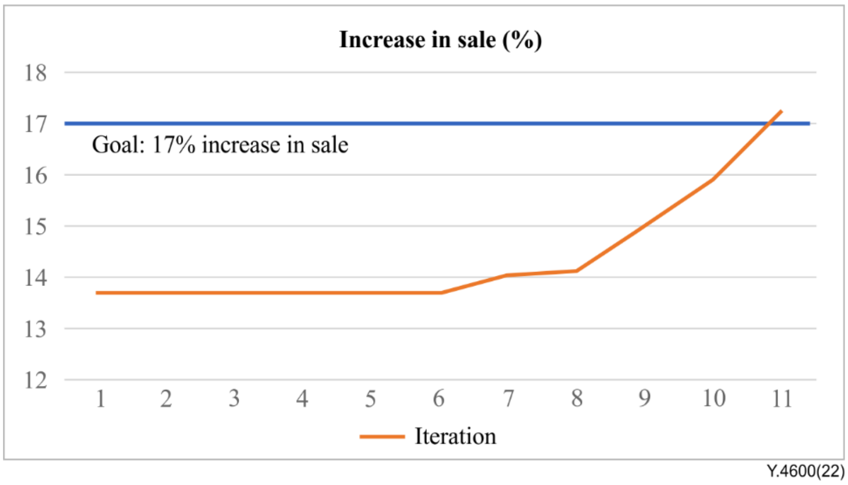

Figure I.3 – Iterations to find optimal parameters

Figure I.4 shows the available list of strategies, their range of parameters which are used as input to the smart city digital twin system and the optimal parameters found.

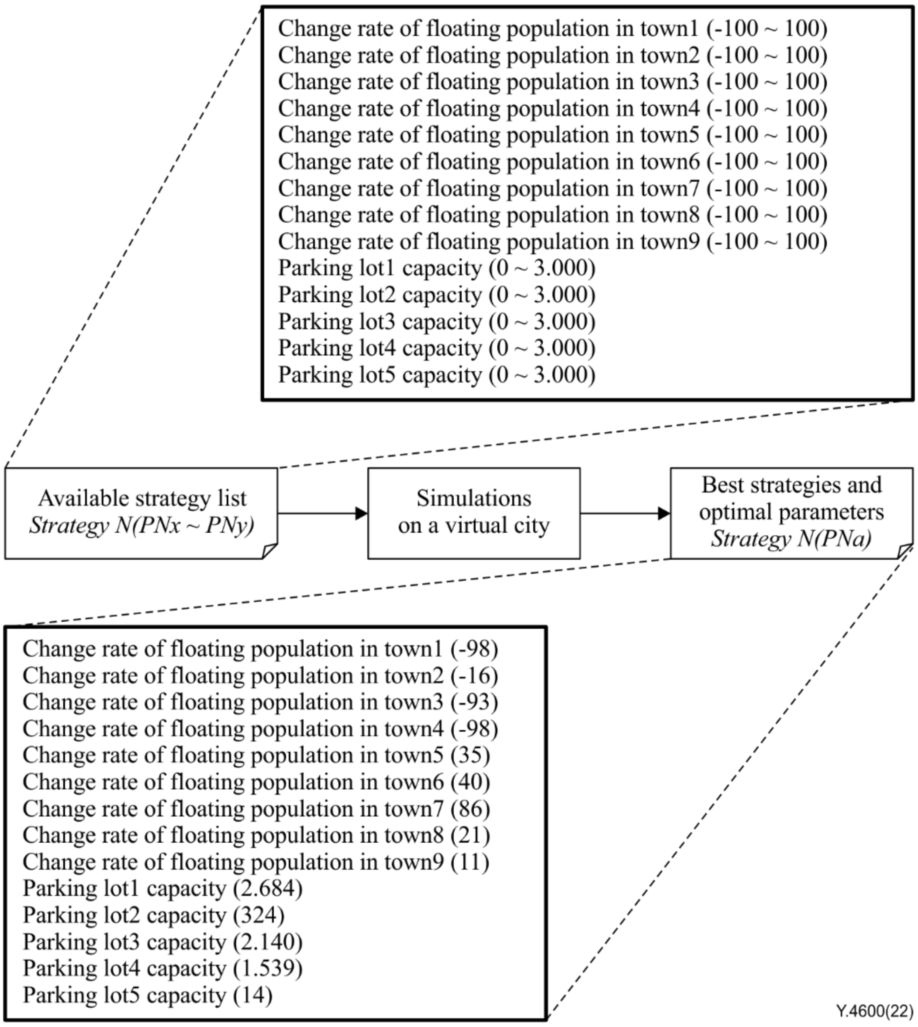

Figure I.4 – Available strategy list and optimal parameters found

According to this result, Sejong city can achieve 17% increase in sales by increasing the change rate of the floating population in town5, town6, town7, town8 and town9, and decreasing the change rate of the floating population in town1, town2, town3 and town4, and building parking area at the specific locations with a capacity of 2,684, 324, 2,140, 1,539 and 14 respectively.

Bibliography

[b-ITU-T Y.4000] Recommendation ITU-T Y.4000 (2012), *Overview of the Internet of things.*

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