Supply Chain Performance Metrics. A Behavioral Perspective*

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Abstract

Organizations use metrics to measure the performances of departments, processes, projects, groups, and individuals. Important decisions are based on performance metrics, such as selecting investments out of a pool of investment options or determining compensations of employees. Performance metrics that measure the relevant performance directly are referred to as fundamental performance attributes.

In operations management, for instance, the inventory value and the cost of goods sold are such fundamental performance attributes. To analyze performance over time or between entities, performance metrics are standardized by evaluating one fundamental performance attribute relative to another. The standardized performance metrics *time supply* and *turn rate* are two examples.

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The *time supply* metric measures the average duration that goods are held in inventory and is computed as the ratio of the inventory value and the cost of goods sold, The *time supply* metric measures the average duration that goods are held in inventory and is computed as the ratio of the inventory value and the cost of goods sold,

$$\text{Time supply} = \frac{\text{Inventory value}}{\text{Cost of goods sold}}. \tag{1}$$

The *turn rate* metric measures the number of times inventory is turned over in a period and is computed as the ratio of the cost of goods sold and the inventory value,

$$\text{Turn rate} = \frac{\text{Cost of goods sold}}{\text{Inventory value}}. \tag{2}$$

Time supply is usually specified in days and the turn rate usually as an annual rate. An inventory system with a time supply of 90 days, for instance, has an annual turn rate of four. Time and rate based metrics are not only used in inventory management, but in various areas of operations management. Table 1 lists some examples. Time and rate based measures are also used in other functional areas, such as marketing (e. g. adoption rate) and finance (e. g. asset turnover).

Because the rate based metrics are simply the reciprocal of their time based counterparts, both metrics contain the same information. The fundamental performance attributes can be computed based on both types of metrics and a rational decision maker who is interested in optimizing the fundamental performance makes the same decisions under both metrics. Based on either metric, the decision maker determines the effect of all options on the fundamental attribute and selects the option that optimizes the fundamental attribute.

However, the behavioral literature suggests that actual decision makers might not be immune to the metric that is used and their decisions might be affected by the type of standardized metric that is used. In a setting that is related to ours, Larrick and Soll (2008) analyze the effect of fuel efficiency metrics on investment decisions. Fuel efficiency can be measured in miles per gallon (MPG) or gallons per 100 miles (GPM), where one metric is the reciprocal of the other. In their MPG treatment, subjects can invest in increasing the fuel efficiency of one fleet of cars from 15 to 19 MPG or invest in increasing the fuel efficiency of another fleet of cars from 34 to 44 MPG, where both fleets have the same annual mileage. Only 25% of the subjects choose the first option, which reduces fuel consumption more than twice as much as the second option. In the GPM treatment, where the only difference to the MPG treatment is the metric that is used to measure fuel efficiency, subjects can invest in increasing the fuel efficiency from 6.67 to 5.26 GMP or from 2.94 to 2.27 GPM. In this

	Time based	Rate based
Inventory	Time supply (90 days)	Turn rate (4/year)
Warehousing	Picking time (30 sec/unit)	Pick rate (120 units/hr)
Production	Takt time (1 min/unit)	Production rate (60 units/hr)
Reliability	Mean time between failures (10 years)	Failure rate (10 %/year)

Table 1: Examples of time based and rate based performance metrics used in operations management

treatment, 64% of the subjects choose the first, correct option.

The results of the experiment can be explained by substitution heuristics: When confronted with a difficult question, people answer an easier question instead and are often even unaware of the substitution (Kahneman and Frederick 2002), in particular if the relationship is non-linear (Svenson 2011). Hsee et al. (2003) show that individuals do not necessary make decisions that optimize the fundamental attribute, but decisions that optimize a medium that is more readily available, even they are made aware of the relationship between the metric and the fundamental attribute.

Translated to the analysis of performance metrics, the results suggests that at least some individuals optimize the performance metrics as opposed to the fundamental performance attribute. In this paper, we address this issue. We use laboratory experiments to analyze how the inventory performance metrics time supply and turn rate affect decisions. We chose these metrics, because inventory is one of the key assets of a company (Hausman 2003) and both metrics are commonly used in practice (Cohen et al. 2007). In recent survey, we asked 93 managers of manufacturing companies about the performance metrics used at their companies: 32% use time supply only, 27% use the turn rate only, 33% use both metrics, and only 8% use neither time supply nor turn rate.

While both metrics are popular in practice, companies do not seem to decide consciously which one they use. In informal discussions with the managers, no managers knew why one or the other metric is used and not the other. Those who use both metrics do not follow a transparent approach for selecting the metrics for different objectives and it seems to much a matter of personal preferences which one is used. The literature provides little guidance about the advantages and drawback of time and rate based metrics and the objective of this paper to provide some insights into the effect of metric type on decisions.

Although the time and rate based metrics contain the same information, they differ in an important aspect, that is, the structure of the functional relationship between the fundamental attribute and the metric. Time supply is a linear function of the fundamental performance attribute inventory value (Equation 1) and the turn rate is a convex function

of the inventory value (Equation 2). An individual who relies on the time supply metric to evaluate an inventory reduction, assigns a value to the reduction that is independent of the initial inventory, which is correct. Under the turn rate, however, the individual assigns a value to the reduction that is decreasing in the initial inventory. That is, the lower the initial inventory, the higher the value associated with the reduction. Thus, the turn rate can incentivize non-optimal investments in inventory reductions, which is a drawback of this metric compared to the time supply metric. However, the turn rate can be superior to time supply for incentivizing effort. Because the turn rate is convex increasing in inventory reductions, it can motivate individuals better than time supply to reduce inventory.

From a managerial perspective, the results of our research have important implications. They show that different performance metrics that contain the same information can result in different decision making and and in different employee motivation. We provide a behavioral model that explains how inventory changes are valued and use the model to analyze the effect of the performance metric on investment decisions and effort. We validate our model with laboratory experiments with student subjects and managers. The results of our analysis provide guidance for the design of performance metrics to incentivize the desired behavior of individuals. Our focus is on inventory metrics, but the results are likely to generalize to other metrics.

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