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Optimal production model for EVs manufacturing process in Turkey: A comparable case of EMQ/JIT production models for EVs' battery production

Bilgehan Yıldız[a], Murat Ustaoğlu[b]a*

[a]*New Jersey Institue of Technology, Newark, NJ, 07102, USA*
[b] *Istanbul University, Beyazıd Fatih, Istanbul 34452, Turkey*

Abstract

In order to keep pace with the ever-changing global community, numerous manufacturing companies have switched to the Just-In-Time (JIT) production model, and many others are considering this approach as well. The competition in global markets pressure domestic and Multi National Corporations (MNCs) to meet "global production" standards that enable simultaneous production, or concurrent engineering. Various benefits have been asserted for the companies that utilize the JIT production model for inventory management such as reduced process inventory costs and holding costs.JIT production strategy – also called "Toyota Production System" – is implemented successfully by various automotive manufacturing firms. Turkey has beenmanufacturing the Electric Vehicles (EVs) for the domesticand global markets as well as establishing a production strategy for EVs. Considering that EVs will be penetrating the Turkish auto market for the first time after several unsuccessful attempts (by other countries) throughout the 20th century, it is left up to manufacturers to determine the production strategy due to inadequate supply-demand forecasts. Since the EVis still in its early stages in Turkey, the traditional economic production models(EPQ)might not be the best reference for manufacturers. This paper focuses its investigation on which optimal production model is suitable for a EVs' battery manufacturing process, and at what point should producers switch from JIT to EMQ in order to reduce costs.

Keywords:JIT, EMQ, EVs battery manufacturing, Automotive Industry, Turkey

1. Introduction

In today's global world, the real challenge for manufacturing firms is providing excellent quality, cost, and delivery performance to attain customer satisfaction. The only way to achieve staying ahead of the

* Corresponding author. Tel.: +1-201-888-1903
E-mail address: by34@njit.edu

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competitors is through maintaining customer satisfaction (Amasaka, Applying New JIT-Toyota's global production strategy: Epoch-making innovation of the work enviroment., 2007).The global market has been pressuring manufacturing firms to reduce costs and the adoption of Supply Chain Management (SCM)relationships lead firms to revise their inventory management systems (Zomerdijk & Vries, 2003).In order to expand into the global markets, firms are required to make more efficient and less costly means of production than the domestic manufacturers. Therefore, the result is a more intense competitive atmosphere for international corporations than for domestic corporations (Ustaoğlu & Yıldız, 2011).For the past 40 years, JIT operations have been drawing interest from manufacturing firms in industrialized and developing countries. These manufacturing firms have acknowledged many benefits; Japanese firms' main key to success was claimed to be the JIT systems. As previously mentioned, these systems are also called "Toyota Production System" and are manifest under names such as JIT manufacturing, lean manufacturing, and stockless production (McLachlin, 1997). JIT manufacturing systems were presented as a new production management principle for 21st century production systems (Amasaka, 2000).KakuroAmasaka believed that the key to success of a manufacturing company is a "global production strategy" that allows the supply of leading products with high quality assurance in industrialized and developing countries (Amasaka, 2007).Vosstakes a further step by defining JIT as a disciplined approach to improving overall productivity and eliminating waste. These enable cost effective manufacturing and delivery of quality parts at the right quantity utilizing the least resources(Voss, 1987).

The implementation of new policies under green technologies by many industrialized and developing countries throughout the world enabled sustainable innovations. These innovations played a vital role in the economic and technological development of the automotive industry. Turkey, as a developing country, has adopted these policies and its government enacted a law for registration of EVs. Some car manufacturers in Turkey planned to introduce new EVs models to the Turkish automotive market byend of the 2012(Ustaoğlu & Yıldız, 2012). Although the government offered incentives to EV manufacturers and R&D investments are planned , the number of charging stations and the necessary infrastructure are not at the forecasted level(Deloitte, 2010). Considering these facts, plus the ambiguity of the actual demand of the automobile, JIT management – which allows manufacture by the order quantity – might be much more economical for the EV manufacturers compared to mass production. This paper focuses its investigation on whether JIT management is superior to the conventional EMQ systems for EV production and based on EVs potential market share and governmental subsidies, does JIT production model suit Turkish automanufacturers and meet final consumer expectations?

2. Literature Review And Hypotheses

To endure global competition, large manufacturing companies throughout the world have been promoting global marketing goals to achieve the same quality and production levels at optimal locations. Thus, manufacturing companies require a new strategic management technology to succeed(Amasaka, 2007). The classical economic quantity models (EMQs) aim to find the optimal order quantity. EMQ has become one of the most important inventory management strategies in the manufacturing world since Harris' work (Harris, 1915). The conventional EMQs do not necessarily cover all the relevant holding costs since they are too complex or are sometimes neglected in the model (Wacker, 1986). Inventory holding costs such as depreciation, rent, and housing costs are usually ignored in the inventory costs but they represent up to 40% of the total inventory costs (Heizer & Render, 2001). The EMQ and JIT usually focus on two categories of costs such as running and holding costs (Cao & Schniederjans, 2004). Corbey and Jansen studied the economic lot size and set up costs and claimed utilizing EMQ models might not be the best option since opportunity costs are lost in the calculations (Corbey & Jansen, 1993). Schonberger and Schniederjans stated that opportunity costs, material control costs, and physical storage space costs are usually neglected in the classical economic order quantity models (EOQ) (Schonberger &Schniederjans, 1984). In later research, Voss also claimed that facility space reduction is one of the crucial elements of costs savings and for a successful JIT system (Voss, 1990). Jaber and Bonney stated that it is easier to shift to a JIT system than to the conventional EMQ models, when production rate is much higher than the demand rate or in the case of infinite production (Jaber & Bonney, 1999). Especially when considering the demand is significantly less in comparison to the conventional automobiles (Ustaoğlu & Yıldız, 2012), as Jaber and Bonney suggested JIT production strategy might be a better fit for EV production(Jaber & Bonney, 1999).

3. Methodology and Data Collection

3.1. Research Goal

This paper focuses on determining the most efficient production model and the suitability of JIT production model in order tomaintain profit maximization for the manufacturers and the capability of supply to meet potential demand of the final consumers.

3.2. Data Collection

The statistical data used was collected mainly through internet sources: the Turkish governments' official statistical webpageTurkStat (Basic indicators by sections in industry and service sectors), Turkish Automotive Manufacturers Associations (Total automotive production statistics, Turkish automotive industry total export and total import); The International Organization of Motor Vehicle Manufacturers (worldwide automotive production statistics)(OSD, 2011; Deloitte, 2010; Sanayi Genel Müdürlüğü, 2011; Deloitte, 2011).

3.3. Nomenclature of the EMQ and JIT Models

In order to determine the best production model for EVs manufacturing in Turkey, authors will use the calculations and comparison that Cao and Schniederjans have used in their research (Cao & Schniederjans, 2004).

The notations below are employed in the derivation of the EMQ and JIT models for this paper:

D	annual demand in units of inventory
h	annual inventory holding cost per unit ($/unit/year)
H	average inventory holding cost ($)
k	setup cost for a production-run (an average $ cost per run)
p	production rate (units)
q	JIT lot-size or manufacturing quantity (units)
Q	EMQ lot-size or manufacturing quantity (units)
Q*	optimum EMQ lot-size or manufacturing quantity (units)
u	usage rate (units)
m	ratio of the number of production runs or setups under EMQ by the number under a JIT lot-

size system

TC total annual costs ($/year)

Z cost difference between EMQ and JIT models ($)

PEMQ cost to produce a unit of product using an EMQ lot-sizing system in a finite production ($)

PEOQ cost to produce a unit of product using an EMQ lot-sizing system in an infinite production ($) PJ cost to produce a unit of product using a JIT lot-sizing system ($)

Dind indifference point of demand at which the total costs of comparative EMQ and JIT models is equal (units)

Subscripts

EMQ refers to the EMQ model

J refers to the JIT model

rev refers to the revised EMQ/JIT production model

JP refers to the JIT model product cost

JC refers to the JIT model setup cost

3.3.1 The EMQ Model

The classic EMQ model needs the development of a total annual production cost function (TCEMQ). This function is the sum of the annual costs of run setups, holding costs for produced inventory in stock, and the production costs (Harris, 1915). When these are plugging into a formula:

TCEMQ= Annual setup costs+Annual carrying costs + Annual production costs

This leads to:

$$\mathrm{TC}_{EMQ} = \frac{kD}{Q} + h\frac{(p-u)Q}{2p} + P_{EMQ}D \qquad (1)$$

Onlyrunningcostsandholdingcostsvaryas afunction ofQunitsproduced. Takingt h e derivativeoftherunning costsandholdingcostsintheTC$_{EMQ}$ functionandsettingthederivativeequaltozeroleads u s totheoptimumEMQ (Q):

$$Q^* = \sqrt{\frac{kD(2p)}{h(p-u)}} \qquad (2)$$

Let

$$H = h\frac{(p-u)}{p} \qquad (3)$$

Plugging Equation 2 and 3 into Equation 1:

$$TC_{EMQ} = \sqrt{2kDH} + P_{EMQ}D \quad (4)$$

Eq. 4 is the obtained optimal total production costs function for the EMQ production model.

3.3.2 The JIT Production Model

Fazel, Fischer and Gilbert (1998) explained theJITtotalproduction costfunction astheproductofthecost toproduce aunittimesthenumberofunitsofasingleinventory itemdemandedannually[21].

After formulizing the JIT production, total cost can be denoted as:

$$\mathrm{TC}_{JP} = P_J D \quad (5)$$

Thetotal setup costs(TCJS) can berepresented asaratio of setup times andthecostofthesetup. When formulized, it becomes:

$$\mathrm{TC}_{JS} = \frac{kD}{q} \quad (6)$$

Adding the costs in Eq. 5 and Eq. 6 the total cost for the JIT model becomes;

$$\mathrm{TC}_{J} = P_J D + \frac{kD}{q} \quad (7)$$

It is necessary to mention that thismodelassumes that itispossibleforJITinventory coststoachieveavalueofzero although in practice it is not possible for all JIT products.

Inreality,JITsetupcostsaregreaterthananEMQmodel's setup costsinthatQ>q.This is the case becausethe JIT systemhasahigher setupchangefrequency than theEMQ system.It is simply causedbytheJIT production principleof using morefrequentbutsmallerlot-sizes.The lettermisusedto reflectthiscostfactor whichisadvantageous to thelessfrequentandlargerlot-sizeEMQ system.

Implement*m* into Equation;

$$m = \frac{Q}{q} \; for \;\; m \geq 1 \quad (8)$$

Plugging Eq. 8 into Eq. 7, the total production cost for the JIT model is formulized as:

$$TC_J = P_J D + \frac{mkD}{Q} \qquad (9)$$

3.4 Comparing EMQ and JIT production Model

In order to figure out the level of demand, it needs to use the smaller JIT lot-size system or the larger EMQ lot size system. The indifference point - where EMQ and JIT production model total costs are equal - needs to be determined.

As mentioned in Fazel, Fischer and Gilbert's work (1998), the total cost difference needs to be determined to find out the indifference point. The indifference point is acquired by substracting JIT model costs from EMQ costs (Fazel, Fischer, & Gilbert, 1998). Therefore it can be substractEq (4) from Eq (9) and equalize it to zero. So it can be written as follows:

$$Z = TC_{EMQ} - TC_J = \sqrt{2kDH} - \frac{m}{2}\sqrt{2kDH} + (P_{EOQ} - P_J)D \qquad (10)$$

Equalizing Z to 0;

$$\sqrt{2kDH} - \frac{m}{2}\sqrt{2kDH} + (P_{EOQ} - P_J)D = 0 \qquad (11)$$

Also can be written as;

$$\sqrt{2kDH}\,(1 - \frac{m}{2}) = (P_J - P_{EOQ})D \quad (12)$$

Logically, we assume this to be a positive number. Then, 1– (m/2) also needs to be positive, 1–(m/2)>0. This yields:

$$m < 2 \qquad (13)$$

The Eq (8) and Eq (9) yield:

$$1 \le m < 2 \qquad (14)$$

As Cao and Schniederjans (2004) stated that the EMQ is more cost effective than the JIT production model other than that 'm' is in the interval of 1<m<2 [12]. When m= 2, the Z values are all negative, in other words, EMQ is more cost effective(Cao & Schniederjans, 2004). However, both sides of Eq (12) cannot be positive at the same time, therefore there will not be an indifference point.

$$2kDH(1-\frac{m}{2}) = (P_J - P_{EOQ})^2 D^2 \tag{15}$$

then, for the demand indifference point;

$$D_{ind} = \frac{2kH(1-\frac{m}{2})^2}{(P_J - P_{EOQ})^2} \tag{16}$$

Using the JIT and EMQ production model calculations, this section is dedicated to a case study for manufacturing the EV battery. Using previous research on Electric Vehicle Production and operating costs by Cuenca, Gaines and Vyas (1999), EV battery costs are easily acquired (Cuenca, Gaines, & Vyas, 1999). A typical Pb-Acid type battery costs PEMQ=$2,475, PJ=$2,500. Using the same logic as Fazel, Fischer and Gilbert's (1998), the production cost for JIT model is assumed slightly higher than EMQ models because of the extra, frequent deliveries (Fazel, Fischer, & Gilbert, 1998). Since the EV's battery one is the latest technologies, the related data required for study is not easily accessible or available. Because the size and manufacturing techniques are similar, the holding setup costs are obtained from the studies on the lead acid-based battery. According to the study done by Elimam and Udayabhanu (2011), the setup cost for battery is k=$4870, and inventory holding cost is H=$15,269 (Elimam & Udayabhanu, 2011).

Table 1 EV Component Costs for Original Equipment Manufacturer

EV Component	Pb-Acid	Ni-MH
Motor	445	445
Controller	1040	1040
Gear Drive	225	225
Air-conditioning drive	75	75
Total EV drive components	1785	1785
Components common with CV	5005	5005
Total cost excluding battery	6790	6790
Battery cost	2475	2475
Total cost	9265	10915

Source: R.M Cuenca, L.L Gaines, and A.D Vyas, 2011

According to study of Cao and Schiederjans (2004) when m=1, JIT models are most likely more cost effective than EMQ models for the given demand. Whereas when m> 2, EMQ models are most likely more cost effective than JIT models (Cao & Schniederjans, 2004).

For the EV battery production case, two m points are chosen: m = 1, m = 1.5.

When the values are plugged in Eq (16);

Dind=

For m =1 and m =1.5, Eq (16) yields indifference points at 29,744 and 7436 units, respectively. These values support the interpretation for JIT production to be more cost effective than EMQ for 1 where the annual demand is less than 29,744 units at m = 1 and 7436 units at m = 1.5.

Conclusion

Increasing the market share of an innovative product depends on consumer demand and manufacturing costs. These costs play a significant role for manufacturers when determining the optimal production model for a product. In particular, in markets such as the automotive industry, the production models change rapidly. In the global world we live in, the greenhouse effect, high waste, high fixed costs, and the global crisis push manufacturing companies to adopt new production models. The JIT production model is one of the most cost effective models, especially in the cases of low consumer demand. Although EMQ models are still very useful for the high volume productions, manufacturers gradually adopt JIT systems that yield less sink costs and provide extra warehouse savings. In this study, the authors used the comparison of previous work and implemented it on a case scenario for EV batteries manufacturing in Turkey. Since the current production level for EVs in 2012 is announced as 30,000 units, this paper studied the most cost effective solutions for EVs battery production (Sayın & Yüksel, 2011). The calculations on the given EMQ/JIT comparison formulas resulted in that JIT systems are more cost effective than the EMQ model when the demand is lower than approximately 30,000 units - where the ratio of production runs under EMQ lot-sizing system by the number under JIT lot-size system m = 1.

Furthermore, when m = 1.5, JIT systems are more cost effective than EMQ model when the demand is lower than approximately 7500 units. Since EV is a relatively new technology for the Turkish automotive market, the expected demand is still at a low figure. Considering the announced production numbers, JIT production models for EV battery production are very favorable under the given demand rates.

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