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# Individual and group dynamics in purchasing activity

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ABSTRACT

As a major part of the daily operation in an enterprise, purchasing frequency is in constant change. Recent approaches on the human dynamics can provide some new insights into the economic behavior of companies in the supply chain. This paper captures the attributes of creation times of purchase orders to an individual vendor, as well as to all vendors, and further investigates whether they have some kind of dynamics by applying logarithmic binning to the construction of distribution plots. It's found that the former displays a power-law distribution with approximate exponent 2.0, while the latter is fitted by a mixture distribution with both power-law and exponential characteristics. Obviously, two distinctive characteristics are presented for the interval time distribution from the perspective of individual dynamics and group dynamics. Actually, this mixing feature can be attributed to the fitting deviations as they are negligible for individual dynamics, but those of different vendors are cumulated and then lead to an exponential factor for group dynamics. To better describe the mechanism generating the heterogeneity of the purchase order assignment process from the objective company to all its vendors, a model driven by product life cycle is introduced, and then the analytical distribution and the simulation result are obtained, which are in good agreement with the empirical data.



## 1. Introduction

Humans participate in a large number of distinct activities for different purposes and these activity patterns show diverse characteristics. Although individual human behaviors are unpredictable, all the behaviors reveal some general laws. However, it is impossible to describe all the activity patterns with a specific process model. In 1837, the French mathematician Poisson derived the Poisson process based on the binomial distribution and from then on, similar models are widely used in communications, transportation, management, economic operation and so on. All these models are based on the hypothesis that the time intervals between two consecutive actions are comparable to each other. In 2005, Barabási et al. studied the e-mail communications and the correspondence patterns of Einstein et al. and indicated that human activity patterns are rather heterogeneous, with long periods of inactivity that separate bursts of intensive activity. More precisely, the inter-event times between two consecutive executions for a given task can be approximated by a heavy tailed distribution [1–3]. After that, some scholars conducted related empirical exploration and theoretical research through human daily behavior and found that power-law distributions occur in an extraordinarily diverse range of activities such as web browsing, communications via electronic and paper mail, and human traffic [4–7]. Based on the task-driven priority queueing model introduced by Barabási, many improvements are obtained, which make the original model fit reality such as variable priority or task-length and deadline, resulting in various power-law exponents such as 1.25, 1.5 and 2.5 [8–13]. According to the present research, the scaling parameter $\alpha$ typically lies in the range $1 < \alpha < 3$, although there are occasional exceptions. The fact that these patterns can't be characterized simply is a sign of complex underlying human dynamics that merit further study.

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**Table 1**
Data profile.

| Fiscal quarter | Q1 | Q2 |
|---|---|---|
| Number of all POs | $4.4 \times 10^4$ | $4.2 \times 10^4$ |
| Number of vendors | $2.7 \times 10^3$ | $2.6 \times 10^3$ |
| Number of POs to the top ten vendors | $2.4 \times 10^4$ | $2.4 \times 10^4$ |
| Number of POs to enterprise *A* | $1.0 \times 10^4$ | $1.1 \times 10^4$ |

However, studies on the properties and mechanisms of human business activities based on the enterprise, an important organization in the real world, are still in their infancy, with only a few related documents. Wang et al. studied the statistical features of the task-restricted work patterns via aerial inbound operation in a logistics company and obtained five power-law distributions with exponents 1.5, 2.0 and 2.5 [14]. Caldarelli et al. illustrated that some financial systems display scale-free properties, with exponents from 1.5 to 3 [15]. Ho et al. investigated the time series of the Taiwan stock price index and obtained a conclusion that the autocorrelation does not decay to zero exponentially but in a power-law manner with exponent 5/3 over a range of frequencies [16]. Hence, it still needs further study to clarify whether the day-to-day business in a company, for example, supply chain operation, production scheduling and staff turnover, has a heavy-tailed property or follows the Poisson process.

Among all the daily activities in a manufacturing enterprise, supply chain management plays an important role. At present, in the dynamic environment and uncertain competitive market, the value and service provided by a good supply chain alliance is more competitive and effective than that by companies without information sharing between each other. Yet, as a separate individual in the supply chain level, a company possesses its own unique view and strategy, forming a complicated relationship with other corporations under the effect of the environment and showing a power-law degree distribution with exponent 1.96 [17]. And the purchase order to a large extent is an epitome of the games of all parties in the complex system. Recent approaches on the human dynamics can provide some new insights into the purchasing behavior in the supply chain based on the time series of purchase orders and, in turn, the results may give a further understanding of the characteristic of the human activity pattern. The goal of this paper is to provide empirical evidence and theoretical analysis for the purchasing process.

## 2. Data specification

In this paper, the data come from the main business of a Fortune 500 company, called enterprise *M* for short in the following. As a corporation with global coverage, the number of daily purchase orders (POs) for this business is as large as one thousand. Under the premise of keeping the business information of enterprise *M* absolutely secret, we investigate the POs created in the two latest fiscal quarters and analyze the scaling characteristics with these actual operation data from the viewpoint of time intervals. There are about $4 \times 10^4 \sim 5 \times 10^4$ POs in each quarter, involving approximately two thousand suppliers. This paper focuses on the inter-arrival time of two consecutive orders, with the precision of a second. But for the global property of enterprise *M* and the actual state in daily work, we don't classify the orders by the creation time, i.e., orders placed at the weekends and other nonworking times in a certain region are not precluded. On the one hand, different teams from various time zones make the work process in enterprise *M* connected to some degree, although the numbers of POs in some time zones are significantly less than others; on the other hand, people responsible for the PO process deal with orders at the weekend if needed. For instance, in Fig. 4(c), purchasing activities occurred on a Sunday.

The analysis of each time interval between two consecutive purchase orders is performed by the normalized logarithmic binning to remove the noise tail and reduce the uneven statistical fluctuations common in empirical analysis. In contrast with simple logarithmic binning, it further removes the artifact while maintaining the advantage of using larger bins where there are fewer values of abscissas [18]. Naturally, prior to conducting the analysis, we compared the three fitting curves generated by this approach, probability density curves and cumulative distribution curves on logarithmic scales respectively, and finally decided to apply this method to data analysis for it is more explicit and legible on the premise of fitting accuracy without altering the real distribution characteristics of the orders [19].

In the following section, we mainly discuss two types of distributions on the group and individual dynamics level respectively: one is the time interval distribution of all the purchase orders of enterprise *M* without recognition of the PO suppliers, while the other is of orders to a specific supplier.

As shown in Table 1, enterprise *M* placed POs to more than two thousand vendors during the two quarters, among which about fifty percent were assigned to only ten suppliers and over twenty percent to enterprise *A*. In the case of the heterogeneity during the PO assignment, here we just discuss the purchase orders to the largest supplier *A* in detail as a paradigm to clarify the individual dynamics of the purchasing process.

## 3. Individual dynamics in the purchasing activity

The individual characteristic of purchasing activity is analyzed through the statistical properties of the time intervals of orders to a specific vendor. Obviously, the individual purchasing frequency may show great variety with time. As