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Study of a Manufacturing System with Transport Activities in Urban Area

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Abstract: This paper study a manufacturing system composed of a machine, a purchase warehouse, a vehicle and customers that demand a random quantity of products. For transporting the products from the warehouse to the customer in urban area, two cases are considered: in the first case the transport is performed by an electric vehicle and the second case by a petrol vehicle. The objective of this paper is to provide a decision aid to the manufacturer to choose the suitable transport vehicle type according to different costs of the manufacturing system. To describe both cases, a discrete flow model is adopted that takes into account the machine and vehicle failures, carbon penalty and maintenances actions. Both cases of the transport are simulated and numerical results are presented to compare the totals costs and then to provide an aid decision for the manufacturer.

Keywords: Manufacturing system, discrete flow model, decision aid, electric vehicle.

1. INTRODUCTION

In last few years, due to the environmental legislations pressure, many governments impose a carbon tax for the petrol vehicles and sometime they impose an additional tax for the vehicles that circulate in the urban area. Hence, many transporters or manufacturers are thinking to use electric vehicles for transporting the products in the urban area in order to avoiding paying the carbon tax. However, the electric vehicles are not reliable as the petrol vehicle that has an impact on the performance of the manufacturing system (Tolio (2005)). Realising the importance of transport, Swihart and Papastavrou (1999) developed a stochastic and dynamic model for the pick-up and delivery problem. They considered the unit-capacity vehicle and multiple-capacity vehicle variations; they use vehicle formulations in which customers can only be dropped off at their desired destinations. Dolgui and Ould-Louly (2002) presented a model for supply planning under lead time uncertainty. The authors take account the item holding costs and the lost sale costs. Van Ryzin et al. (1991) considered the impact of the transport for optimal flow control of job shops in order to minimize the discount and infinite-horizon average cost. Turki et al. (2013) studied a manufacturing system with delivery activities, the authors considered the machine failures and the delivery time of the vehicle. However, these works don't consider the vehicle failures and its availability that probably cause delays for satisfying the demands.

In this paper, we study a manufacturing system that operates two cases of transport vehicles: electric vehicle and petrol vehicle. The vehicles repairs and there availability are considered. Also, we take into account to the carbon tax cost in the case of the petrol vehicle. Another characteristic of the transport vehicle will be considered in this work that is the maintenance actions (Hajej et al., (2009), Ayed et al., (2012); Hajej et al., (2015)). For modelling both cases, we will use discrete flow model which is the most realistic.

Discrete flow model (Mourani et al. (2007), Turki et al. (2012)) is widely used for design, optimal control and optimisation of supply chain systems. It is considered as an alternative paradigm to queuing network for analysis and synthesis of discrete event systems. This model is the most realistic for discrete supply chain systems the fact it allows tracking individual parts part by part either in performance evaluation or real-time flow control and is generally easier to simulate. For the simulation, we will use simulation based discrete event system.

Thus, the contribution of this paper is to provide an aid decision system that allows to the manufacturer to take decision for using petrol or electric vehicle according to the different costs (the maintenance cost, transport cost, carbon penalty cost etc.).

The paper is organized as follows. We present the manufacturing system with transport activities in urban area in section 2. In section 3 we will provide the aid decision system with the numerical results. Finally, the last section concludes the paper and gives some perspectives to our work.

2. MANUFACTURING SYSTEM WITH TRANSPORT ACTIVITIES IN URBAN AREA

In this paper, we study a manufacturing system (see Fig.1) composed of a machine M, a purchase warehouse W, a vehicle V and customers that demand a random quantity of

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products $d(t)$. The demand is satisfied from W and transported by the vehicle V to the customers that are located in an urban area. The machine M and the vehicle V are subject to random failures and repairs. When the demand is unsatisfied, the demand is lost. We assume also that when the vehicle is down, the quantity of products that will be transported does not leave the warehouse and is supposed as unsatisfied demand (lost).

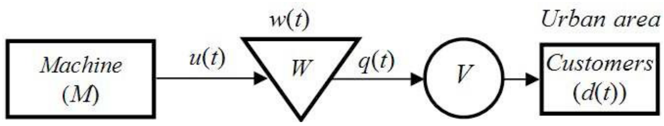

Fig. 1. Manufacturing system with transport activities in urban areas.

The machine M is assumed that is never starved. The machine M is either down or up. The state of the machine at time t, denoted $\alpha(t)$, is given by:

$$\alpha(t)=\begin{cases}1 & \text{If the machine } M \text{ is up}\\ 0 & \text{If the machine } M \text{ is down}\end{cases} \quad (1)$$

When the machine is up, the production rate of M, denoted by $u(t)$, could take a value between 0 and its maximum rate U, i.e., $0 \le u(t) \le U$. When the machine is down $u(t)=0$. The times to failure and times to repair are random. The failure/repair process is an independent random process. It does not depend on the system parameters.

The state of the vehicle V at time t, denoted $\beta(t)$, is given by:

$$\beta(t)=\begin{cases}1 & \text{If the vehicle is up}\\ 0 & \text{If the vehicle is down}\end{cases} \quad (2)$$

In what follows we present the assumptions:

- If the demand is unsatisfied, the demand is lost with a corresponding cost (lost sales cost).
- For building the warehouse W and for avoiding to have always unsatisfied demands, we assume that the maximal production rate permits to satisfy the demand, i.e. $U \ge d(t)\ \forall\, t$.
- At time $t = 0$, we suppose that we have enough parts in the buffer to satisfy the first demand, i.e. $x(0) \ge d(0)$.
- When the vehicle is down, the quantity of products that will be transported does not leave the warehouse and is supposed as unsatisfied quantity (lost demand).
- The capacity of the warehouse W is limited.

Let $[0,T]$ be the finite horizon and which is discretised to n period denoted by Δt. This period is the simulation time step, thus the total simulation time $T = n.\ \Delta t$.

We denote by $w(t)$ the warehouse inventory level which is replenished by the machine ($u(t)$) and satisfies the demand. Thus, the purchase warehouse level $w(t)$ is described by the following equation:

$$w(t)=w(t-\Delta t)+u(t-\Delta t)-z(t) \quad (3)$$

With $z(t)$ is the number of products outgoing from the warehouse at time t and which corresponds to the number of products that will be satisfied. $z(t)$ is described by the following equation:

$$z(t)=\begin{cases}d(t) & \text{if } w(t-\Delta t)\ge d(t)\\ 0 & \text{if } w(t-\Delta t)=0\\ w(t-\Delta t) & \text{if } w(t-\Delta t)<d(t)\end{cases} \quad (4)$$

To control the production, we use the hedging point policy which has been proved to be the optimal for a one-product manufacturing system (Akella and Kummar (1986), Turki and Rezg (2015)). Indeed, the hedging point policy ensures that the part does not exceed a given number of products that is the capacity of the warehouse and which denoted by h.

The control policy is defined as follows:

$$u(t)=\begin{cases}d(t) & \text{if } \alpha(\mathrm{t})=1 \text{ and } w(t)=h\\ 0 & \text{if } \alpha(\mathrm{t})=0 \text{ or } w(t)>h\\ U & \text{if } \alpha(\mathrm{t})=1 \text{ and } w(t)<h\end{cases} \quad (5)$$

We denote by $l(t)$ the number of unsatisfied demands that depends on the demand $d(t)$ and the warehouse inventory level $w(t)$. Indeed, the number of unsatisfied demands is the difference between the demand and the number of products outgoing from the warehouse. Hence, the number of unsatisfied demands is defined as follows:

$$l(t)=d(t)-z(t) \quad (6)$$

In what follows we present the both cases of the cost function.

2.1 Cost function in the case that the transport is performed by an electric vehicle.

In this part we will present the cost function that describes the manufacturing system with an electric vehicle. In this case, we denote the variable $\beta(t)$ by $\beta_e(t)$ and which corresponds to the state of the electric vehicle at time t :