Optimization of logistic concepts in Bangladesh by using Automated Guided Vehicle (AGV) to enhance efficiency, productivity and security in Warehouse Management System (WMS)

by

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List of acronyms

AGV	-	Automated Guided Vehicles
WMS	-	Warehouse Management System
LFR	-	Line Follower Robot
ERP	-	Enterprise Resource Planning
ROI	-	Return on Investment
LGV	-	Laser Guided Vehicle
FTS	-	Fahrerlose Transport systeme
AGC	-	Automated Guided Carts
UV	-	Ultraviolet
gGmbH	-	Die gemeinnützige GmbH (*gGmbH*)
Wifi	-	Wireless Fidelity
MSMEs	-	The Micro- Small and Medium Enterprises
3PL	-	Third-party logistics
FMCG	-	Fast-moving consumer goods
CNF	-	Clearing and Forwarding
HACCP	-	Hazard Analysis And Critical Control Points
RMG	-	Ready Made Garments
IP	-	Internet Protocol
CAD	-	Computer-Aided Design
AC	-	Alternating Current
DC	-	Direct Current
RPM	-	Revolutions Per Minute
PVC	-	Polyvinyl Chloride
LiPo	-	Lithium Polymer batteries
IR Sensor	-	Infrared Sensor
LED	-	Light Emitting Diode
MOSFET	-	Metal Oxide Semiconductor Field-Effect Transistor
UART	-	Universal Asynchronous Receiver-Transmitter
PWM	-	Pulse Width Modulation
VIN	-	The input voltage
GND	-	Ground pins

VRP	-	Vehicle Routing Problems
VRPTW	-	Vehicle Routing Problem with Time Windows
PDPTW	-	Pick-up and Delivery Problem with Time Windows
AGVS	-	Automated Guided Vehicle System
MRP	-	Material Requirements Planning
WIP	-	Work In Process
FIFO	-	Fast In Fast Out
OSHA	-	Occupational Safety and Health Administration

Abstract

In the recent time, the automated guided vehicles (AGV) are becoming more common sights in the manufacturing industries and the large warehouses for the purposes of logistic supports and in many other aspects. But in case of third world developing countries like Bangladesh, the idea of implementing of the automation technologies like Automated Guided Vehicle (AGV) is not so much popular among the investors due to high initial setup cost, low human labor cost and some other facts. In this paper, we are trying to build up a model i.e. a line follower robot (LFR) with a carrier at its top which is following both straight and curly paths having some obstacles, carrying specific amount of loads and unloading them in specified position in the laboratory. Hence by performing this experiment for several times we are trying to prove to enhance the efficiency, productivity and security in the warehouse management system. We are trying to use local raw materials and available technologies to construct an automated guided vehicle (AGV) locally and hence are trying to reduce the initial setup cost to encourage the investors for setting up the automated guided vehicle system for improved productivity, security and efficiency in the manufacturing industries especially in warehouse management system (WMS) in Bangladesh.

Chapter – 1: Introduction

1.1 Basic Definitions

1.1.1 Productivity

A measure of the efficiency of a person, machine, factory, system, etc., in converting inputs into useful outputs. Productivity is computed by dividing average output per period by the total costs incurred or resources (capital, energy, material, personnel) consumed in that period. Productivity is a critical determinant of cost efficiency.

1.1.2 Efficiency

The comparison of what is actually produced or performed with what can be achieved with the same consumption of resources (money, time, labor, etc.). It is an important factor in determination of productivity.

1.1.3 Safety

The quality or state of being secure from danger.

1.1.4 Warehouse Management System (WMS)

It is a software application that supports the day-to-day operations in a warehouse. WMS programs enable centralized management of tasks such as tracking inventory levels and stock locations. WMS systems may be standalone applications or part of an Enterprise Resource Planning (ERP) system.

This is modern method of managing the warehouse operations and this is how escalates the process of logistics handling:

1) Maximum Functionality
2) Ease of Use
3) Complete Transaction Management
4) Flexibility
5) Useful, Easy-to-read Metrics
6) Seamless ERP Integration

7) Proven Track Record

8) Value for ROI

9) Commitment to Warehousing and Logistics

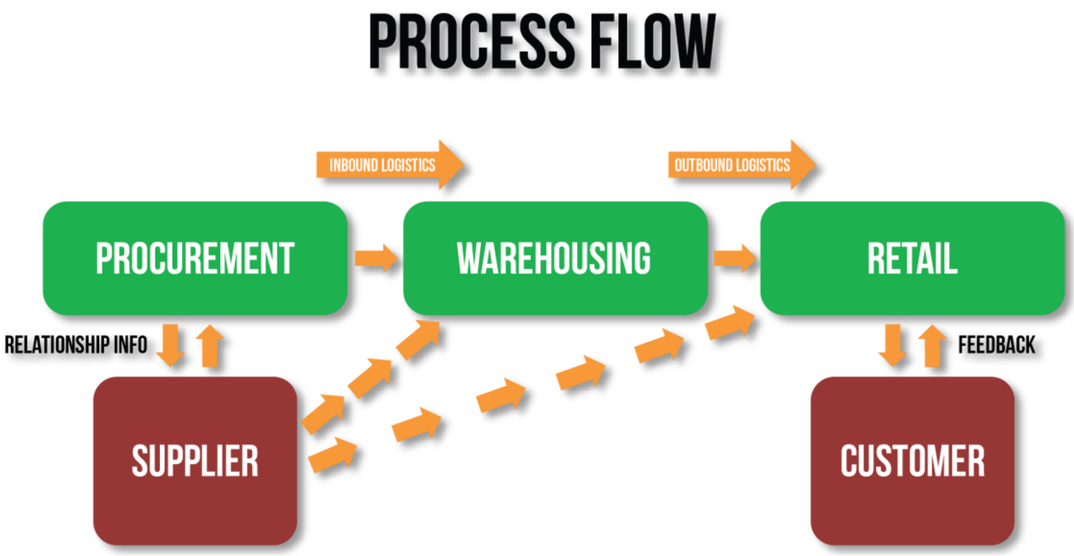

Figure 1 : Position of warehouse in the process of logistics operation

1.2 Automated Guided Vehicle

A mobile robot that follows markers or wires in the floor, or uses vision, magnets, or lasers for navigation. This uses an energy neutral system with low carbon emission, as it can operate without air conditioning and lighting.

The AGV can tow objects behind them in trailers to which they can autonomously attach. The trailers can be used to move raw materials or finished product. The AGV can also store objects on a bed. The objects can be placed on a set of motorized rollers (conveyor) and then pushed off by reversing them. AGVs are employed in nearly every industry, including pulp, paper, metals, newspaper, and general manufacturing. Transporting materials such as food, linen or medicine in hospitals is also done.

Figure 2 : AGV Bot manufactured by the company - GreyOrange

An AGV can also be called a laser guided vehicle (LGV). In Germany the technology is also called- Fahrerlose Transportsysteme (FTS) and in Sweden förarlösa truckar. Lower cost versions of AGVs are often called Automated Guided Carts (AGCs) and are usually guided by magnetic tape. AGCs are available in a variety of models and can be used to move products on an assembly line, transport goods throughout a plant or warehouse, and deliver loads.

The first AGV was brought to market in the 1950s, by Barrett Electronics of Northbrook, Illinois, and at the time it was simply a tow truck that followed a wire in the floor instead of a rail. Out of this technology came a new type of AGV, which follows invisible UV markers on the floor instead of being towed by a chain. The first such system was deployed at the Willis Tower (formerly Sears Tower) in Chicago, Illinois to deliver mail throughout its offices.

1.3 Background and present state of the problem:

Almost the entire logistic operation in Bangladesh is carried out by human labor. This results in prolonged worktime and lack of efficiency. In the global context, integration of automation has reached the warehouse management system far back, but Bangladesh is lagged behind in this very sector. The reputation of Bangladesh is coined as “Time-lagger” when it comes to delivery of commodities and the prime reason behind this being- lack of automation and skilled methodology of operation in the fullest extent.

This study will show the various aspects of Automated guided vehicles and their scope of implementation in the context of Bangladesh.

1.4 Objectives with specific aims:

- Evaluate current warehousing facilities in Warehouse Management System.
- Identifying how AGVs can enhance key performance in terms of overall
    - **Productivity**
    - **Efficiency**
    - **Security**
- Evaluate the scopes of implementation in Bangladesh

1.5 Methodology

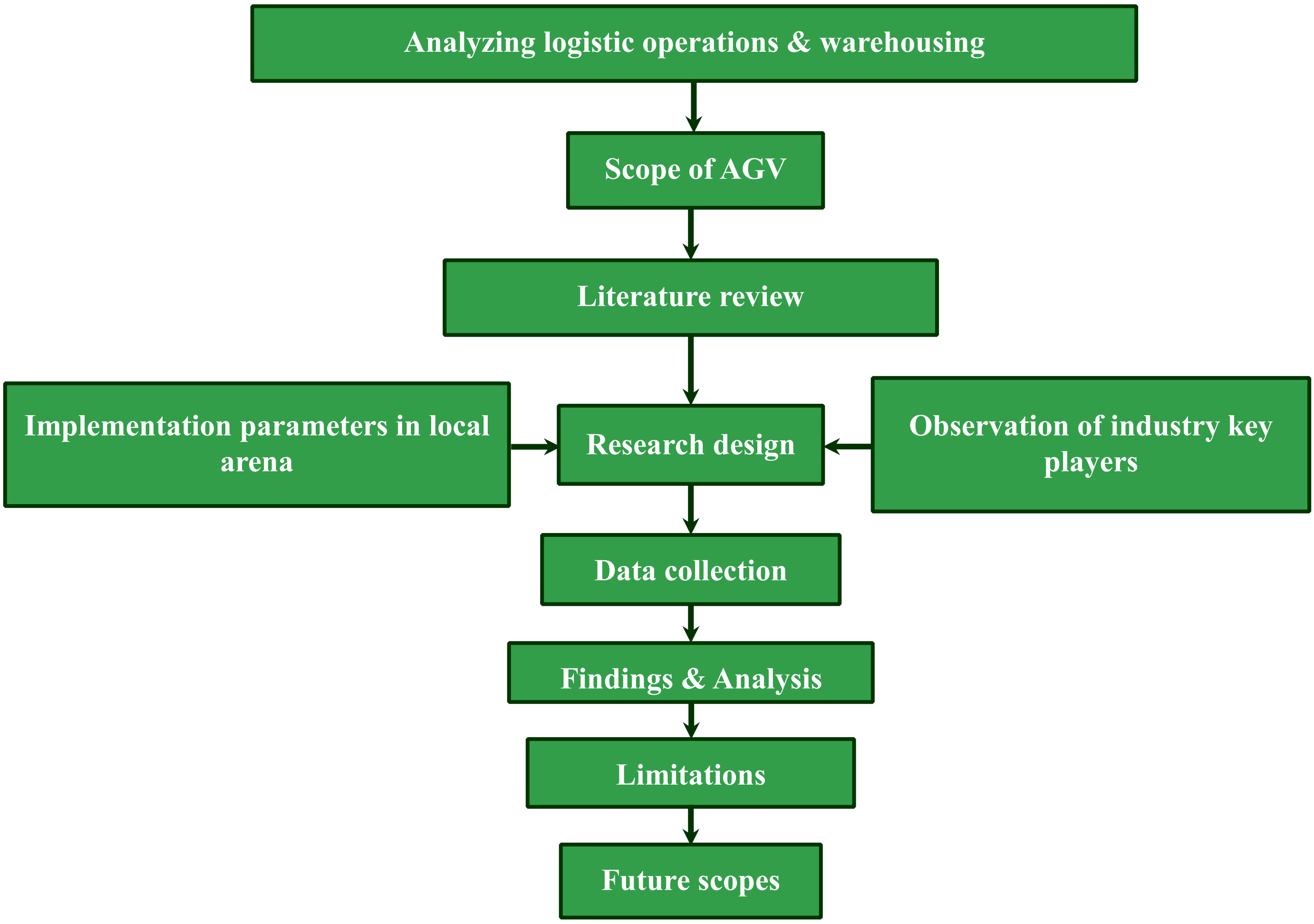

Figure 3 : Methodology followed to perform the research

The entire industry of logistics operation and warehousing was properly screened and upon analysis, we developed the scope of AGV implementation in the context of Bangladesh. This was done keeping live monitoring of the existing conditions of the respective warehouses. Related literature review were then Sought-after to the selected area of study to obtain a theoretical base for the research and help determine the nature of the research. The research design was then formulated keeping the implementation scopes open in the local arena as mentioned before. The decision mentality of the industry key players was also taken into consideration. The research design put forwarded the data accumulated from case study helped to reach some findings and upon analyzing them, the limitations and future scopes were provided.

1.6 Organization of this thesis:

This study comprises of four chapters. Chapter – 1 gives a brief overview of the background and the concept of the study. Finally, significance of the research and the objectives of this study are summarized. It also dictates the detailed process of methodology followed in the course of this study. This chapter also outlines the organization of the discussion.

A comprehensive literature review is given in the Chapter – 2, which is briefly categorized into two sections. The first one deals with the hospital management industry citing examples of two modern hospitals of the developed world. The second category deals with the warehouse management of E-commerce platforms. The examples of two major key players of the developed world have been cited in this section.

Chapter 3 describes the outline of the research design and includes discussion on all of its aspects in details. This highlights the attempts of collecting industry insights, chalking out ideal design of the prototype and necessary modifications to develop the functioning prototype. This chapter also includes the design considerations of an AGV and primary conditions on the selection of the best AGV for a particular plant.

Chapter 4 focuses on the analytics and core findings from the data collected in Chapter 3. The discussion in briefly categorized into four major criteria – Finance, Productivity, Efficiency and Security. Relevant examples and analysis have been included respectively.

The conclusions and summary of the contributions have been mentioned in Chapter – 5. In addition, directions for future scopes related to this study are also presented.

Chapter: 2 – Literature review

2.1 Hospital management industry

2.1.1 The Augusta-Kranken-Anstalt (AKA) Hospital in Bochum, Germany

This is set up as a gGmbH (charitable limited company) and is led by the protestant foundation Augusta headquartered in Bochum. While seeking for cost saving potential, the hospital came across material management and logistics processes.

The company started implementing AGV in their operations with 10 vehicles and 46 stations covering an approximate of 1100m and they have found that, their cost for internal logistics processing have reduced drastically. Not only that, they have a transparency and control of their delivery status which insures just in time delivery of material. Using AGVs for product handling have increased their staff productivity by 60% and also their storage capacity by 20%.

During the project phase, the highly complex and personal-intensive transport processes were analyzed and comparison between actual and future logistic solutions was submitted. A positive side eff ect was that all process participants (hospitals, material administration, consulting and services) had to analyze their logistic processes, material flow and transport quantities in detail. The result was an optimized, tightened, and improved material transport flow.

Figure 4 : AGV Bots implemented in AKA Hospital in Bochum, Germany

2.1.2 University Medical Center Hamburg-Eppendorf (UKE)

They consist of 14 centers and brings together more than 80 clinics, hospitals, and medical institutes, therefore benefiting from the interdisciplinary cooperation within the UKE. With 1248 beds and 165 beds in the University Heart Center Hamburg GmbH, the University Medical Center Hamburg-Eppendorf is one of the largest hospitals in Hamburg.

The AGV system consists of 33 vehicles covering track length of 2100m having 91 stations taking over the automated transportation of meal, laundry, waste, pharmaceutical, and sterile containers at UKE in Hamburg-Eppendorf , safely transporting goods to their respective destinations – 16 hours a day, seven days a week..

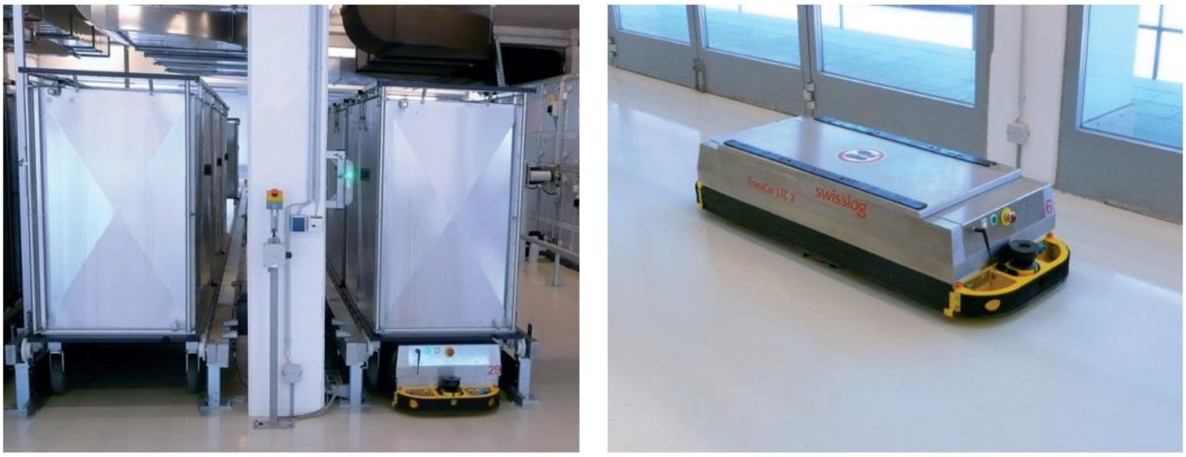

Figure 5 : AGV Bots implemented in UKE

Thanks to the resulting flexibility, even transportations at peak hours run smoothly. Moreover, changes in routes and schedules can be realized at any time via the software control using the laser technology, therefore providing an ever-increasing flexibility of the system. There are no transport delays thanks to the separate logistic infrastructure, as the routes for the transport of goods do not cross with the routes for patients and patients' transports, visitors, or employees. The vehicles are guided by a laser scanner along so-called points of references of the buildings.

Summarizing this, we see that transparency and control of delivery status has improved. Higher quality through reliable delivery processes resulting into Just-in-time delivery of goods can be ensured.

2.2 Warehouse management of E-commerce platforms

2.2.1 Alibaba's Smart Warehouse

Alibaba is the world's largest and most valuable retailer as of April 2016. Occupying 3,000 square metres (0.7 acres), the warehouse is situated in Huiyang, south China's Guangdong Province, and is owned by T-mall. The automated delivery boys started working at the warehouse in July, and have helped the warehouse increase its output by threefold, according to Quicktron, the manufacturer of the robots. The machine has been named Zhu Que, or the Vermilion Bird, which is a spirit creature in the Chinese mythology.

Figure 6 : AGV of Alibaba Smart Warehouse

The robots receive instructions via Wifi signals. They would then find the goods and move them to the designated drop-off points for human workers to pick up. Each of the machines is fitted with laser detection which prevents them from bumping into each other.

Traditionally, a worker could sort 1,500 products during a 7.5-hour shift after taking 27,924 steps; with the help of Zhu Que, the same worker could sort 3,000 products during the same period of time and only 2,563 steps need to be taken.

2.2.2 Warehouse of Flipkart

Flipkart is India's largest e-commerce marketplace with over with over 60% market share of mobile commerce. With a registered customer base of 75 million, Flipkart offers more than 40 million+ products across 80+ categories including Smart Phones, Books, Media, Consumer Electronics, Furniture, Fashion and Lifestyle. Launched in October 2007, Flipkart is known for its path-breaking services like Cash on Delivery, experience zones and a 30-day replacement policy. Flipkart is a pioneer in services such as 'In-a-Day Guarantee' (across 50 cities) and 'Same-Day-Guarantee' (across 13 cities) at scale. With over 85,000 registered sellers, Flipkart has redefined the way brands and MSMEs do business online.

Flipkart was also looking at improving its processes to handle the strong demand surge during festive seasons to provide best experience to their end-customers. Manual sortation of thousands of packets for hundreds of pin codes in a few hours, while operating within the limited space in its warehouses and transit centers was leading to costly inefficiencies. Further Flipkart partnered with a large number of third-party logistics (3PL) vendors for last mile delivery across India, who would charge for each shipment based on manually approximated packet weight and dimensions. This meant potential revenue loss for Flipkart due to lack of accurate data.

Flipkart partnered with GreyOrange to leverage next-gen robotic solutions for automating their fulfilment center and transport centers and to resolve the challenges it faced with order sorting, routing and inaccurate billing for shipments by vendors.

GreyOrange installed two double decks and five single deck sorters of capacity 6000 sorts/hour and four sorters of 3000 sorts/hour across 8 transport centres and the Hyderabad fulfilment centre. It resulted into the following advantages:

- Achieved sorting throughput of 48000 sorts/hour across operations and across all of our facilities
- Reduced sorting processing time by half
- Improved dimensioning and weighing accuracy by 16-18%, resulting in increased revenue recognition by around 10%
- Optimized warehouse space utilization with savings up to 2.5 times

Chapter: 3 - Research Design

3.1 Basic Flowchart

The process of research initiated through field work analyzing the status quo. This involved visiting the warehouse of various organizations of varied interests. Some of them are: FMCG, CNF, Electrical components, Pharmaceuticals etc. All the operations of the warehouse of these companies were observed carefully along with interrogation of the responsible officials.

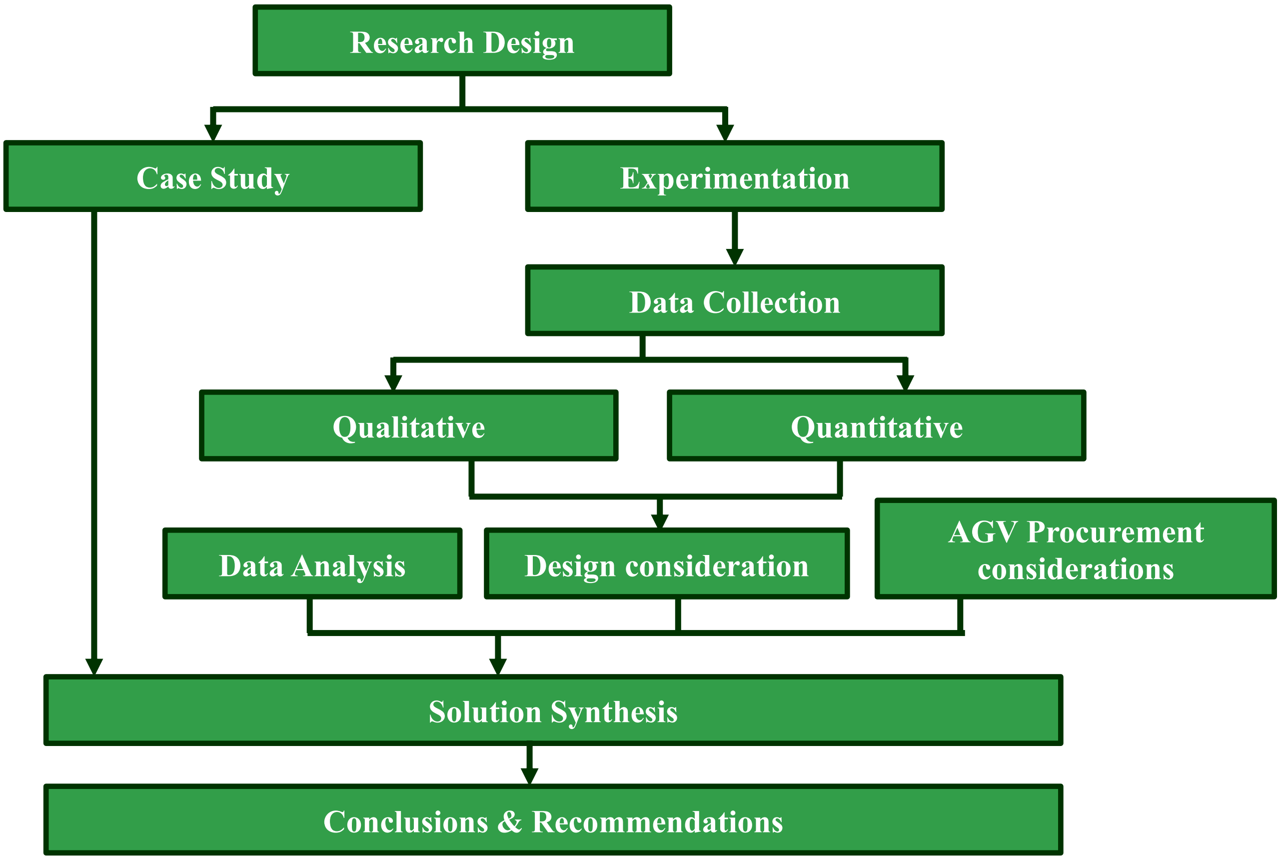

Figure 7 : Research Design flowchart

Furthermore, we also constructed a prototype of the proposed AGV in a small scale and performed various experiments. This gave us the pool of data and information which were then sorted qualitatively and quantitively and reserved for analysis. Alongside, we also gathered information on the design consideration and AGV selection considerations which were also analysed. This analysis process gave rise to the empirical situations helping us to reach a solution synthesis. The solution synthesis contains the brief segmentations of the advantages and the limitation of the area of the study. Understanding these and taking them into consideration, the future scopes and recommendations were laid out.

3.2 Status Quo Analysis and Case Study

We visited three different type of warehouse in Bangladesh and also consulted with the warehouse specialist of a few well-known company who are currently handling Logistics in Bangladesh**.** These companies include British American Tobacco, Fedex, Unilever, ACI Limited.

3.2.1 PRAN Warehouse

PRAN takes a comprehensive approach to all kinds of agro-processed food products, considering all of the ways their lives can be enriched through ensuring hygienic and quality food products. With HACCP compliance to ensure best quality products reaching to the consumers, PRAN places great importance on hygienic manufacturing processes. This encompasses everything from choosing quality materials to the use of storage facilities and careful monitoring of products using electronic sorting. Furthermore, company’s computer systems offer continuous monitoring of all manufacturing process to ensure the highest level of quality.

It has a warehouse situated in Rupgonj, Narayengonj. They chose this location for their warehouse because it is near to Dhaka and for availability of large space. The warehouse had a floor space of about 60,000 square feet. It mostly deals with the consumable product that PRAN manufactures. Currently they are using Human labor, regular trolley, forklift and some other conventional warehouse tools. This particular warehouse handles approximately 60 trucks per day including loading and unloading. Warehouse in charge of that warehouse admitted that they are thinking of modernizing the warehouse to increase efficiency and they are willing to consider AGVs for product handling. They might start using AGVs in the near future, which is approximately within the next 10 years.

Figure 8 : PRAN Warehouse

3.2.2 Hellmann Worldwide Logistics

Founded in 1871, Hellmann Worlwide Logistics started with one man, Carl Heinrich Hellmann, using a horse-drawn cart to deliver parcels in and around the town of Osnabrueck, northern Germany. Four generations later, Hellmann is a company with a worldwide network of 19,500 people in 437 branches in 162 countries.

They have one of their warehouses located in Station Road, Tongi. They have selected this located because of its proximity to the international airport of the city. It was a medium sized warehouse with floor space of 10000 square feet. This warehouse mainly deals with RMG, Medicines, Lather Products, etc and handles 10 trucks per day including loading and unloading. This particular warehouse is mainly depended upon their human labor for product handling. They also use some regular tools like trolley, fork lift etc. Hellmann admitted that using regular tools prolongs their handling time so they are also wiling to embrace AGV system within the next 30 years.

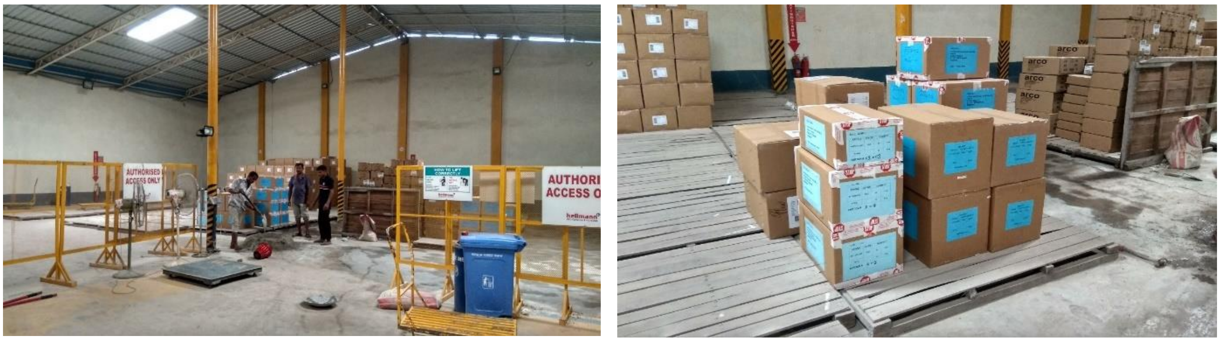

Figure 9 : Hellmann Warehouse

3.2.3 CISCO and TnT Express Warehouse

Cisco was founded in 1984 by a small group of computer scientists from Stanford University. Since the company's inception, Cisco engineers have been leaders in the development of Internet Protocol (IP)-based networking technologies. In addition to its products, Cisco provides a broad range of service offerings, including technical support and advanced services.

They have installed a new warehouse in Mohakhali, Dhaka, considered as one of the busiest commercial hubs of Dhaka. It is termed as Express Warehouse, meaning that products are kept for a very short period of time in this warehouse. Most of the product they deal with are environment sensitive.

Figure 10 : Express Warehouse of CISCO

They suffer of prolonged handling time due to inefficiency of human labor. Plans on adopting digitalized and automated techniques of handling. This particular warehouse is comparatively small one but as it handles delicate products including electronic devices they are very keen to embrace AGV system but labor cost in Bangladesh is really cheap and AGV System has a pretty hefty intial cost they are thinking of using AGVs within next 40 years down the line.

[Sketch](# 3.3 Experimentation

3.3.1 Initial CAD design

The following designs were prepared initially using a CAD software. However, it was modified in order to ensure proper balance of the center of gravity and weight distribution.

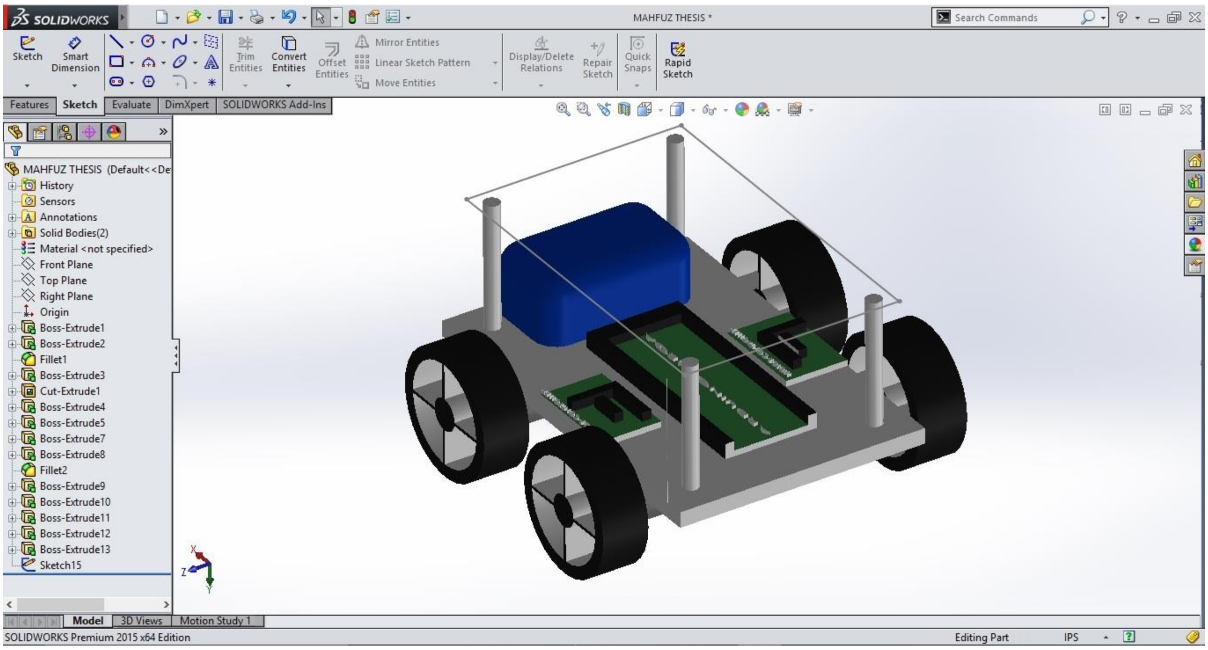

Figure 12 Perspective View of the initial design of the bot - 02

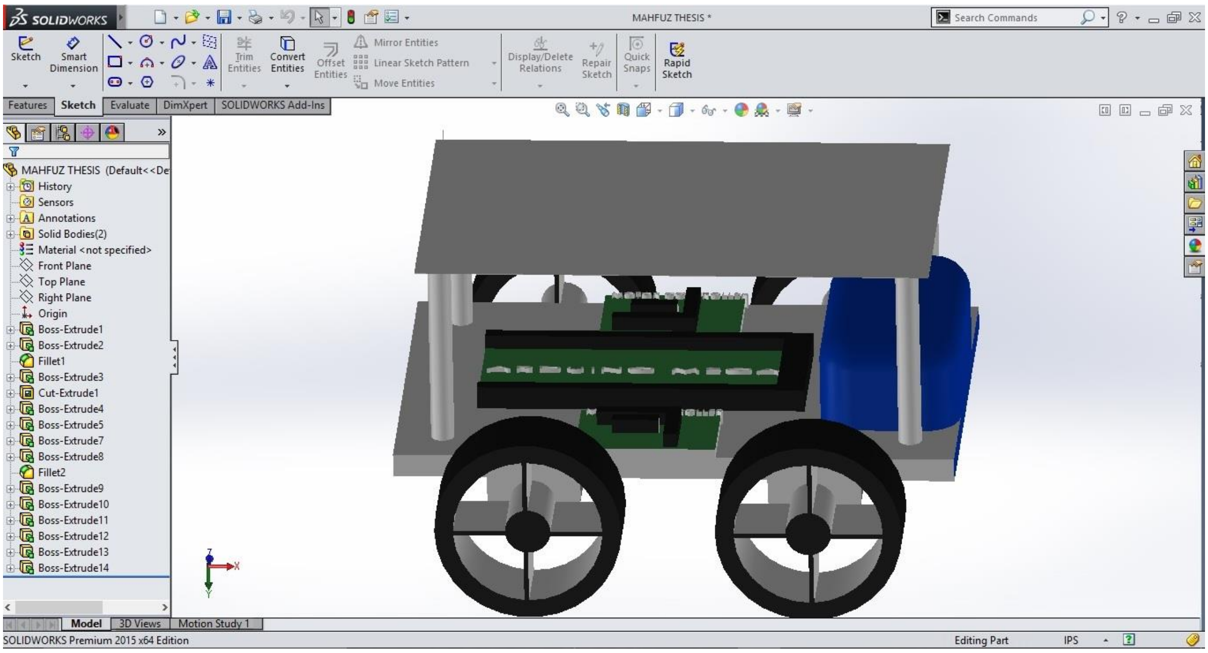

Figure 11 : Perspective View of the initial design of the bot - 01

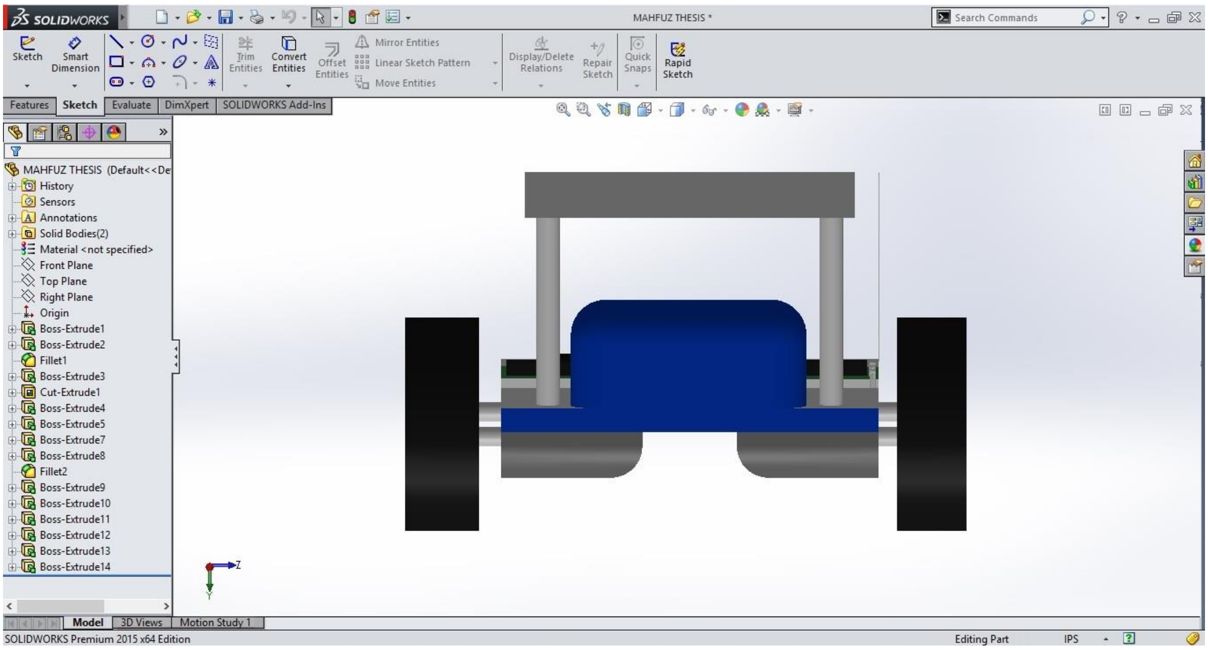

Figure 14 : Front View of the initial design of the bot - 01

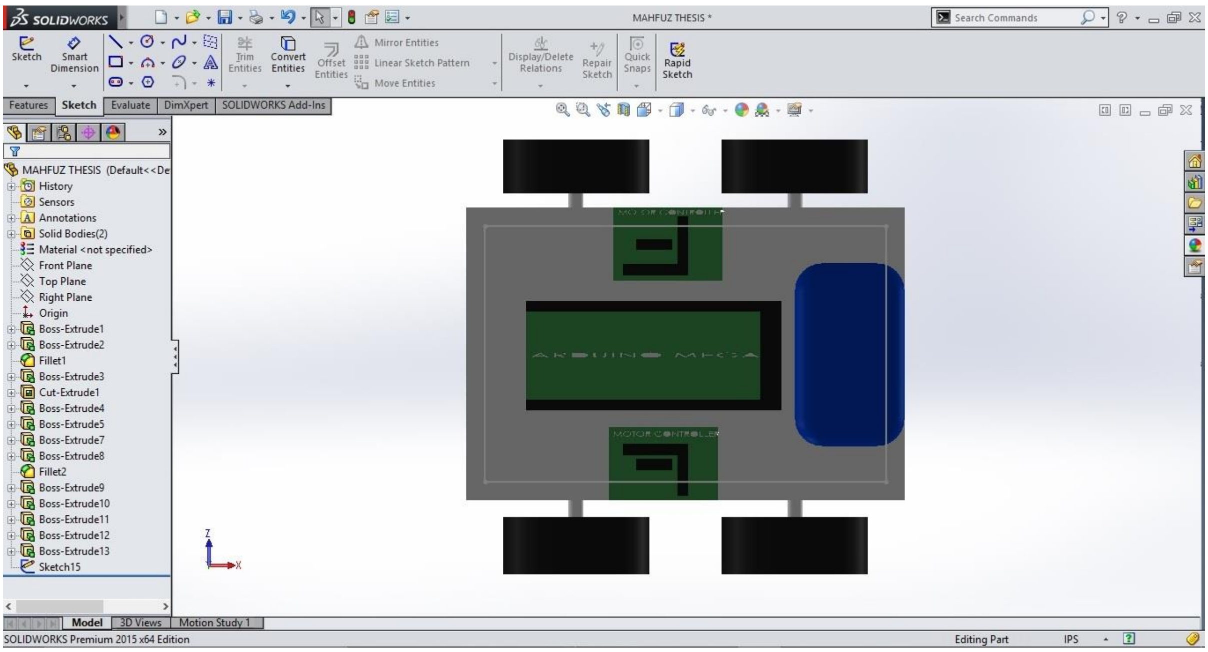

Figure 13 : Top View of the initial design of the bot - 01

3.3.2 Functioning prototype construction

A functioning prototype was developed with the vision of imitating an actual AGV. It could follow line to perform locomotion.

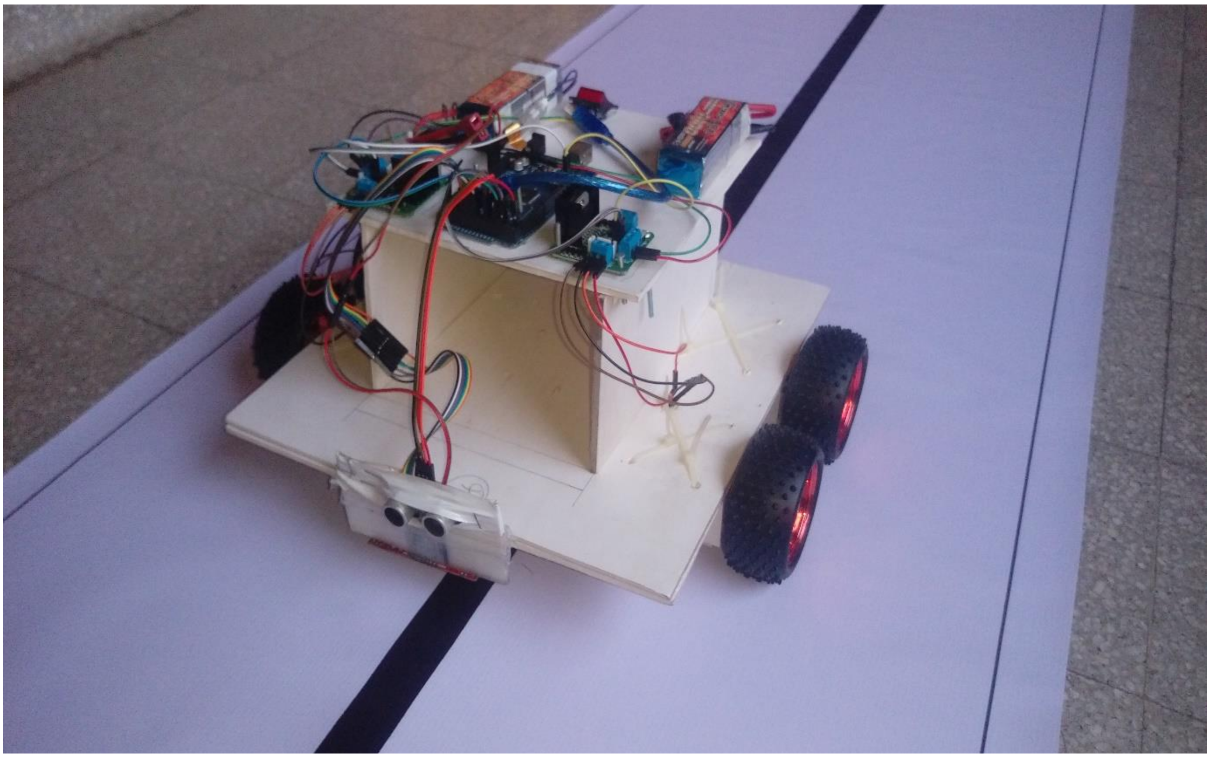

Figure 15 : Perspective view of the AGV Prototype

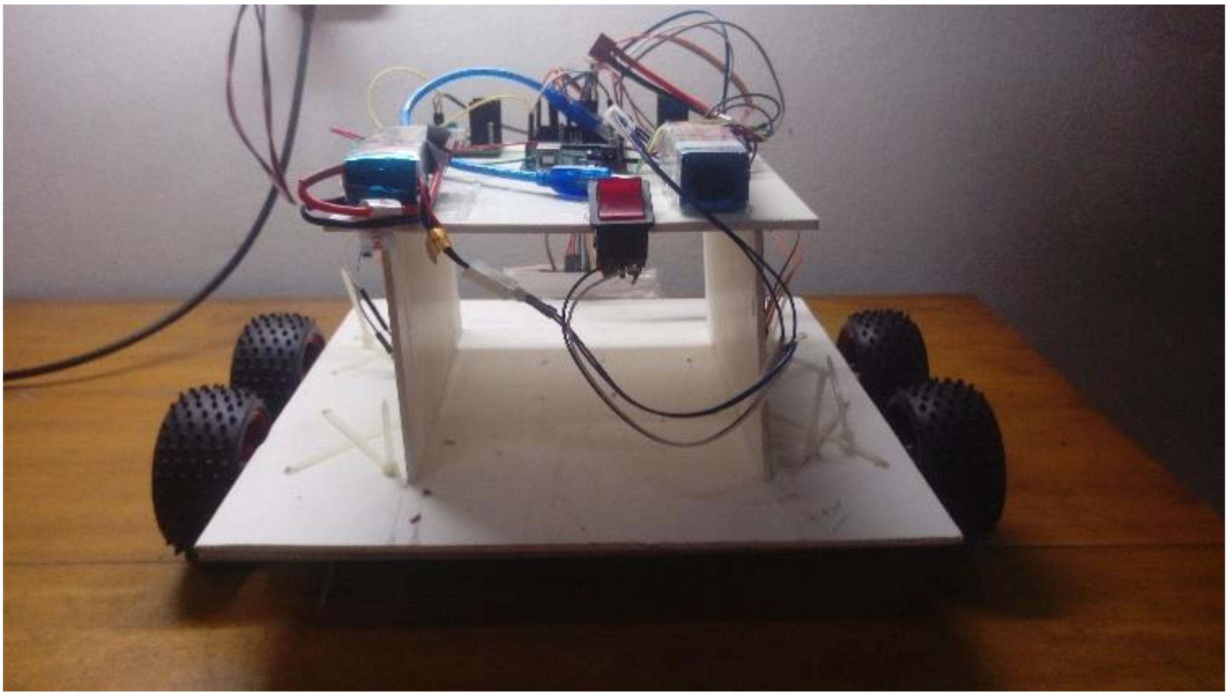

Figure 16 : Front view of the AGV Prototype

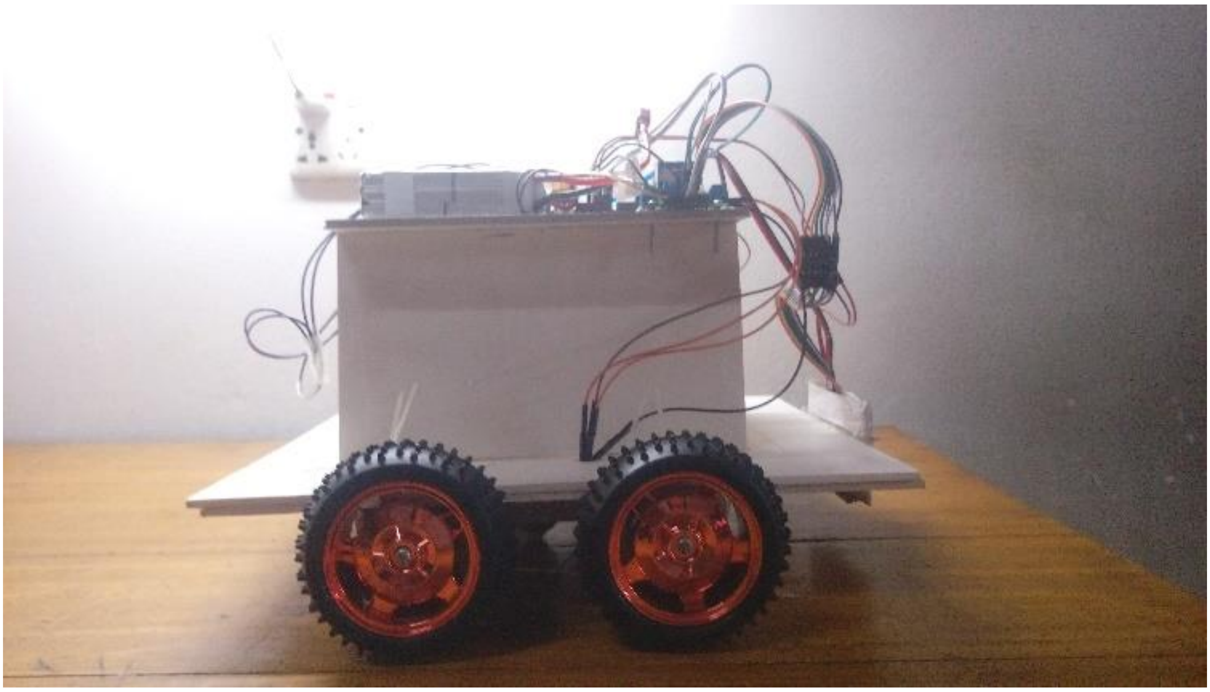

Figure 17 : Side view of the AGV Prototype

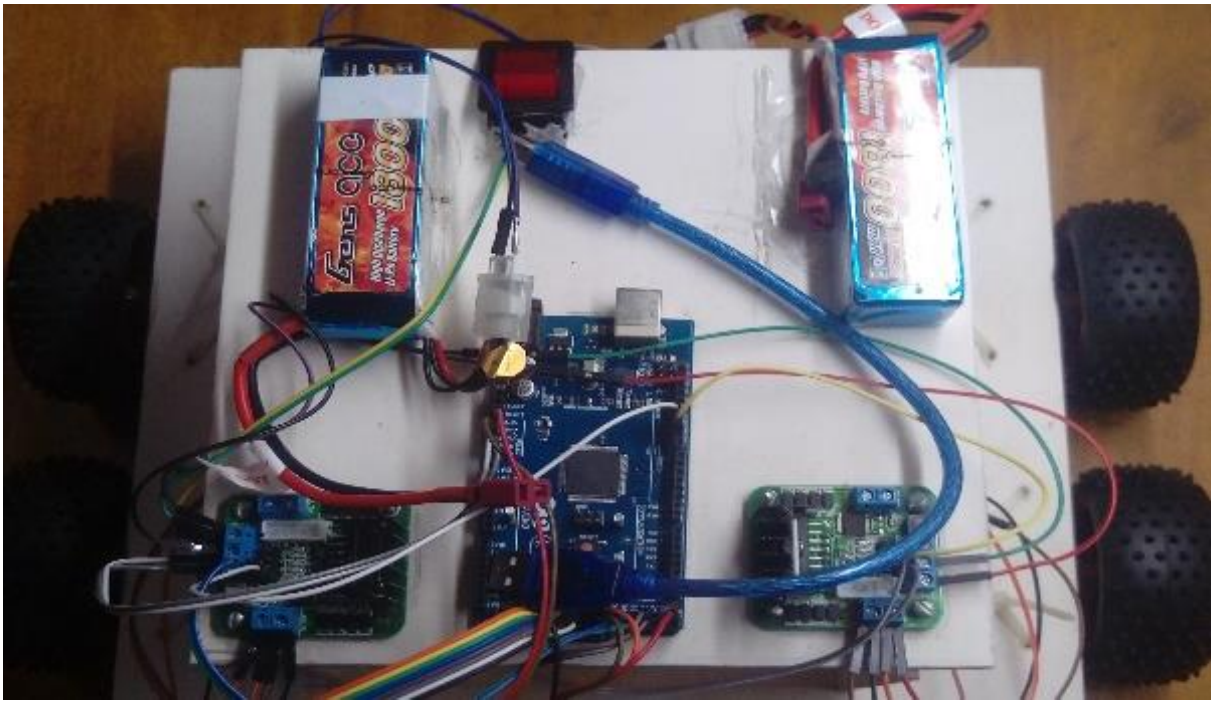

Figure 18 : Basic circuit system of the AGV Prototype

3.3.3 Features of the AGV prototype:

1. **DC powered robot**
    - Four high torque motors were used for propelling the robot
    - This high torque low RPM motors are the best available ones to tackle 2kg load.

2. **Plastic Wood Body**
    - Plastic wood was used for body material because it is light and capable of taking high load.
    - 10 layers of plastic wood has been used to build the chassis.

3. **Can follow black line over white background and vice versa**
    - While doing test run the applied code could steer the bot along black line over white background but if need be the code can be changed so that the robot can follow white line over black background.
    - The lines can be placed in any solid medium. The experimentation was performed over printed PVC sheet'

4. **It had a maximum weight carrying capacity of 2000 grams.**
    - The high torque motors could take 2kg of load and operate effortlessly.
    - In our test run our speed was compromised as we couldn't find high torque high RPM motors.

5. **It had a velocity of 0.5m/sec**
    - In the initial condition of battery charge, it was capable of 0.5metres per second.
    - The velocity gradually decreased with the decreasing level of the battery

6. **The total construction cost was approximately 17000 BDT.**
    - All the components were collected locally
    - The assembly was made by involved in this study
    - The coding was done under the supervision of experts

3.3.4 Components used in the Dummy AGV

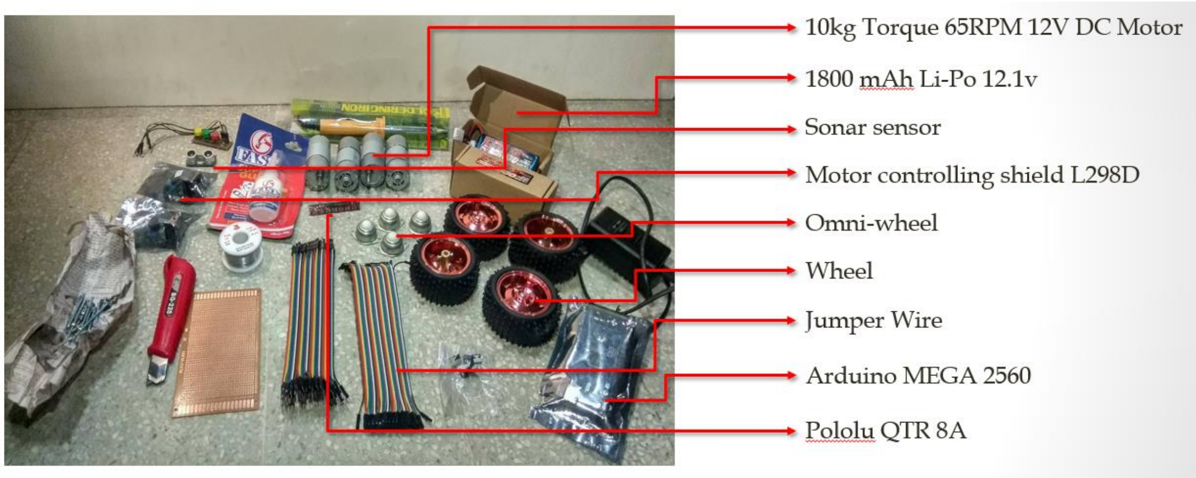

Figure 19 : Parts of the AGV Prototype

1. Li-Po Battery
    - Lithium Polymer batteries (henceforth referred to as "LiPo" batteries), are a newer type of battery now used in many consumer electronics devices. They have been gaining in popularity in the radio control industry over the last few years, and are now the most popular choice for anyone looking for long run times and high power.
    - LiPo batteries are much lighter weight, and can be made in almost any size or shape.
    - LiPo batteries offer much higher capacities, allowing them to hold much more power.
    - LiPo batteries offer much higher discharge rates, meaning they pack more punch.
    - We have used two LiPo batteries each of them were 1800 mAh.

2. DC Motors
    - A DC motor is any of a class of rotary electrical machines that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields.
    - This DC or direct current motor works on the principal, when a current carrying conductor is placed in a magnetic field, it experiences a torque and has a tendency to move. This is known as motoring action. If the direction of current in the wire is reversed, the direction of rotation also reverses. When magnetic field and electric field interact, they produce a mechanical force, and based on that the working principle of DC motor is established.

- We have used four 10kg/cm Torque motors.
- They have a highest speed of 65 RPM

3. Motor Controlling Shield L298D
    - The Arduino Motor Shield module is a special card for motor control. This card has two channels, channel A and channel B. These outputs can be used to control two DC motors or you can combine both channels to control a motor to Steps.
    - We have used two motor controlling shield to control the four DC motors.

4. Sonar Sensor
    - Sonar sensor is an ultrasonic sensor.
    - Ultrasonic sensors emit short, high-frequency sound pulses at regular intervals. These propagate in the air at the velocity of sound. If they strike an object, then they are reflected back as echo signals to the sensor, which itself computes the distance to the target based on the time-span between emitting the signal and receiving the echo.
    - As the distance to an object is determined by measuring the time of flight and not by the intensity of the sound, ultrasonic sensors are excellent at suppressing background interference. Virtually all materials which reflect sound can be detected, regardless of their color. Even transparent materials or thin foils represent no problem for an ultrasonic sensor.
    - We have used sonar sensors so that the bot can avoid any object that comes in front of it.

5. Omni Wheel
6. Regular Wheel
7. Jumper Wire
8. Pololu QTR 8A sensor
    - This is a IR sensor used for line sensing.
    - This sensor module has 8 IR LED/phototransistor pairs mounted on a 0.375" pitch, making it a great detector for a line-following robot. Pairs of LEDs are arranged in series to halve current consumption, and a MOSFET allows the LEDs to be turned off for additional sensing or power-savings options. Each sensor provides a separate analog voltage output.

- The QTR-8A reflectance sensor array is intended as a line sensor, but it can be used as a general-purpose proximity or reflectance sensor. The module is a convenient carrier for eight IR emitter and receiver (phototransistor) pairs evenly spaced at intervals of 0.375" (9.525 mm). Each phototransistor is connected to a pull-up resistor to form a voltage divider that produces an analog voltage output between 0 V and VIN (which is typically 5 V) as a function of the reflected IR. Lower output voltage is an indication of greater reflection. The outputs are all independent, but the LEDs are arranged in pairs to halve current consumption. The LEDs are controlled by a MOSFET with a gate normally pulled high, allowing the LEDs to be turned off by setting the MOSFET gate to a low voltage. Turning the LEDs off might be advantageous for limiting power consumption when the sensors are not in use or for varying the effective brightness of the LEDs through PWM control. The LED current-limiting resistors for 5 V operation re arranged in two stages; this allows a simple bypass of one stage to enable operation at 3.3 V. The LED current is approximately 20-25 mA, making the total board consumption just under 100 mA.

9. Microcontroller (Arduino MEGA)
   - The Arduino Mega is a microcontroller board based on the ATmega1280 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.
   - Microcontroller ATmega1280
   - Operating Voltage 5V
   - Input Voltage (recommended) 7-12V
   - Input Voltage (limits) 6-20V
   - Digital I/O Pins 54 (of which 15 provide PWM output)
   - Analog Input Pins 16
   - DC Current per I/O Pin 40 mA
   - DC Current for 3.3V Pin 50 mA
   - Flash Memory 128 KB of which 4 KB used by bootloader

- SRAM 8 KB
- EEPROM 4 KB
- Clock Speed 16 MHz
- The Arduino Mega can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector. The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

  The power pins are as follows:

  - VIN. The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
  - 5V. The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.
  - 3V3. A 3.3 volt supply generated by the on-board FTDI chip. Maximum current draw is 50 mA.
  - GND. Ground pins.

This robot was made by the purpose of showing that our engineers here in Bangladesh also have a great potential of making AGVs by themselves and contribute.

3.4 Design consideration of an AGV

In design problems many decision variables arise. The impact of decisions on mutual interactions and performance might be difficult to predict. It might be hard to decide on one thing without considering other decision variables. At least the following tactical and operational issues have to be addressed in designing an AGV:

3.4.1 Flow path layout

AGVs can travel along fixed guidepaths, which are indicated by, for example, wires in the ground. A flowpath layout connects machines, processing centres, stations and other fixed structures along aisles. This layout is usually represented by a directed network in which aisles intersections and pick up and delivery locations can be considered as nodes. The arcs represent the guidepath the AGVs can travel on. Directed arcs indicate the direction of travel of vehicles in the system. The layout of this flowpath directly influences the performance of the system. For example, it impacts the travel time to transport a load from its origin to its destination, the number of vehicles required and the degree of congestion.

The layout of the flowpath can be designed in various ways. Firstly, the layout of the building, the layout of the flowpath and the location of pick-up and delivery points can be simultaneously determined. Secondly, the design of the flowpath and the location of pick-up and delivery points can be determined by considering the layout of the facility as an input factor. Thirdly, the flowpath can be designed, considering the layout of the facility and the location of pick-up and delivery points as input factors. Using the information on the layout of the facility and the number and location of aisles and pickup and delivery points, a fully connected network consisting of arcs and nodes can be created. Nodes represent corners of aisles, intersections between aisles and pick-up and delivery points. In this network each node is connected with any other node and the complete path between two nodes can be traversed by a load without changing of vehicles.

3.4.2 Location of pick-up and delivery points

In the design of the layout of the AGV system the locations of pick-up and delivery points have to be determined. The pick-up and delivery points connect the AGV network to, for example, machines, (un)load stations, inspection stations and places of storage. Furthermore, the pick-up and delivery point can be used as a transfer station from one material handling network to another.

The objective is to minimize the total costs of the movement of material in the system. Firstly, the problem is presented as a quadratic assignment problem, which is NP-complete. Therefore, two heuristics have been developed to solve the problem. The first heuristic takes an interactive search approach with high computation times. The second heuristic exploits the layout pattern and returns a solution in O(mn) time, where m equals the maximum number of pick-up and delivery points in the system. Both heuristics have been tested for problems with 4–12 departments. The second heuristic has an average error of 0.32% for 7 test problems compared to the best solution found with the first heuristic. The authors conclude that these error rates are acceptable considering the time savings involved. from an AGV in one zone to an AGV in another zone. In Huang (1997) a design concept has been proposed to find the optimal location of the pick-up and delivery point for each zone. For each zone just a single the pick-up and delivery point is assigned. As a result, a simple traffic control for the movement of materials between zones is obtained. No research has been performed on location decisions for pick-up and delivery points in large AGV systems. With an increase in the number of all types of stations in the network an large increase in the number of pick-up and delivery points might be expected. To avoid bottlenecks at pick-up and delivery points, due to large numbers of AGVs in the system, and to reduce waiting times of loads, the location decision is even more important for large AGV systems. It needs to be studied if existing methods can still be applied for AGV systems with large numbers of AGVs or that new methods have to be developed.

3.4.3 Vehicle requirements

The minimum number of vehicles required in the system has to be determined when the AGV system is designed. To ensure that all tasks are performed within time, sufficient vehicles have to be available. However, for economic reasons the number of vehicles should not be overestimated.

Furthermore, too many vehicles in the system leads to more congestion. To determine an optimal AGV fleet size, capable of meeting all requirements, many factors have to be taken into account. Several of these factors are:

- Number of units to be transported,
- Points in time at which units can be or need to be transported,

- Capacity of the vehicle,
- Speed of the vehicle,
- Costs of the system,
- Layout of the system and guide path,
- Traffic congestion,
- Vehicle dispatching strategies,
- Number and location of pick-up and delivery points.

The point in time at which a job could be transported can be indicated in various ways. Firstly, a single time point is given at which the transport should start. Earlier or later transport is not allowed. Secondly, for each job a time-window with a release time and due time is indicated in which the transport of the job should start. Transport before the release time and transport after the due time is not allowed. In most cases, the layout of the system and the guide path has already been defined before the minimum number of vehicles is determined. The way in which vehicles travel through the system (one way, bidirectional and so on) influences the vehicle fleet size.

3.4.4 Vehicle dispatching

Dispatching refers to a rule used to select a vehicle to execute a transportation demand. This problem exists already as long as people or goods have to be transported from one destination to another by, for example, public transport systems, trucks, trains and airlines.

The dispatching problem can be observed from different points of view. Firstly, a load is available for transport and needs to be assigned to an idle AGV. Secondly, a vehicle becomes idle and need to be assigned to a new task. Consequently, the dispatching problem is divided into two categories, namely workcentre initiated dispatching and vehicle initiated dispatching rules. The problem is workcentre initiated if the vehicle has to be selected from a set of idle vehicles to transport a load. The problem is vehicle initiated if an idle AGV has to choose a load from a set of transportation requests. In off-line control systems all data on transportation requests are available at the start of the transportation process. As a result, vehicles can be assigned to loads in an optimal way by formulating the dispatching problem as an assignment problem. The set of transportation requests and the set of vehicles form a complete bipartite graph with a weight (for example, transportation times) assigned to each arc. By applying the Hungarian method, the problem can be solved efficiently. A simple heuristic used in on-line control systems is the first-come-first-served rule, which dispatches a free AGV to the load that requested transport at the earliest time. Bartholdi and Platzman (1989) present the first-encountered first- served rule, which can be applied for decentralized on-line control for AGVs travelling in a single loop. The AGV with multiple loads continually travels in a single loop and picks up, if space is available on the vehicle, the first load it encounters. The load is unloaded at its destination. With simulation it has been shown that this heuristic outperforms other heuristics, like the first-come-first-served rule, if it is applied in a single loop.

The following heuristic rules can be applied in decentralized control systems for workcentre initiated dispatching:

- Random vehicle rule: pick-up task is randomly assigned to any available vehicle regardless of the location of the vehicle and the load,
- Nearest vehicle rule: the vehicle at the shortest distance of the load is assigned to the load, farthest vehicle rule: the vehicle at the greatest distance of the load is assigned to the new transportation request,
- Longest idle vehicle rule: the vehicle that has remained idle for the longest time among all idle vehicles is dispatched to the load,
- Least utilized vehicle rule: the vehicle with the minimum mean utilization is assigned to the new job.

The dispatching of AGVs in distribution, transshipment and transportation systems is less explored. Well known dispatching rules from manufacturing applications are applied to the new areas of application. However, for real-life systems with large numbers of AGVs more research for advanced heuristics or optimal approaches is required. In this context the following aspects are of utmost importance: low computation times for large systems with high workloads, interface with other vehicles to avoid congestion, deadlocks and delays, infinite or rolling planning horizons, and a small gap between optimal solutions and solutions of heuristics. In the new areas of application the interface with the other types of equipment, such as storage and (un)loading equipment is very important. Hardly any attention has been paid in literature to the simultaneous dispatching of multiple types of material handling equipment. In integral dispatching of vehicles and other types of equipment in large AGV systems, side constraints are very important. One could think of capacity restrictions at the transfer buffer from storage equipment to AGVs or priority of one type of equipment above another one.

3.4.5 Vehicle routing and scheduling

If the dispatching decision is made, a route and schedule should be planned for the AGV to transport the job from its origin to its destination over the AGV network. A route indicates the path which should be taken by the AGV when making a pick-up or delivery. The related schedule gives arrival and departure times of the AGV at each segment, pick-up and delivery point and intersection during the route to ensure collision free routing.

The selection of a certain route and schedule influences the performance of the system. The longer it takes to transport a job, the fewer the jobs that can be handled within a certain time. Therefore, one of the objectives of the routing of AGVs is to minimize transportation times of loads.

Algorithms have to be developed to solve the routing problem. Two categories of algorithms can be distinguished, namely static and dynamic algorithms. With static algorithms the route from node i to node j is determined in advance and is always used if a load has to be transported from i to j. In this way, a simple assumption is to choose the route with the shortest distance from i to j. However, these static algorithms are not able to adapt to changes in the system and traffic conditions. In dynamic routing, the routing decision is made based on real-time information and, as a result, various routes between i and j can be chosen. Static routing problems in AGV systems are related to vehicle routing problems (VRP) studied in transportation literature. In the vehicle routing problem a set of n clients with known demands need to be served by a fleet of m vehicles with limited capacity. The vehicles are all housed at one depot. The route of each vehicle starts and ends at this depot. m least costs (length) routes have to be planned such that each customer is served exactly once and that the total demand of the customers served by each vehicle does not exceed the capacity of each vehicle. The objective is to minimise the total distance of all routes under previously mentioned conditions. This is an NP-hard problem to solve The vehicle routing problem has been studied extensively in literature. The vehicle routing problem with time windows (VRPTW) is a generalisation of the vehicle routing problem. For each customer a time window is defined. The time window [s,t] restricts the service time of the customer to fall into the time interval from s to t. Such time-windows arise, for example, due to traffic restrictions or fixed time schedules of customers and their products. Finding a feasible solution to the vehicle routing problem with time windows is an NP-complete problem. Numerous studies on the vehicle routing problem with time windows have been executed.

A generalization of the vehicle routing problem with time windows is the pick-up and delivery problem with time windows (PDPTW). Optimal routes have to be constructed such that transportation requests requiring pick-up and delivery are met. The VRPTW is a special case of the PDPTW, in which all destinations are the same depot. A special version of the pick-up and delivery problem and a combination of a vehicle routing and a vehicle scheduling problem is the dial-a-ride problem. This kind of problem is concerned with dynamic routing of vehicles and real-time response to customers. Each customer should be served within a time-window and penalty functions are used to minimize waiting times of customers. Analogies between these problems from transportation literature and routing and scheduling problems for AGVs in automated guided vehicle systems are clear. A number of loads at various locations have to be transported by vehicles at a certain start time or at a certain moment within a time window. However, the use of the described models from transportation literature is not always possible. These models do not take into account congestion in the system. Furthermore, most models are not developed to deal with real time response to dynamically changing transportation requests. Therefore, attention is paid in the literature to developing non-conflicting routes for AGVs. With a non-conflicting route, an AGV arrives as early as possible at the destination without conflicting with other AGVs. for finding conflict free routes, attention should be paid to the presence of interruptions in the system. Interruptions might occur due to, for example, vehicle breakdowns, objects on AGV paths and manual intervention. As a result of interruptions, AGVs may be blocked and routes cannot be finished. Therefore, if an AGV encounters an interruption it has to be rerouted in such a way that no conflicts with other AGVs occur.in the context of manufacturing areas, static and dynamic algorithms have been developed to solve the routing of vehicles. Network models, queueing networks, simulation and intelligent routing techniques are used to route AGVs conflict free through the network. The routing of AGVs through distribution, transshipment and transportation systems is hardly studied. From the literature discussed above, we conclude that scheduling and routing issues are often studied separately. The integration of scheduling and routing aspects however forms a challenging problem.

3.4.6 Battery management

If AGVs use batteries, frequent battery changing might be required. The time required for replacing or charging batteries can impact the number of vehicles required. A significant increase in the number of AGVs required while incorporating battery management issues in the simulation study compared to neglecting these issues in the studies. Furthermore, the time required for charging batteries impacts throughput, congestion and costs.

In most manufacturing and distribution areas AGVs travel over relatively short distances and during idle times batteries can be replaced or charged. However, in manufacturing systems with non-predictable AGV routes and at container terminals and transportation systems AGVs need to travel long distances and, as a result, have short idle times. The author provides the reader with guidelines when to incorporate battery management issues in simulation studies. He indicates that it might not be necessary to incorporate these issues for systems with off-shift times for AGVs, low utilization of AGVs (less than 50%) and on-line charging systems. It develops control rules to take battery constraints into account in an underground transportation system with large numbers of AGVs. With simulation, the author compares the performance and costs for systems in which batteries are charged during travelling and systems in which batteries are replaced.

We conclude that battery management is hardly addressed in AGV research. However, according to the results of the performance of AGV systems with high utilisation and hardly any off-shift times, is influenced by incorporating battery management. These characteristics belong especially to AGV systems in transportation and transshipment areas. Thus, in future research for large AGV systems, it is of great importance to incorporate battery management decisions. These decisions should be integrated with decisions on routing, scheduling and dispatching of full and empty AGVs.

3.4.7 Equipment failures

In most literature the impact of equipment failures on the system is neglected. If only few AGVs are used, failures will have little effect on the occurrence of congestion in the system and, as a result, on the performance of the system. In contrast to manufacturing areas large numbers of AGVs are used at container terminals and outdoor transport systems. For these systems failures may occur more often. These failures might cause congestion and deadlocks in the system.

Hardly any literature has been found on this subject. In research more attention should be paid to the relationship between control of AGVs and the occurrence of failures to ensure a high reliability of the AGV system.

3.5 AGV Procurement considerations

3.5.1 Having evidence of fleets operating in real world facilities

Step into any manufacturing or distribution trade show, it's seen that AGVs easily navigating around booths using tape, lasers or various other types of infrastructure. While it's certainly an impressive sight, it's a little trickier to navigate a narrow plant aisle packed with humans, forklifts, and other robots.

Before it is determined which AGV vendor to partner with, it's important to see the product in action. It's important to assess whether the vendor has fleets of vehicles working every day in complicated, real world environments. If the AGV vendor can't prove this real-world experience, significant amount of risk in implementing an unproven product is taken.

3.5.2 Provide a list of reference customers

If potential vendor AGV is found to navigate a trade show booth, there's a chance they're still working off a prototype. Many robotics companies don't have end user customers at all. To mitigate the risk associated with purchasing an untested product, the vendor should be asked for a list of reference customers.

3.5.3 Give plant tours where robots are already hard at work

There's nothing like seeing a fleet of the AGVs flawlessly navigating a busy plant floor. By visiting a plant where robots are already hard at work, there are benefits of speaking to the peers about the specific challenges they've faced, and how they've solved them with autonomous vehicles. A better understanding of the applications and workflows that similar companies have deployed can be understood. This conversation with the peers provides reassurance and helps to eliminate the risk associated with automation.

3.5.4 Provide solutions that scale across applications and facilities

When selecting an automation vendor, it's important to consider not only your current needs, but future applications as well. Such an AGV solution is needed that will grow with the company, adapting to the changing industry and taking on the challenges faced as the business grows.

If the consideration is of a solution with lasers, wires, magnets or tape, it should be expected to pay a hefty fee for the AGV vendor to retrain the robot any time we want it to follow a new route. Thus, infrastructure-based solutions are unrealistic for the many manufacturers and distributors who routinely experience peak seasons and new product launches. Conversely, vision guided vehicles can be retrained in-house in minutes. Because they are 100% infrastructure-free, VGVs can handle extensive environmental change, allowing them to be moved from one work process to another, or from facility to facility to handle peak seasons or expansions. This type of flexibility saves the chance from risking time and money—now and a year from now—as the business continues to grow.

3.5.5 Deliver robots that are infrastructure-free

An AGV solution that can be installed in the plant without interrupting the flow of production, should be 100% flexible and infrastructure-free.

Traditional AGV vendors and other material transporters require wires, magnets or tape for their vehicles to navigate plant floors. These solutions require costly upfront installation of physical landmarks throughout your plant, which can disrupt production. Additionally, if modification of the route is necessary after the placement of these landmarks, most AGV vendors have to send a team of engineers to make the retrain the route. This process is costly, and can take days or even weeks, which risks downtime in your plant.

Lasers and geo-guidance solutions—favored by some newer AGV companies—use structural environments like walls, columns and racks to auto-locate. Because their recordings are based on 2D maps, laser-based AGVs often get "lost" when boxes are moved off racking, or if anything else changes between the vehicle's initial training and when it embarks on its route. If the plant often moves product, people, or vehicles in or out of the AGV's path, a laser-based AGV solution should be avoided.

3.5.6 Create and influence AGV safety standards

Because AGVs must navigate plant floors already busy with humans and other forklifts, AGV companies are required to follow a strict set of safety standards. It's important to partner with an AGV vendor that not only complies with industry standards, but is actually setting the standards for the rest of the AGV industry.

3.5.7 Install vehicles quickly and efficiently

Because AGV vendors offer a variety of solutions, the installation process differs greatly between AGV companies. If looking for a quick ROI, consider that an infrastructure-based solution requires an extensive install period upfront as landmarks are placed and many tests are run to ensure the vehicle can recognize them. Long lead and installation time delays the ROI on the AGV investment.

Chapter: 4 - Analytics and Core Findings

4.1 Financial Analysis:

One of the most compelling reasons to switch from a manual operation to an automated one is to save money. An AGV system will run 24 hours a day, seven days a week and are designed to operate without supervision. If your business runs three shifts a day, five days per week the annual cost per forklift is $240,000. This cost includes; three driver's wages, capital expenditure or leasing for the vehicle and running costs. Over ten years with equates to $2.4 million per forklift in your operation. In most cases you will replace one forklift with one AGV. An AGV will cost the same in the first year for outright purchase and less if using a leasing option. However, the costs for the AGV drop dramatically in the following years, averaging only $4000 to $6000 per year. Over the ten-year period you will save nearly $2.1 million per forklift by investing in an AGV system. The more shifts you run the more money you will save as our AGVs will run on a 24-hour rotation without any additional staffing costs or penalty rates. Any company that works its factory floor for more than 8 hours a day will recognize instant cost savings by switching to an AGV system.

Furthermore, AGVs reduce costs by eliminating all the Human resource management costs such as recreational break, sick leave, vacation, bonuses and increments AGV operations will ensure better Return on Investment in comparison to human labor. It will reduce utility costs as the AGVs can operate in lights-out environment. It can work at a steady consistent speed leading to lower maintenance.

4.1.1 Examples of typical leasing costs

- 1 vehicle pallet-forklift type AGV system with up to 20 load and unload positions and a travel distance of up to 100 meters. Monthly cost for 5 years, with no residual: A$ 5,400/month (comparable cost for 1 forklift and 3 drivers in a 3-shift operation ~A$20,000/month)

- 3 vehicles pallet-forklift type AGV system with up to 50 load and unload positions and a travel distance of up to 200 meters. Monthly cost for 5 years, with no residual: A$ 12,100/month (comparable cost for 3 forklifts and 9 drivers in a 3-shift operation ~A$60,000/month)

- 5 vehicles pallet-forklift type AGV system with up to 100 load and unload positions and a travel distance of up to 300 meters. Monthly cost for 5 years, with no residual: A$ 19,200/month (comparable cost for 5 forklifts and 15 drivers in a 3-shift operation ~A$100,000/month)

- 10 vehicles pallet-forklift type AGV system with up to 1000 load and unload positions and a travel distance of up to 500 meters and a small Warehouse Management Solution. Monthly cost for 5 years, with no residual: A$ 36,500/month (comparable cost for 10 forklifts and 30 drivers in a 3-shift operation ~A$200,000/month) *.

4.1.2 Operating Costs as Scale of Economy

Contrary to man-operated industrial trucks the operating costs of AGVS are only marginally affected by the development of the labor costs. From this it results that relating to the labor costs a high calculative planning reliability can be achieved in the long-term. This is a general advantage of all automated material flow systems. On the assumption that the labor costs will rise even more strongly in the future than in the past, AGVS will increase above average in comparison to personnel intensive material flow systems.

The development of the labor costs, as for example a start-up financing for the creation of a job or a shortening of subsidies, may not remain unconsidered. Each of these factors can either promote or restrain the development of the AGVS-market.

The investment in a plant with an AGVS is usually higher than for a plant with man-operated industrial trucks. That has consequences on both the cost-accounting interest and the height of the depreciation. For AGVS higher cost-accounting interests result. The height of the interest rate has to be oriented at the development on the capital market. If the interest rate decreases, the profitableness of AGVS is affected positively.

The depreciation has to be regarded under two criteria, namely according to tax law and cost accounting criteria. It has to be an aim of the plant operators to estimate the economic lifetime of the plant as short as possible. Therewith it should be reached that the depreciation of the fixed capital can be made valid for taxation as promptly and completely as possible. The labor costs, the interest trend at the capital market and the amortization period belong to the substantial economic factors, which determine the development of the AGVS-market. The development of these factors cannot be affected by the AGVS-manufacturers, the factors affect the market from the outside. The amortization period defined by the technical lifetimeis applied to the cost comparison method, thus for the system decision. A long technical lifetime affects the system comparison positively. The technical lifetime is specified internally considering the tasks and the operating conditions. For the success of the European AGVS-manufacturers on non-European markets the rates of exchange are relevant. with a low US-Dollar price per Euro the European AGVs-manufacturers can make attractive offers for the international market. In the year 2006 about 23 % of the AGVS by European producers were installed outside of Europe.

4.2 Productivity Analysis

- **Optimization of warehouse functions:**

  Implementing AGV in warehouse operations ensures proper tracking of the palette handling, material transfer, and exchange of goods to and from the warehouse. Thus, it ensures smooth integration of the data into Enterprise Resource Planning (ERP) & Material Requirements Planning (MRP) systems.

- **Complete working shifts:**

  Unlike human labor, the AGVs is capable of working complete eight hours per shift. This eventually decreases the time lags caused due to downtime, recreational leave, rest time etc.

- **Rapid Charging mechanism:**

  The AGVs are equipped with high configuration battery system in which quick charge of 5 minutes ensures up to 5 hours of continuous operations.

- **Proper control of WIP:**

  AGV operations are completely controlled by computerized commands and thus the entire work in progress remain in the control. As a result, any unexpected changes in the demand or delivery time can be addressed properly by adjusting the operation of the AGVs.

- **Smooth feedback insurance:**

  The working progress of the AGVs can be traced transparently and thus it gives proper insurance of the feedback. These feedbacks can be used to bring any desired changes in order to obtain maximum output.

- **Easy expandability:**

  AGV operations can be initiated with limited number of bots and can be expanded with the necessity of the operation. On the contrary, a fixed automation system, once implemented, is difficult and costly to move; AGVs on the other hand can be easily reprogrammed to follow new paths.

4.3 Efficiency Analysis

- **Weight loading capacity**

  A typical AGV can carry up to 2000 kg of weight at a time facilitating the option to bring about changes in the plant layout, process layout etc. This is impossible on the part of a human being to carry weight of such limit.

- **Highly optimized throughput**

  Insurance of highly optimized throughput can be made possible by the proper utilization of the plant space. Furthermore, the AGVs can reach such heights and passages which are impossible for the human labor to accomplish.

- **Steady speed**

  A typical AGV can move at an average speed of 20m/min (carrying 500kg). This speed is maintained to be steady without any turbulence. This makes it easy to predict delivery time and handling time precisely.

- **Disciplined handling system**

  AGV follows order fulfillment policies such as pick-by-time/after-time or pick-by-FIFO, expiry or manufacturing date. This ensures proper discipline of the operations inside the plant and reduces the scopes of error to the utmost extent.

- **Adaptive handling system**

  AGV intelligently adapts in real-time to changing inventory profiles and order fulfillment patterns and thus opens up the opportunity of staying intact to the committed delivery time.

- **Increased Inventory Accuracy**

  This is another area where human error reigns supreme. A simple miscount can throw off figures and create issues, but automated inventory systems can easily solve that issue. And it’s another area where costs can be cut.

4.4 Security Analysis

- **Improving workplace safety**

  Utilizing automatic guided vehicle systems enhances workplace safety in a variety of ways. First, they can perform tasks that would normally be considered dangerous for humans. Second, they operate in a smooth, controlled manner, which means fewer risks of human-operated vehicles injuring other employees. And enhanced workplace safety can also decrease costs, including insurance rates and OSHA penalties.

- **Diminishes the scope of damages**

  AGVs handles the products in a comparatively safer way and thus the amount of accumulated damage decreases. This further results in decreasing the loss incurred due these damages.

- **Handling hazardous items**

  AGVs are dependable to carry hazardous items which might impose threats to human labor. This also facilitates the continuation of the work under extreme operations.

- **Insurance of machine safety**

  AGVs are equipped with overload sensors, and makes sure that it won’t move if it is overloaded. This ensures both the AGV & PRODUCT SAFETY

Chapter: 5 - Conclusion & Recommendations

4.5 Limitations

In the context of Bangladesh,

- **Low labour costs**

  Bangladesh is reputed in the global context for its low labour cost, and thus the industrialists give less emphasis on the digitalization and depends on the human to get the job done.

- **Not suitable for Non-repetitive tasks**

  AGVs are not suitable for non-repetitive task as the cost of AGVs depends on the stations they visit, is the number of the stations they need to visit is different in every cycle it won't be cost efficient. Then again customization of AGV is possible.

- **Lack of investment in automation**

  Logistics operators not interested to invest in such automation project as Bangladesh have a pretty cheap labour cost. So, investing a great sum of money up front is not acceptable for them. This is the major problem why Bangladesh is lagging behind in the field of warehousing.

- **Flexible lead time**

  Enjoy comparatively flexible lead time in logistics handling, so, automation not in first priority as a part of technical integration, this flexible lead time is offered because Bangladesh has a bad reputation in this sector. All the multinational logistics companies know that Bangladesh needs more lead time as the warehouses here are not automated. So, they allow up comparatively long lead time but this is in the long run bad for us.

4.6 Future Scopes and recommendations

- **Global competitiveness**

  International heavy logistics handlers operating in Bangladesh should adopt AGV because it will raise the bar for local logistics handler and make the local industry more competitive. In Bangladesh the main problem is that logistics handlers are happy with the current scenario so they don't find the urge to modernize and this is why they are neglecting the bigger future.

- **Focus on the air and seaport**

  All the Major ports and export zones are semi-automated in our country, making them automated can drastically increase the efficiency and effectiveness of the whole process.

- **Development of local engineering sector**

  Making AGVs is pretty common for Bangladeshi engineering students, the problem is, they are simple line followers or obstacle avoider they need to step up the game and big shot companies should work alongside them to produce industry grade AGV systems which can be used and imported.

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