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CPN Based Modeling of Tourism Demand Forecasting

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Abstract

The tourism demand has become more and more diversified and sensitive to traveling environment, resulting in the high volatility of tourism market. Travel agencies, scenic spots, hotels and other tourism businesses in the tourism supply chain (TSC) need a tight collaboration in order to minimize cost and improve responsiveness and service level. The existence of the bullwhip effect will cause the waste of resources and low efficiency, thus collaborative demand forecasting becomes a good practice to enhance sharing of information and resources, and as a result improving the efficiency and effectiveness of tourism demand forecasting. This paper proposes a collaborative tourism demand forecasting framework based on Colored Petri Net (CPN), which can simulate and examine the effectiveness of tourism supply chain collaboration.

Keywords: tourism supply chain (TSC), tourism demand forecasting, colored petri net (CPN), collaboration

1. Introduction

1.1 Tourism Supply Chain

Over the last several decades, the tourism industry, especially in China, has increased and modernized considerably. It has become a business more than $1 trillion US Dollar a year now. The global informatization and fierce market competition are now impacting on all rather than individual member companies of a supply chain link . As a service industry, tourism is even more so regarding this impact. The competitive and volatile tourism industry environment has driven tourism companies to search for how to gain their competitive edges. One of the ways that tourism companies could go to enhance their competitiveness is tourism supply chain management (TSCM) (Zhang, Song, & Huang, 2009). A tourism supply chain (TSC), referring to other pioneer supply chains, can be thought as a special supply chain linking tourism companies with different activities consisting of the supply of tourism services and the marketing and delivery of tourism products at certain tourism destinations. SCM is the holistic and systematic management of a supply chain to optimize customer value and then accomplish a sustainable competitive edge. Even though attracting widespread academic interest and practical applications in the manufacturing industry, SCM has not been paid too much attention in the tourism industry. In contrast, the tourism industry fits well to the supply chain concept. It is the characteristics of tourism industry that matches supply chain management strategy, thus TSCM can be a strong methodology to solve the problem how a tourism supply chain (TSC) upgrades its competitiveness in a more sustainable and holistic manner, especially when the tourism demand volatility is much high. This is also a new and promising research opportunity as a blank field.

Nowadays supply chain collaboration has been keeping as a hot topic. It is no doubt that the companies with effective collaboration across the integral supply chain can benefit from significant reductions in inventory and cost, together with lifting of service levels and customer satisfaction (Tapper & Font, 2004). Accordingly, the TSC collaboration will also be essential because all stakeholders in the tourism industry have to interact with each other to achieve their heterogeneous business objectives with different business scopes.

1.2 Collaborative Tourism Demand Forecasting

Demand forecasting usually is the first step for many key decisions including product pricing, marketing, planning, and development of new products etc. For a supply chain, the demand cannot be accurately forecast by individual supply chain member companies on their own, and the close collaboration among supply chain partners is a must. Collaborative demand forecasting has been well applied in supply chain management beyond tourism industry, because it can achieve information sharing amongst the links in the chain and resilience (Dong, S., Zhang, Z., & Xi, B. 2010). The merit of collaborative forecasting is about the broad information exchange to provide a basis of forecasting accuracy when the supply chain members do the job through joint knowledge of production promotions, pricing and marketing strategies, and full production information. Although there is a large body of literature focusing on collaborative supply chain forecasting for physical goods, it has not yet gained the same attention in such a service industry as tourism. Actually TSC is facing more dynamics and uncertainty, thus an accurate and adaptive demand forecasting becomes more important to business success (Zhou-Grundy, Y., & Turner, L. W., 2014). Collaborative demand forecasting for a TSC needs a variety of individuals from various echelons of the chain to work together (Zhang, X., & Song, H., 2012). In a highly collaborative and tightly integrated TSC, collaborative forecasting should guide all partner planning activities to get to accurate and timely forecasts with such features as affordability, flexibility, and simplicity as well.

Information is the "lifeblood" for almost all industries, and no exception for tourism industry, especially under e-commerce environment. Collaborative forecasting channels the "island of information" and bridges TSC partners to share information and forecasting models for demand forecasting. Colored Petri Net (CPN) is utilized for the modelling and simulation of collaborative demand forecasting process in manufacturing industry (Zhang, Z., Xi, B., & Yan, H. 2009). CPN model is a computerized representation of a system including its states and the events or transitions that result in state change of the system. Simulations of a CPN model can be used to explore and examine the behaviors of a system under various scenarios. CPNs' relatively small basic vocabulary can achieve great modeling flexibility for a variety of domains, such as data networks, communication protocols, distributed systems, and embedded systems.

This paper proposes a collaborative TSC demand forecasting framework outlining the process and data flow, and CPN is employed to model and simulate the framework, and also examine and analyze its effectiveness with an illustrative case study.

2. TSC Collaborative Forecasting Framework

2.1 The Conceptual Framework

In a TSC, travel agents is the core, but only have a weak control over other travel suppliers, such hotels and scene spots. Travel agents have a strong dependence on the upstream and downstream companies in the chain. In fact, the relationship among the TSC members is rather loose. Tourism demand information may be distorted along with the TSC without collaboration among the TSC members. The advent of e-commerce facilitates the collaboration of TSC members and brings incentives for the collaboration. TSC collaboration can take many forms, ranging from the direct business process integration to the contractual arrangements. A TSC is a dynamic system that keeps evolving over time. One well-known supply chain phenomenon is bullwhip effect referring to forecast amplification moving upstream along the supply chain. It is found that the lack of information sharing is the root cause. The dynamics of TSC is much severe not only due to the fast changing demand but also the evolution of TSC relationships.

The collaborative tourism demand forecasting is conceptually depicted in Figure 1, centered on information sharing and collaborative forecasting.

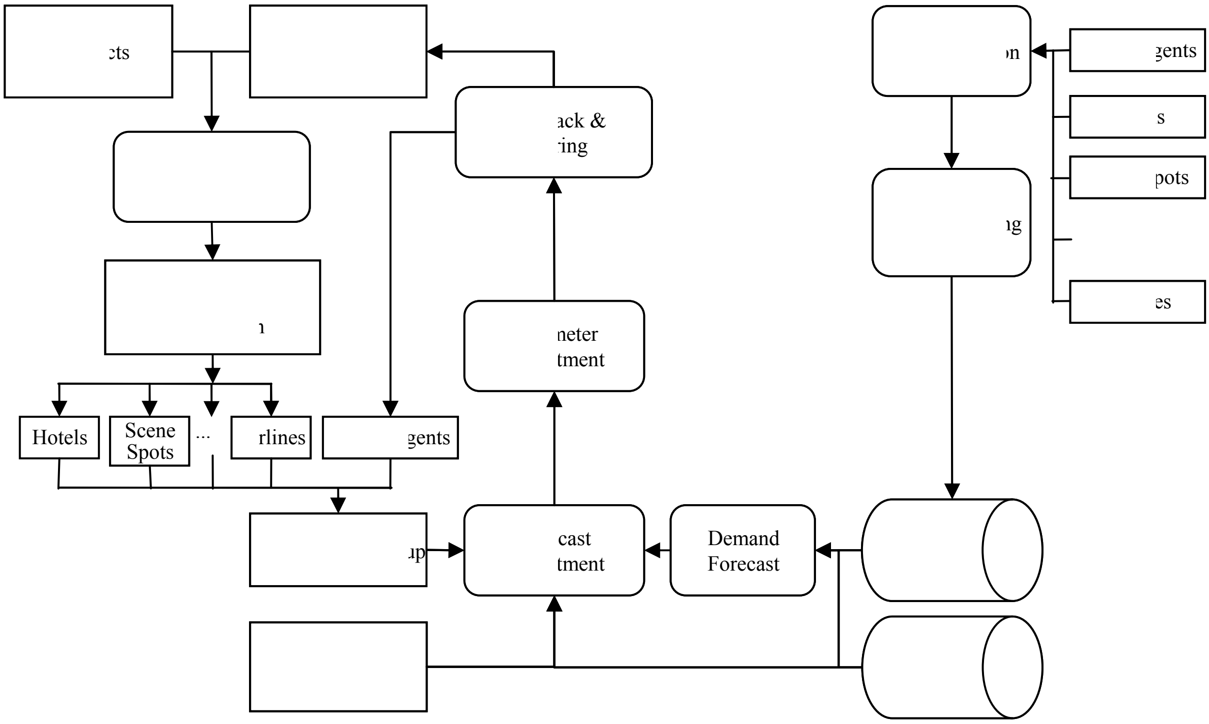

Figure 1. TSC collaborative forecasting conceptual framework

2.2 TSC Collaborative Forecasting Process

TSC collaborative forecasting is an on-going iterative process including:

(1) Collection of all related information on the TSC from travel agents, hotels, scenic spots and airlines. Centralization of information is the base of accurate and timely demand forecasting. The related information should include the study results of TSC members besides the raw data.

(2) Transformation of information to computer data. Semantic web technologies can process the information into unified data format and store into the demand forecasting database.

(3) Coordination of forecasting approaches and results and emergency plans. A workgroup should be formed to determine and adjust the forecasting models and approaches, to analyze the results, and to response to any emergencies.

(4) Guidance of resource allocation based on the demand forecast. It is ensured that the forecasts will be shared by all TSC members, and decomposed to their own demand forecasts. This paper proposes BOM ((Bill of Materials) based decomposition. It is assumed that the demand forecast of tourism product A is FD composed of {D1, D2, ⋯, Dm}, and BOM list is {BD1, BD2, ⋯, BDm }. The potential suppliers of the product A are {S1 , S2 , ⋯, Sn } with the proportion matrix:

$$\begin{bmatrix} P_{D1S1} \cdots P_{D1Sn} \\ \vdots \qquad \vdots \\ P_{DmS1} \cdots P_{DmSn} \end{bmatrix}$$

Then the demand Di will be supplied by

$$F(Di) = (F_D \times B_{Di}) \times (P_{DiS1} \quad P_{DiS2} \quad \cdots P_{DiSn})$$
$$= \left[(F_D B_{Di} P_{DiS1}) \quad (F_D B_{Di} P_{DiS2}) \quad \cdots \quad (F_D B_{Di} P_{DiSn}) \right]$$

(5) Postmortem and adjustment. After collecting the actual demand, the postmortem and model adjustment will be the last step.

3. CPN Based Modeling

3.1 CPN and CPN Tools

CPN is a graphical language to model and validate such systems with the characteristics of concurrency and synchronization. CPN models can facilitate the simulation, state space analysis, behavioral visualization, and simulation-based performance analysis. A Petri net is a kind of directed graph with nodes, places, and arcs, as shown in Figure 2. The nodes represent transitions (denoted by rectangles) and places represent conditions (denoted by circles). The directed arcs (denoted by arrows) linking the nodes and places depict which places are pre- and/or post-conditions for which transitions. The places may contain a discrete number of tokens. The places, transitions, and arcs can be interpreted as different implications depending on the system. Places may represent operations or status, transitions may be the start/end of processes, and arcs could be data flow or resource movement. Transitions occur at the start/end of processes. In the processes of simulations, activities or events can be modeled by transitions. Activities could be a kind of the processes or system logics. When some events happen at a time, the activities will cause a change in the state. Tokens are the certain conditions which must be met to fire a transition. The marking of a Petri net is the distribution of tokens among places. In the pictorial representation, tokens are depicted by black dots. To fire a transition, its incoming and outgoing arcs must provide the number of tokens needed (labeled on the arcs by weights). If the pre-place can meet the incoming arc weights, the transition is thought as "enabled", and the transition may be fired. Once a transition is fired, the tokens will be re-distributed, reaching a new round of marking. When the associated transition fires, a certain number of tokens will be removed from a place according to its outgoing arc value, and at the meantime the incoming arc value determines the number of tokens to add to the place.

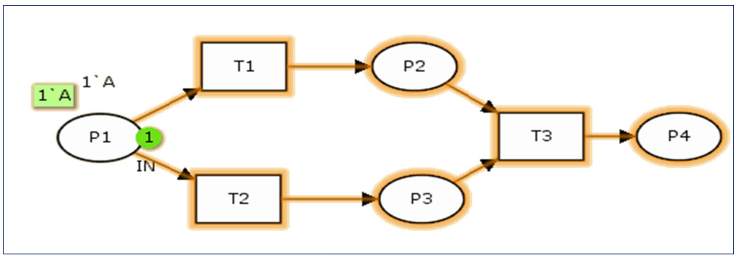

Figure 2. Petri net

CPN is an augment of Petri net to add differentiation on the tokens. In a CPN model, a token can be assigned a data value which can be with a rich set of types (color sets). An arc inscription may not be a constant, and computable expressions are allowed. In an ordinary Petri Net, tokens are the same and cannot be distinguished, while in CPN all tokens are assigned their own values. The token values of are declared as a certain type.

However, the application of CPN depends on the existence of computer tools to accomplish the construction and manipulation of models. CPN Tools is such a software package that the user can edit, simulate, and analyze a CPN. CPN Tools was originated from the CPN Group at Aarhus University. CPN Tools also features incremental code generation with syntax checking, while a net is being constructed. Its simulator can efficiently handles untimed and timed nets. Full and partial state spaces can be generated and analyzed.

3.2 CPN Definitions for the Collaborative TSC Demand Forecast

To define the CPN model, the first step is the declaration of color sets and variables. In the CPN, variables can be used in inscriptions which can be different expressions, but must be with a certain color set. The collaborative TSC demand forecast model can have the following declaration shown in Figure 3.

```
▼colset Amount = INT;
▼colset Item = STRING;
▼colset Component= STRING;
▼colset Ratio= INT;
▼colset Supplier = STRING;
▼colset Forecast= product Item * Amount;
▼colset Index = product Item * Ratio;
▼colset BOM= product Item * Component * Amount;
▼colset ORDER = product Component * Amount;
▼colset Demand = product Component* Amount;
▼colset Contract = product Supplier * Component * Ratio;
▼colset Distribution = product Supplier * Component * Amount;
▼var am, b_am: Amount;
▼var ratio : Ratio;
▼var supp : Supplier;
▼var comp : Component;
▼var item : Item;
```

Figure 3. CPN definitions for TSC demand forecast

3.3 CPN Model of TSC Demand Forecast

The Create toolbox in CPN Tools is used for creation and editing of the basic CPN components such as places, transitions, and arcs. CPN Tools also provides other useful guideline tools, for example, net structure alignment and component cloning. The initial marking of the net is the input to a CPN simulation. The input sets up an individual state of the system, and the transition will change the state and thus the whole state of the system. The states, or the final marking of the CPN, can be combined as output.

The information sharing and collaboration mechanism among the TSC members, such as travel agents, hotels, and scene spots, can be modelled in the CPN as shown below (without tokens). The simulation of this CPN can validate the mechanism and give insights to the mechanism. The intermediate states or markings give more details about the dynamic process.

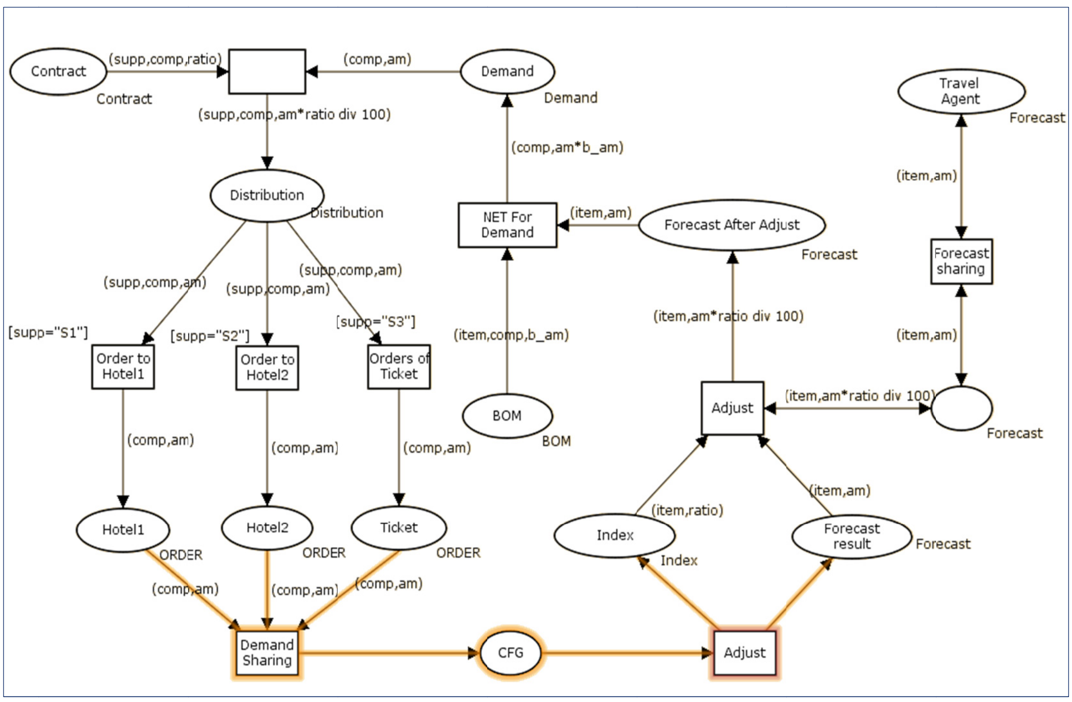

Figure 4. CPN modelling of TSC demand forecast

CPN simulation could be in an automatic mode or interactive mode. The interactive mode allows the user to pick a transition and bind a variable, which is often used for model debugging. The automatic mode provides two sub-modes, play mode and fast forward mode. The play mode runs with various markings displayed at each execution step, whereas the fast forward mode only shows the final markings until the end of simulation. A simulation run is finished by checking the stop criteria which may be the clock reaching a certain value, or a predefined number of steps, or other conditions specified by breakpoint monitor.

4. Case study

4.1 The Case Description

It is assumed there are three tour packages: A, B and C. Package A provides single-person two-day scenic spot tour; Package B provides loving couple two-day scenic spot tour; Package C provides two-student two-day scenic spot tour. Let B1 donate single bed, B2 double bed; T1 is adult entrance ticket, T2 is student entrance ticket. We get table BOM as follows:

Table 1. Tour package BOM

Package	Bed Type	Bed Number	entrance ticket	Ticket Number
A	B1	1	T1	1
B	B2	1	T1	2
C	B1	2	T2	2

There are two hotels offering B1 and B2, and a scenic spot offering T1 and T2:

Table 2. Suppliers' provision

Supplier	Product	Number
Hotel 1	B1	30
Hotel 2	B2	60
Hotel 2	B1	70
Hotel 2	B2	40
Scenic spot	T1	100
Scenic spot	T2	100

It is assumed that the demand forecast (based on the historical data and TSC information) is: A: 100, B: 400, and C: 200.

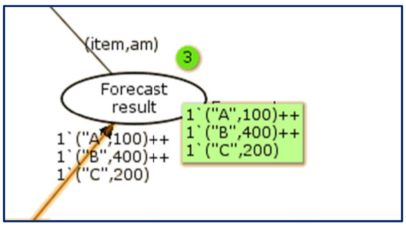

Figure 5. Demand forecast

Then the workgroup will fine-tune the forecast by adjusting some parameters. For example, the "index" value in Fig. 6: the probabilities of package A, B and C are 140%, 90% and 70% respectively.

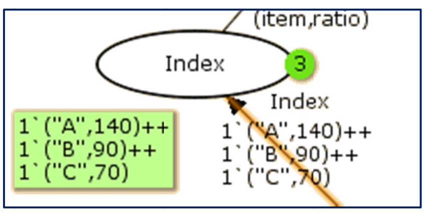

Figure 6. Parameter adjustment

With sufficient tokens, the adjusted ideal demand forecast is shown in table 3 and 4 with the equations (1) and (2):

$$\text{Item}=\text{amount}*\text{ratio} \tag{1}$$

$$\text{Item}=\text{amount}*\text{ratio}*\text{box\_amount}*\text{ratio} \tag{2}$$

Table 3. Adjusted demand forecast

	Package A	Package B	Package C
Demand forecast	140	360	140

Table 4. Final suppliers' provisions

	B1	B2	T1	T2
Hotel 1	126	216		
Hotel 2	294	144		
Scenic Spot			860	280

4.2 Simulation of Collaborative Forecasting

The collaborative forecasting is simulated by adjusting the tokens shown in Figure 7.

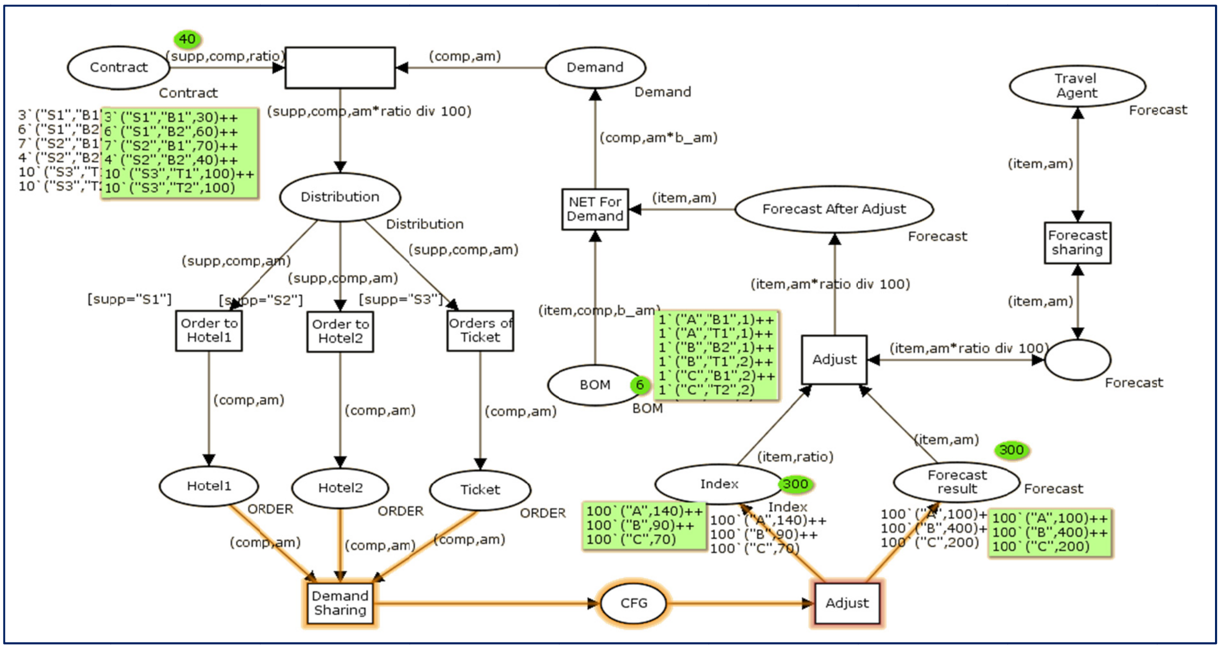

Figure 7. Collaborative forecasting by adjusting CPN tokens

CPN simulation of collaborative forecasting links all partners in TSC through information sharing, which is warranted by the demand forecasting workgroup. Once a forecast is given by the workgroup, all relevant partners, such the travel agents, hotels and scenic spots will forecast their own forecast according to BOM lists. This CPN simulation demonstrates the feasibility and effectiveness of collaborative forecasting. However, the demand forecasting approach and process may be complex, which needs large historical information, suitable forecasting models, and adaptive updating and adjustment.

5. Conclusion

Demand forecasting is a key function for all TSC members. Every member company has its different information and models for the forecasting. Due to the volatility of tourism market and demand sensitivity, individual member cannot fully master the demand information and suitable forecasting models to obtain an accurate forecast. Collaborative TSC demand forecasting emerges as a promising approach to tackle this issue. The collaborative forecasting of TSC as a whole will not only promote the forecasting accuracy and effectiveness, but also enhance the TSC resilience by sharing information and feedback among the partners.

This paper proposes the framework of TSC collaborative demand forecasting, and presents the CPN based simulation and analysis. CPN based simulation constructs the data flow and process flow, and demonstrates the feasibility of the information sharing and communication for the collaborative demand forecasting.

In the simulation, the forecasting models and technics are not built due to their complexity and variety. And time variable is not included in the simulation, which may affect the collaborative forecasting process.

Furthermore, a TSC is a relatively complex network compared with other supply chains. The member companies along TSC have their own market structures, and are loosely combined. Usually tourism organizations must consider the interactive effects between their market and those of other members. Further, one of significant phenomena in the tourism industry is the dynamics of supply chain structure, and the players may often adjust business partners to obtain higher profitability or to improve their competitiveness. All these make collaborative TSC demand forecasting a challenging task, because the close collaboration among the players from a variety of echelons in the TSC needs a trusting relationship and strong motivation and even binding mechanisms.

Acknowledgments

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