Picking productivity estimation in Distribution Warehouses

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Abstract

We examine problem of picking productivity estimation in distribution warehouse. We formulate model attempting to capture variability in picking operations using regression analysis and ANOVA. We consider the two important order attributes: number of lines and number of cases, and derive relation between time/case and cases/line for reserve warehouse setup.

Key Words: Picking Productivity, Regression Analysis, Order Profile

Introduction

Warehouse operations are classified into five basic types: (1) Receipt and Inspection, (2) Put Away and Storage, (3) Picking, (4) Order Consolidation, and (5) Dispatch related activities. Studies show that order picking is the most time consuming, costliest and most labour intensive activity among warehouse operations (Coyle et al, 1996). Picking is defined as "the process of extracting requested goods from inventory as per demand, bring them together to form a shipment accurately, on time and in good condition (Rushton et al, 2006). Time and cost related to picking activity is largely dependent on routing policies and routes decided thereby. Researchers have attempted to determine optimal routes for different routing policies in manual (e.g. Hall, 1993) and automated (e.g. Kim et al., 2003) warehouses.

Due to time consuming and labour intensive nature of picking activities, productivity assessment and improvement in picking is a major concern for industrial engineers (Le-duc and De-Koster, 2005). Accurate productivity estimation is also needed for manpower planning. Picking activities are not highly "repetitive" as found in assembly or mass manufacturing system. Rather, pickers perform a large number of similar tasks in a cyclic manner over period of time. Some recent studies focus on productivity analysis of manual warehouses, with consideration of picking activity (Chan and Chan, 2011; Taljanovic et al., 2011; Rouwenhorst et al., 2000). Travel distance, order retrieval time, multiple numbers of pickers, high volumes, small parts and small orders are some of the factors examined in these studies. Professionals routinely use historical productivity data for manpower assessment. However, these data include a large amount of non-value added time which overestimates manpower requirements. Hence, better methodologies remain to be evolved to assess picking productivity accurately and provide guidelines for improvements. This study proposes one such methodology based on regression model to examine factors affecting picking productivity and provide pointers for improvement.

The rest of the paper is organised as follows: In section 2, we discuss a framework for examination of picking productivity in manual warehouse system. In section 3, the methodology for data collection and analysis is presented. Further in Section 4, we present the data collected and build the regression model. Finally, we discuss the implications on productivity and derive the pointers for improvement in Section 5.

Framework

We define picking productivity as the number of cases picked per labour hour. This is influenced by following four time components of the picking task: a) Basic Time or Set-up Time, b) Gripping Time, c) Idle Time and d) Way time of picker between issue points (Hompel and Schmidt, 2007). Way time contributes to approximately 50% of total picking time (Tompkins et al., 2003) and is an increasing function of travel distance. Further this time is affected by the attributes of warehouse design and operations (layout, slotting, zoning, routing) and attributes of order (Number of cases, number of lines and cases per lines).

Picking time can be estimated by stopwatch time study (ILO), predetermined time standards or Group timing techniques (Maynard). Although these techniques estimate the mean task time with a reasonable accuracy the variability in the task time still needs to be captured. The statistical technique of multiple regression analysis is suitable for the calculation of variable time (ILO). The majority of the literature related to picking productivity examine the warehouse design attributes for the impact on productivity. We attempt to address the impact of order attributes on the order completion time and overall picking productivity. To this effect we use the historical data and the regression analysis in combination.

Methodology

The methodology adopted for this study consist of three phases: 1) As-is Analysis, 2) Data collection and Data Analysis and 3) Improvements as shown in Figure 1. The existing processes are reviewed and the process flow is mapped. Time estimation and regression modelling are used for data collection and analysis. The study is carried out in the warehouse of Cosmetic Company having 1000 SKUs, 18000 Stock Locations and 20000 m^2. The case picking activity is single order picking where a pick-list is given to an individual picker. The activity is observed over 16 days period and 337 readings are taken. The start time and the end time of the picking activity are recorded in each case. Additionally number of cases picked in each order and number of lines visited for the same are recorded. As the operations involved temporary workers, the readings related to them are removed from data set to eliminate the bias of learning curve and 276 readings are used for data analysis and modelling purpose. A closer look at the distribution of picking time over a period (Figure-2) shows that the picking times follows Beta distribution. Hence consideration of average task time for manpower calculations results into overestimation of the manpower for a given order size.

Results

The time taken to complete the order is expected to vary with number of cases in the order and number of lines visited. This dependency is verified through correlation analysis and the correlation coefficient between number of lines and picking time ($R = 0.851$) and between number of cases and picking time ($R = 0.797$) are found to be statistically significant ($p < 0.05$). Thus we define the time for order picking as a function of number of cases on the pick list and number of lines required to be visited to complete the order.

$$T(Order\ Picking) = f(N_{Cases}, N_{Lines}) \qquad (1)$$

As *T(Order Picking)* is an increasing function of both N_{Cases} *and* N_{Lines}, we develop a multiple regression equation to model the relationship between three variables. We used 276 readings for this purpose and obtained the R^2 value of 0.773. We observe that the number of lines has five times more impact than number of cases on picking time. The results of regression analysis are shown in Table 1.

This regression equation is used to recalculate the expected time in each case. We then plotted the graph of Time per Case versus Cases per Line as shown in Figure 3. We observed that there is an inverse relation between Time per Case and Cases per Line. This relationship is further validated in Figure 4.

Discussion

The regression equation gives three coefficients: the constant term ($\beta_0 = 801$), the coefficient of number of lines (β_1=76.4) and the coefficient of number of cases (β_2=14.2). These coefficients signify various components of the picking time. The constant term can be interpreted as the sum of set up time and the initial and final travel time, which remain unchanged for a given warehouse configuration irrespective of the order attributes. The factors contributing to the set up time in the constant term are: 1) Searching for empty pallets, 2) Segregation of pick list, and 3) Searching for RF Gun. On the other hand, improper sequencing of pick list contributes to a greater travel time. Further analysis shows a lot of non-value adding movements which may be reduced by pre-routing of pick list and across the aisle arrangement of ABC category SKUs.

Next, the graph of Time per Case versus Cases per Line provides insight into how picking productivity can be controlled by order attributes. Increasing the cases per line reduces the time per case drastically at initial stage and at a diminishing rate at later stage. Thus the strategy should be to increase the number of cases per line. This thing can be achieved by combining orders and picking in batches rather than single order picking. Figure-4 represents Pareto optimality property showing the presence of an *efficient frontier*. The extent of possible improvements in time per case can be traced by the efficient frontier as displayed in Figure 4. This information can be used for calculating optimum manpower requirement for a set of given orders. We analysed the data from the primary distribution warehouse of the case study cosmetic company and found that the warehouse operated primarily in the zone of 1-2 Cases per Line. We suggested to shift the operating zone to 3 Cases per Line to achieve improved picking productivity.

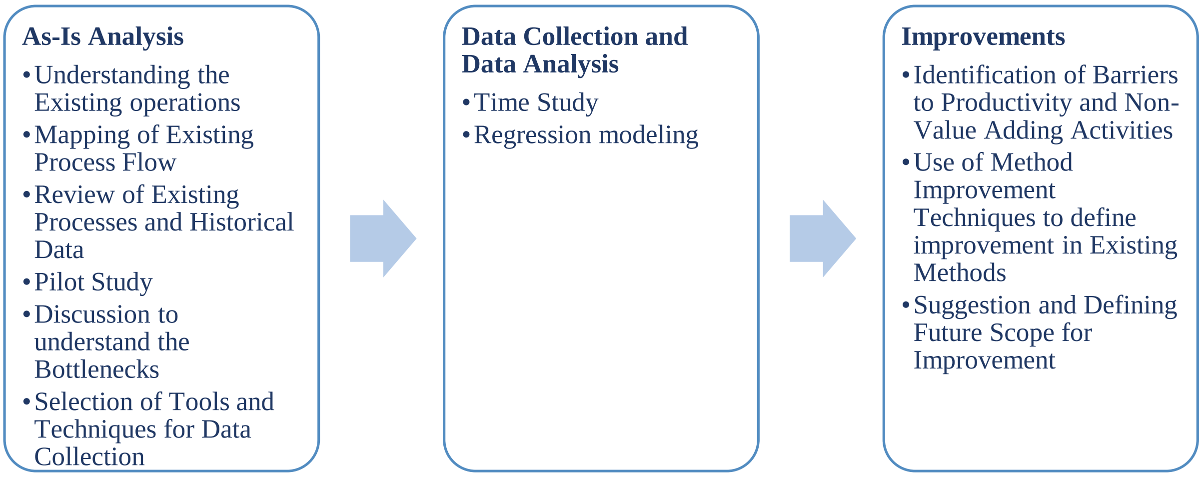

Figure 1 Methodology

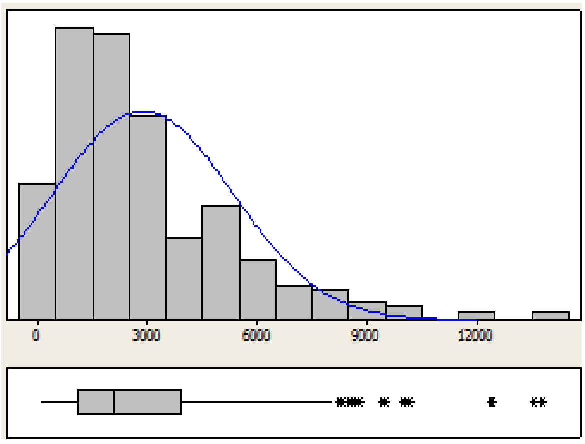

Figure 2 Picking Time Data – Beta Distribution

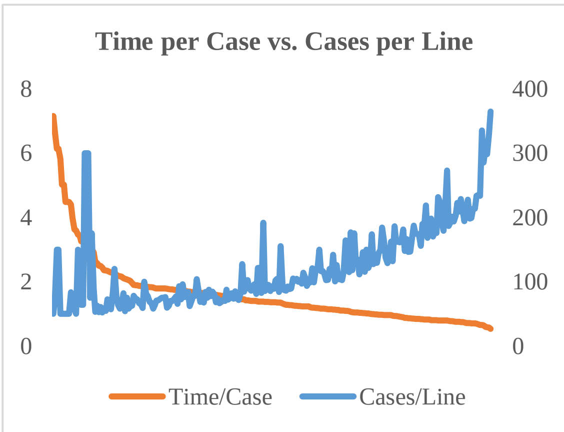

Figure 3 Plot of Time per Case vs. Cases per Line

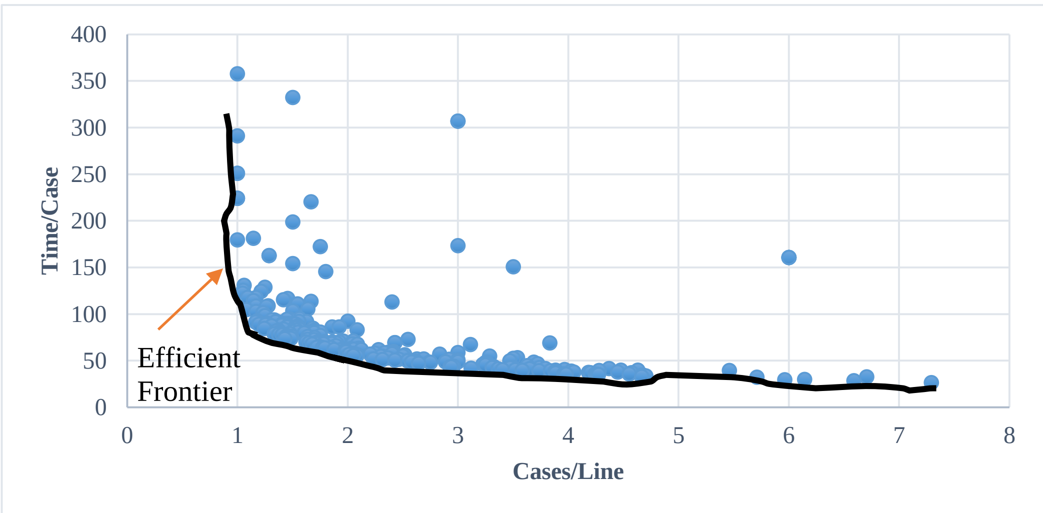

Figure 4 Pareto Optimality Property in Picking Operation

Table 1 Output of Regression Modelling

- **Regression Analysis: Time to Complete Picking of Order vs. No. of Lines and No. of Cases**

The Regression Equation is

Time to Complete Picking of Order = 801.3 + 76.4X No. of Lines + 14.2X No. of Cases

Predictor	**Coef.**	**SE Coef.**	**T**	**P**
Constant	801.3	151.4	5.29	0.000
No. of Lines	76.409	5.891	12.97	0.000
No. of Cases	14.181	1.810	7.83	0.000

S = 1486.52 R^2 = 77.5% R^2(adj) = 77.3%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	2081757085	1040878543	471	0.000
Residual Error	274	605465332	2209727		
Total	276	2687222417			

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