

Assignment 1 – Written Report (ACPA7004)

Introduction to Industry 4.0

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Abstract

The Royal Mint (TRM) have recently had a number of incidents with fork lift trucks (FLT's) and powered hand trucks (PHTs) within the main production hall. As a result, alternatives to worker operated machines are to be investigated.

Suggested implementation framework for industry 4.0 technologies is outlined in the report using a system developed by Neumann et al (2020).

Automated guided vehicles (AGVs) are a materials handling system used in a large number of industries. This report will highlight types of AGVs available to TRM, along with navigation technologies used and potential layouts.

Quantitative analysis is completed using mathematical equations, which have been developed to describe the operation of vehicle-based material transport systems. All assumptions made in the calculations have been stated.

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1.0 Introduction

1.1 The Royal Mint

The Royal Mint (TRM) is a Limited Company, wholly owned by Her Majesty's Treasury. It holds the exclusive contract to supply the UK's coinage. The Royal Mint also exports to an average of 60 countries a year, making up 70% of its total sales.

Recently, there have been a number of incidents involving fork lift trucks (FLT's) and powered hand trucks (PHT's) whilst moving bulk containers of coins and blanks. To determine whether a better method of moving blanks and coins around the production hall, TRM have requested a technical report on all available alternative options.

1.2 Industry 4.0

The fourth industrial revolution (Industry 4.0), as described by Posada et al (2015) is a collective term for a number of technologies from value chain organisations, with components of industry 4.0 categorised as:

- The Internet of Things
- Cyber Physical Systems
- Internet of Services and
- Smart Factories

The concept of industry 4.0 focuses on a way of production where everything works in interaction, with the products and the machines, linked in a network itself connected to the all supply chain using high performance devices, resulting in an interconnected global system (Tjahjono, 2017).

Hedelind and Jackson (2011) claim the use of autonomous robots have accelerated with the emergence of industry 4.0 technologies, this is largely attributed to organisations having the new ability to implement smart, just-in-time (JIT) and continuous improvement strategies.

2.0 Aims and objectives

2.1 Aims

To determine the most suitable transportation method for moving coins and blanks in and around production areas. The materials handling system selected should be able to move bulk containers (up to 800kg) to the correct process at the right time automatically. The power source should be a rechargeable battery, as it is to be used indoors, making diesel unsuitable. The selected materials handling system should be capable of completing forty (40) deliveries per hour.

2.2 Objectives

- Investigate all (alternative to FLT's and PHT's) available methods to transport bulk containers of blanks and coins around the production area.
- Price is not to be included in the report. This is to be considered at a later stage

3.0 Implementation methodologies

3.1 Method

Frank et al (2019) and Neumann et al (2020), both write of the lack of understanding businesses have when implementing industry 4.0 technologies. TRM has been a slow adopter of these newer technologies, implementation of industry 4.0 would therefore be challenging.

Following research, Neumann et al (2020) suggested a systematic framework to follow in the form of a single A4 worksheet (Figure 1).

← macro-perspective		micro-perspective →				
Step 1: Technology identification Industry 4.0 element under consideration: Characteristics: Objective:						
Step 2: Affected Humans Stakeholder	Step 3: Task scenarios Role change:		Step 4: Human impacts of the task changes			
	Work added	Work removed	Perceptual	Cognitive	Knowledge	Physical
1)						
			Step 5: Outcome Analysis			
	Economic/financial impacts		Human effects			
			System Performance			
2)	Role change:					
			Step 5: Outcome Analysis			
	Economic/financial impacts		Human effects			
3)						
	Economic/financial impacts		Human effects			
			System Performance			
4)	Role change:					
			Step 5: Outcome Analysis			
	Economic/financial impacts		Human effects			
			System Performance			

Figure 1 - Framework worksheet for implementation of industry 4.0 technologies (Neumann et al, 2021)

4.0 Background Research

Automated guided vehicles (AGVs) are a materials handling system that use independently operated, self-propelled vehicles guided along defined pathways (Aized, 2010). A distinguishing feature of an AGVS, compared to rail-guided vehicle systems and most conveyor systems, is that the pathways are unobtrusive. For this reason, these material handling methods were not considered.

4.1 Types of AGV

There are many types of AGV available. The main parts of an AGV include structure, steering mechanism, drive system, battery and on-board computer for control.

4.1.1 Driverless Automated Guided Train

This is a type of towing vehicle that will pull one or more trailers to form a train (see Figure 2). The typical application for this vehicle is moving large payloads over long distances, without the requirement to stop on route. The driverless train was the first AGV to be introduced to industry (Patil, 2020)

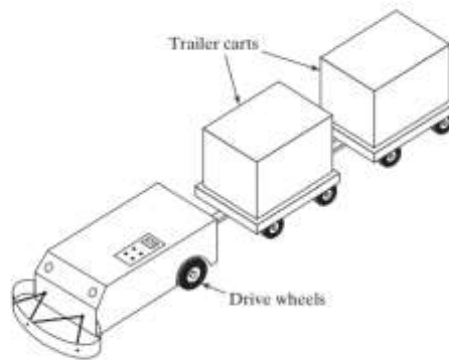


Figure 2 - Driverless automated guided train

4.1.2 AGV pallet truck

The primary use of this type of AGV is to move palletized loads along predetermined routes. The machine requires human interaction to guide the pallet onto the forks and raises above the floor. The computer then requires an input to program the next destination. The load capacity for the AGV pallet truck can be several tonnes (Patil, 2018).

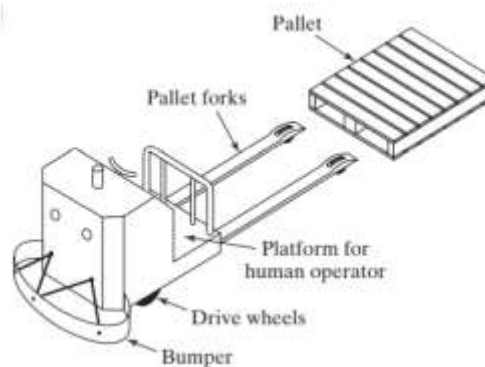


Figure 3 - AGV pallet truck

4.1.3 Fork Lift AGV

Much like the AGV pallet truck, this automated version of an FLT designed primarily for moving pallets. The advantage this vehicle has over the AGV pallet truck is it has significant vertical movement, ideal for removing items from high racking (Seelinger & John-David, 2006).

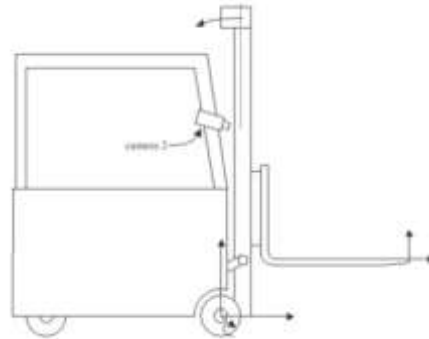


Figure 4 - AGV fork lift truck

4.1.4 Unit load carrier

Unit load carriers are typically used for carrying loads between processing stations. This type of vehicle is able to both load and unload materials automatically. Many variations of this unit are available, including light load, assembly line AGVs and heavy duty AGVs. The heavy duty units are used in large industries such as cargo/ logistic (shipping), steel works and printing (Aized, 2010)

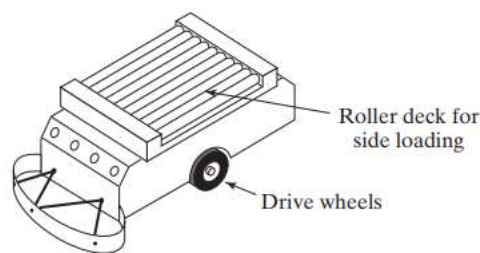


Figure 5 - Unit load carrier

4.2 Vehicle Guidance Technologies

The guidance system is the method by which AGVs pathways are defined and vehicles are controlled to follow the pathways. In some cases however, vehicles are self-guided (SGV).

4.2.1 Imbedded Guide Wires

This guidance system requires electrical wires to be installed in small channels just below the surface of the floor. Le-Anh and De Koster (2005) explain the wire is connected to a frequency generator which emits a low-voltage, low-current signal. In turn, this induces a magnetic field along the pathway that can be followed using a sensor on-board the AGV.

4.2.2 Magnetic Strips

Magnetic tape can be applied directly onto the factory floor, allowing the physical guide path of the AGV to be defined. Inside of the unit, is a sensor that can detect a magnetic field, similar to the previous mentioned guidance technique.

4.2.3 Paint Strips

Paint can be used to define a pathway. The paint may be taped, sprayed or painted directly onto the floor. The vehicle uses an optical sensor system capable of tracking the paint. Paint strip guidance is useful in environments where electrical noise renders the guide wire system unreliable, or when the installation of guide wires in the floor surface is not practical.

4.2.4 Laser Guided Vehicles (LGVs)

Unlike the previous mentioned systems, LGVs can operate without defined pathways. Laser guided system uses a rotating laser mounted on top of the AGV and use a combination of dead reckoning and reflective beacons located within the area. Dead reckoning is the process of calculating current position by using a previously determined position (Ullrich, 2015).

4.2.5 Global Positioning System (GPS)

Just like with automobiles, satellites are used to determine the position of the GPS receiver. One limitation of this technology within a manufacturing environment is clear line of site to the sky is required.

4.3 AGV Layouts

A typical AGVS layout contains multiple loops, branches, side tracks, maintenance areas, as well as pick-up and drop-off stations. It is possible to implement all of the below within one large manufacturing area.

4.3.1 Unidirectional

This layout is used where vehicle flow is constrained to only travel in one direction. Ko and Egbelu (2010) claim the distance travelled in this system may be greater than if the AGV moved point to point. The complexity of this layout is low.

4.3.2 Bidirectional

In this more complex system, vehicle flow occurs in two directions. This reduces the travelling distance and time for each AGV significantly when compared to unidirectional.

4.3.3 Single Loop

As the name suggests, the system layout occurs in one loop, eliminating any other alternative or branched routes. Single-loop flow paths are important material handling systems with many advantages, including simplicity, flexibility, low initial investment, and low expansion costs (Ahmadi - Javid and Ardostani – Jaafari, 2021).

4.4 Analysis of AGV Systems

One of the main tools for displaying and analysing data in materials handling systems are network diagrams. A network diagram consists of nodes and arrows. In material handling, the nodes represent locations (e.g. load and unload stations), and the arrows represent material flow and/or distances between the stations.

Mathematical equations can be developed to describe the operation of vehicle-based material transport systems.

4.4.1 Network Diagram for Production Hall

The following network diagram was created in a loop layout of the production hall at TRM.

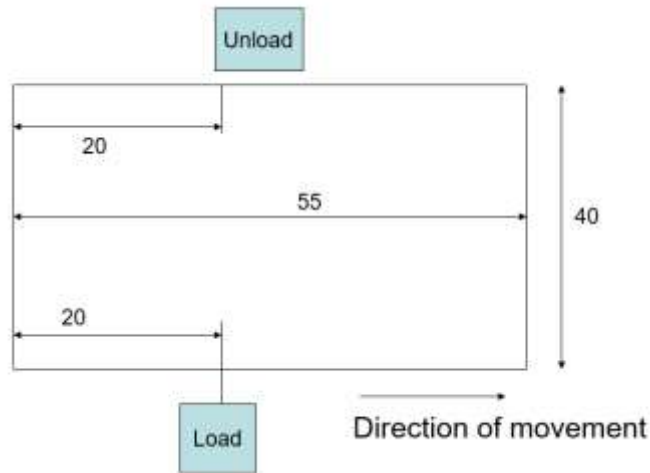


Figure 6 - Network diagram for TRM production hall

4.4.2 Delivery Cycle Time

The time for a typical delivery cycle in the operation of a vehicle-based transport system consists of

- Loading at the pick-up station (T_l)
- Travel time (loaded) to drop-off station (L_d)
- Unloading at the drop-off station (T_u)
- Empty travel time of the vehicle between deliveries (L_e)
- Carrier velocity (V_c)

The total cycle time per delivery per vehicle can be given by:

$$T_c = T_l + \frac{L_d}{V_c} + T_u + \frac{L_e}{V_c}$$

Assuming:

- The vehicle travels at a constant velocity = 50m/ min
- Loading time at load station = 0.75 min
- Unloading time at the unload station = 0.50 min

$$T_c = 0.75 + \frac{110}{50} + 0.5 + \frac{80}{50}$$

$$T_c = 5.05 \text{ minutes}$$

4.1.1 Workload (WL)

Workload can be expressed as:

$$WL = R_f T_c$$

Where R_f is the required deliveries per hour (40):

$$WL = 40 * 5.05$$

$$WL = 202 \text{ min/ hour}$$

4.1.2 Available time per hour (AT)

Where:

- E_w symbolises the worker efficiency (when worker is required, if not $E_w = 1$)
- A is availability (other assets within TRM E_w operate at 0.95)
- F_t is used for traffic factors (unknown, so 0.90 estimated)

$$AT = 60AF_tE_w$$

$$AT = 60 * 0.5 * 0.95 * 1$$

$$AT = 51.3 \text{ mins/hour per vehicle}$$

4.1.1 Number of AGVs Required

To determine the number of vehicles required to make forty (40) deliveries per hour (R_f), we compute the workload of the AGVs and the available time per hour per vehicle.

$$Nc = \frac{WL}{AT}$$

$$Nc = \frac{202}{51.3}$$

$$Nc = 3.94 \text{ vehicles.}$$

$\therefore$ 4 vehicles are required

5.0 Conclusion

- All above mentioned AGVs are suitable for The Royal Mint's application
- From quantitative analysis completed, 4 vehicles are required to fulfil forty (40) deliveries per hour
- Magnetic strips and paint are cheapest navigation systems to implement
- LGV are the most flexible option, as they do not require pre-determined guide paths
- A4 worksheet in Figure 1 to be completed to ensure smooth implementation
- Loop layout is advantageous

6.0 References

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