Energy Efficient Logistic: Issues and Challenges

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Abstract **– The world as we know it is rapidly rotating. The Industrial Revolution is one of history's most important movements (IR). The current fourth industrial revolution is built on the Internet of Things, unlike prior industrial revolutions that depended on steam or mass manufacturing processes, or on computers (IoT). Connectedness allows people, data, and systems to interact in new and novel ways.. Data, system, control, monitoring, automation, and artificial intelligence (AI) are all used interchangeably when discussing "smart technology." Keeping in mind that energy is a vital part of our life is essential. In today's world, energy informatics plays a key role in acquiring environmentally friendly energy. The purpose of the study and the problem investigated is that to design an overview of the energy informatics framework and its role in reducing energy use, CO2, and demand. Energy informatics is used to highlight the function of information systems in creating a green and clean environment. Efforts to become more environmentally friendly have been addressed. In addition, there are recommendations for achieving energy-efficient logistics at the study's conclusion. This paper is designed in such a way to provide a comprehensive overview of the energy informatics frameworks supported with energy efficient logistics. This is followed by samples of real cases and scenarios of smart warehouse. Finally, challenges faced by energy efficient logistics have been considered. One of the major findings is that improving the energy efficiency of the logistics industry is one of the most important things that can be done for the environment in order to make the logistics industry more environmentally sustainable. A brief summary of the interpretations related to the results obtained in this overview has been mentioned as follows: the processes involved in logistics need a lot of energy and have a detrimental influence on the environment. Increasing the use of capacity is one way to improve energy efficiency in the logistics industry, which is essential for maintaining a healthy environment and can be done by itself. So that, it has been given a number of case studies in this direction in order to help readers find effective ways in implementation of energy efficient related to logistics in order to overcome such a concern.**

Keywords – energy informatics; logistics; energy efficiency; information system; freight transportation

I. INTRODUCTION

Whether we like it or not, this age of connection is transforming our lives, work, and communication; it is also likely to alter the things we value and the way we value them in the future. Supply Chain is one of the main pillars of industrial sustainability [1, 2]. Manufacturing and operations, logistics and distribution, customer service, and worldwide deployment are all components in the supply chain management process, which binds them all together to provide a competitive edge [3, 4]. Every one of these steps has a specific definition in the business sector, which varies widely based on the product and the company.

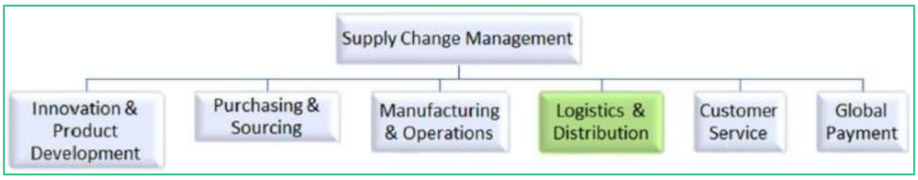


Figure 1: Supply Chain Management Process

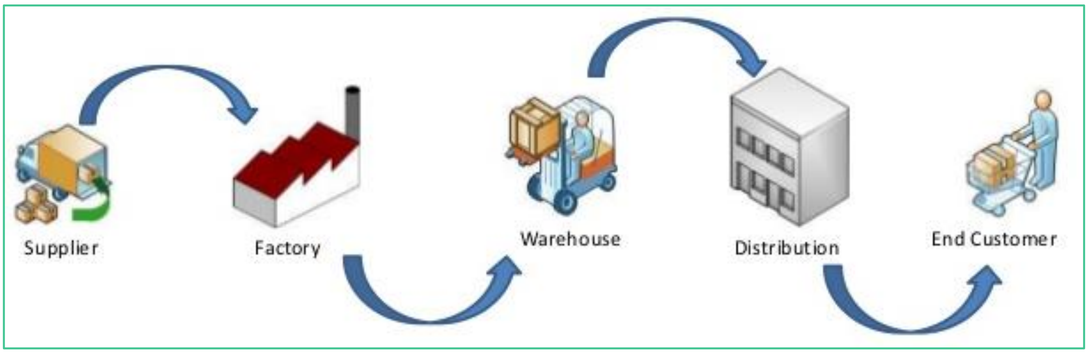


Figure 2: Supply chain flow-process; logistics refers to the movement, storage, and flow of goods, services and information inside and outside the organization

Logistics, as part of the supply chain process, play important roles for transportation, warehousing, packaging and more; to an extent that the customer receives the desired product at the right time and place with the right quality and price. The efficient flow of logistics activities is the core that synchronizes the supply chain. Freight transportation & Warehousing are among the key components of logistics management.

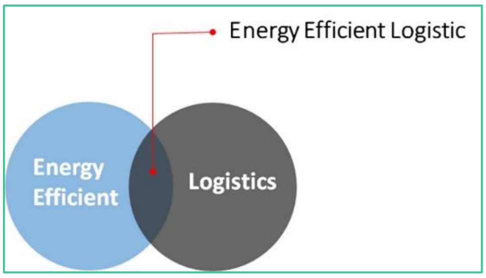


Figure 3: Energy Efficient Logistics

Energy Efficient, on the other hand, has a broad variety of definitions that all contribute to using less energy to complete the same work — essentially, reducing energy waste. As a result, we may define Energy Efficient Logistic as the activity of logistics that consumes less energy; reducing energy waste without endangering the quality of the job output performance.

This paper is organized as follows: Section 2 is dedicated to provide explanation about the energy efficiency in logistic. Section 3 presents a framework of energy informatics. Section 4 discusses the freight transportation conception. In Section 5, smart warehouse examples are introduced. In Section 6, challenges for energy efficient logistics are discussed. Conclusion and recommendations are drawn in Section 7.

II. ENERGY EFFICIENCY IN LOGISTICS

A system's energy efficiency may be evaluated by defining its limits. The results of the energy consumption and efficiency assessment will be influenced by the system boundaries [5]. According to [6], a firm's ability to function, plan, and manage their company inside different system boundaries is clearly shown by the example.

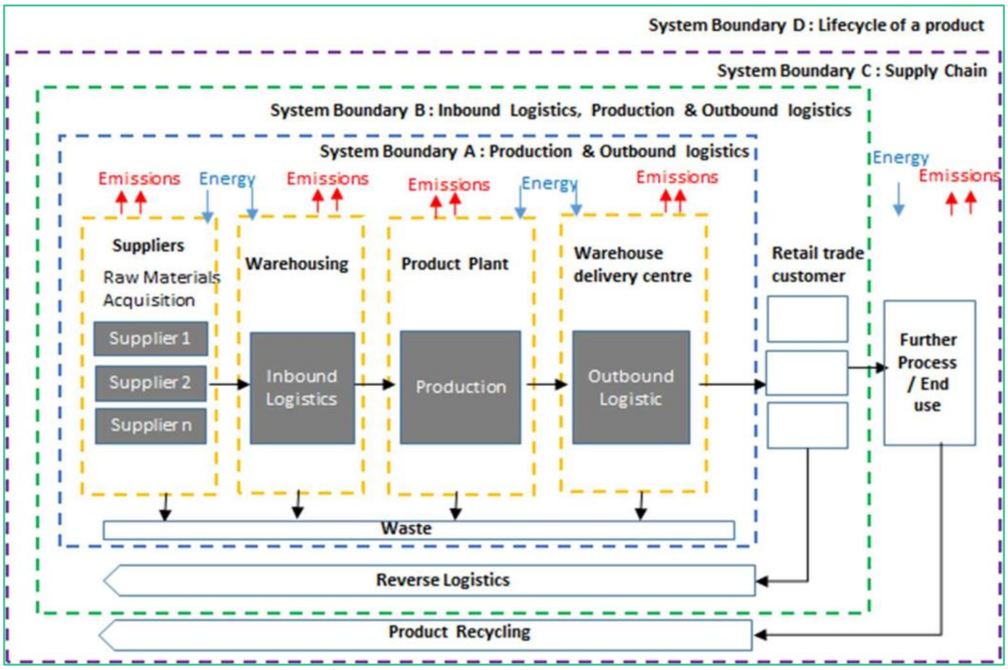


Figure 4: System boundaries for measuring energy efficiency in logistics [Kalenoja et al., 2011]

i) System boundary A encompasses activities, energy consumption, and emissions from manufacturing and outbound logistics.
ii) System boundary B incorporates additional energy and emission flows from incoming logistics, such as warehousing, raw material acquisition from the system's supplier, and garbage.
iii) System boundary C encompasses the whole supply chain, including both logistics to merchants and end users as well as reverse logistics. This system boundary also includes last-mile logistics fulfillment. The term "last mile" refers to the transportation activity that occurs during the last leg of the supply chain, i.e., the transfer of products from the merchant to the end customer.
iv) System boundary D evaluates the whole life cycle of a product, including recycling.

Freight transportation encompasses the most system borders, System Boundary D (Product Life Cycle), since transportation is necessary for the movement of both raw material supply and completed product in all processes. As a result, freight transportation accounts for a significant portion of energy consumption in logistics operations. Not to mention that warehousing for incoming and outbound logistics consumes a lot of energy in the process [7].

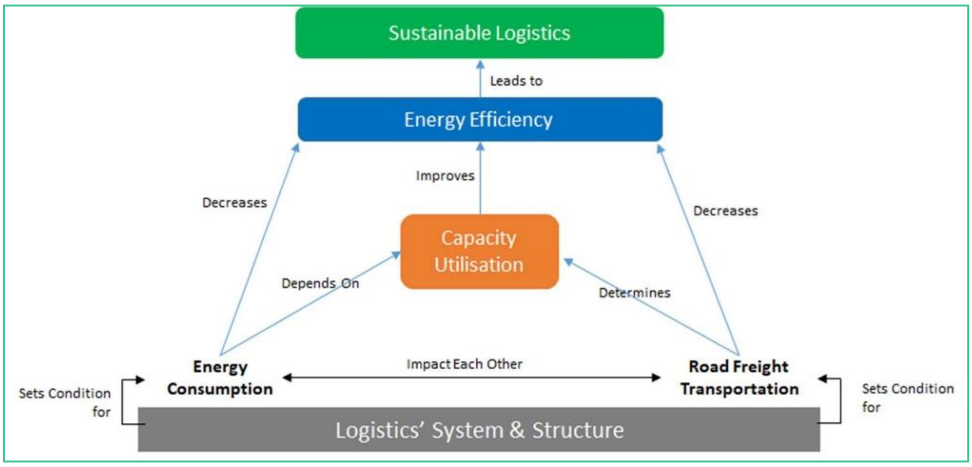


Figure 5: Conceptual Model of Sustainable Logistics [8]

This model, in our opinion, is equally relevant to warehouse management, which incorporates capacity utilization as well as space (area) as factors, in addition to other aspects such as inventory management and mobility.

Following that, we'll go through how energy informatics may assist cut energy use and give real solutions to environmental sustainability.

III. ENERGY INFORMATICS FRAMEWORK

Energy informatics is the study, design, and implementation of systems to improve the efficiency of energy demand and supply systems [9, 10]. This necessitates the collecting and analysis of large amounts of energy data in order to optimize energy distribution and consumption networks. In general, it emphasizes the use of an Information System (IS) to minimize energy usage through sophisticated practical solutions. To embrace environmental sustainability, a systematic scientific method is required to analyze issues while generating ideas to improve productivity, decrease expenses, and increase profitability. In theory, the Information System aids in the solution of global warming while establishing a sustainable society from an engineering aspect. Energy informatics defines the function of information systems in reducing energy usage and CO2 emissions. Thus, the Information System is the framework's beating heart and life force. Using this paradigm, we may better understand how to combine the supply and demand sides of energy to develop an integrated solution. The energy informatics system is shown in Figure 6.

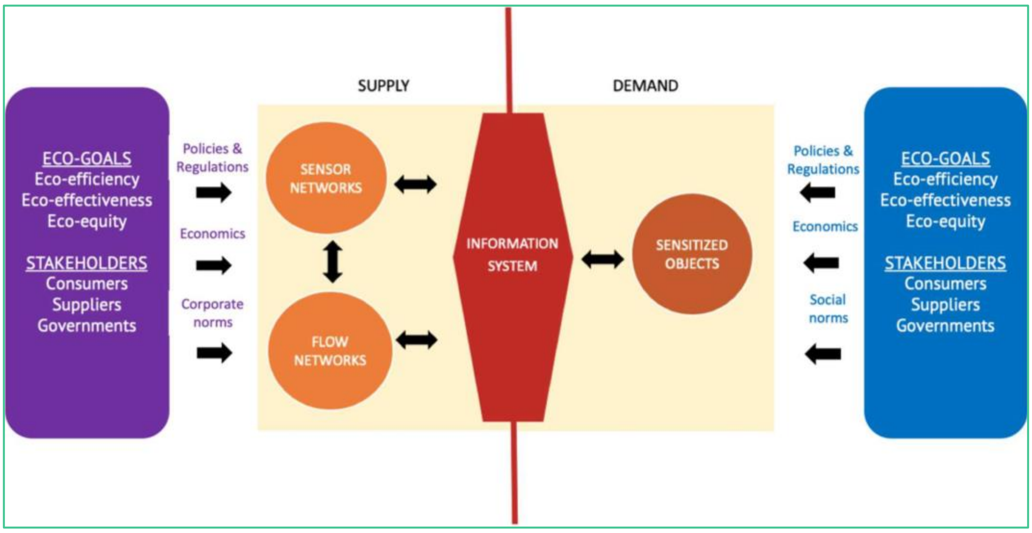


Figure 6: Energy Informatics Framework

Based on Figure 6, the energy consumption transactions included a provider of energy and service as the supply side and a customer from demand side. The information system in the midst of energy framework finds and produces an integrated solution by considering interdependencies of supply and demand side together with other aspects such as flow networks, sensor networks, and sensitized objects.

In order to lower their energy consumption as a cost of doing business, every organization has economic and regulatory concerns that must be addressed. The organization is compelled to minimize its carbon dioxide output according to regulatory laws. In addition, the providers have the power to regulate their customer demand. Because no real-time statistics are available to track changes in customer behavior, the supply side has an advantage in this area.

Flow networks, sensor networks, and sensitized objects are also important components of the energy system technologies in the energy informatics framework. The term "Flow Network" refers to a system of interconnected transport components that facilitates the movement of both discrete and continuous stuff, such as electricity [11], oil [12], air [13], and water [14]. In order to allow for change of state flow, the flow network offers dynamic optimization [15]. However, a Sensor Network is defined as a network of geographically dispersed sensors that provides physical object or environmental condition status. It determines status to address the optimal data consumption of a sensor network. In addition, a Sensitized Object is a physical object owned or maintained by a consumer that needs capabilities to detect and report its data consumption [16].

A relationship between the information system that acts the core of energy informatics framework accompanied with supply and demand on both sides as shown in Figure 7 [17].

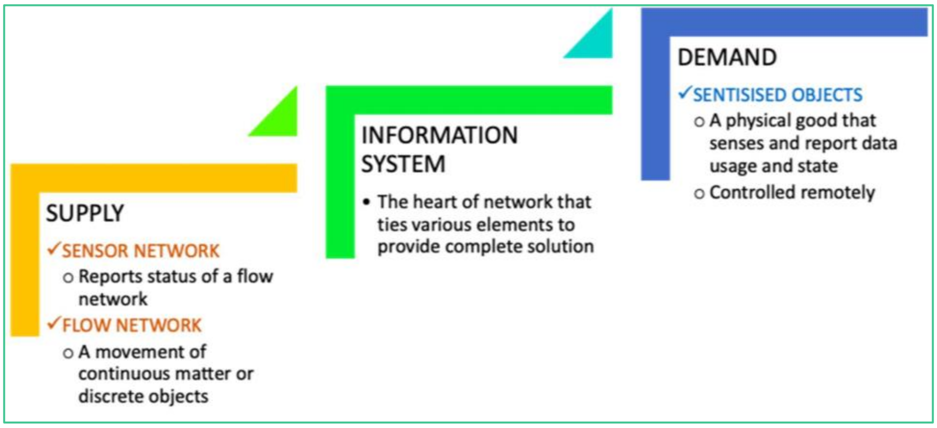


Figure 7: Overview of Energy Informatics Framework

Energy informatics is characterized as a "green" framework via system optimization to enhance environmental sustainability. On the basis of existing sustainability in the field, we can identify three primary sustainability objectives: ecoefficiency, equality, and effectiveness.

Eco-efficiency refers to supply of competitively-priced products and services to meet human demands while minimizing ecological effects and resource intensity for higher quality of life. In addition, eco-efficiency matches to contemporary company aims via organization that fulfills government regulation through cost reduction in manufacturing.

Eco-equity is equitable rights between individuals and generations to natural resources. It underlines societal duty to overcome environmental deterioration and excessive usage of resources challenges. Therefore, an equitable allocation of resources within and between generations is essential to attain these sustainability objectives. Shifting corporate and societal standards on customer behavior are two ways to do this.

"Eco-effectiveness" is a term we use to describe the concept of modifying business strategies in order to solve environmental concerns. Redesigning the economy to focus on efficiency, sustainability, restoration, regeneration and standard organizational aim may accomplish this.

The diagram below shows an overview of sustainability goals: -

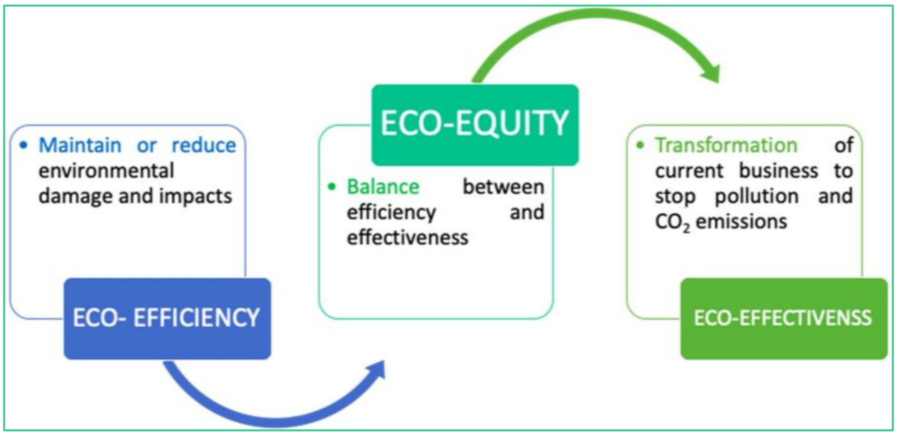


Figure 8: Three sustainability goals

IV. FREIGHT TRANSPORTATION

The transportation of freight by road is linked to the overconsumption of fossil fuels. It is indicated that the overall energy consumption might be lowered when capacity is completely used.

Capacity utilization of freight transportation could be a considerable influence on the energy consumption as it will optimize the loading space, delivery volume and delivery distance. For that reason, we advise the energy informatics framework should be structured in such a manner to meet that purpose of optimization.

Based on the energy informatics architecture depicted in Figure 9, the Flow Network (Freight Transport) are as follows:

i) Location Set on navigator

ii) Good stacked in the truck for delivery

iii) Starts delivery when system confirm optimum capacity and distance.

An empty space in the truck will be detected and sent to the IS by the Sensor Network (camera and sensor at freight transport loading space), allowing it to be used for capacity utilization and operation optimization purposes.

Information System (IS) will receive, analyze or interpret information and convey it to the sensitized object. The IS will give an explanation to the following problems associated with freight transportation:

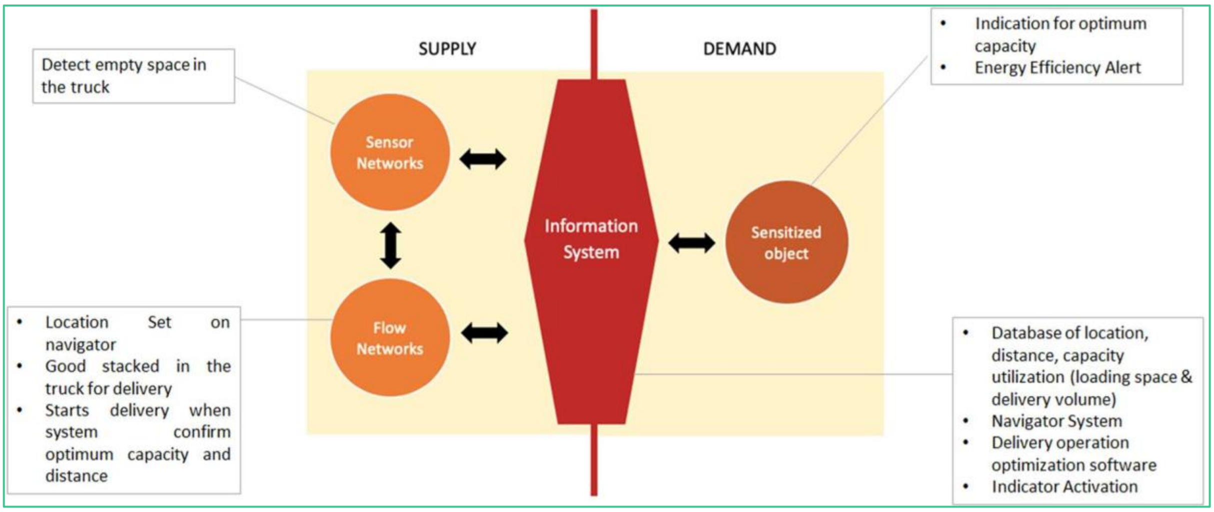


Figure 9: Energy Informatics Framework for Freight Transportation

i) Database of location, distance, capacity utilization (loading space & delivery volume)
ii) Navigator System
iii) Delivery operation optimization software
iv) Indicator Activation

Data use and status will be reported by IS to the Sensitized Object (Control Panel on the Driver Dashboard). For example, the control panel on the driver's dashboard will provide the indicator for optimal capacity (capacity utilization status) and Energy Efficiency Alert based on the real time capacity loading. With this information, the driver may make an informed judgment on whether or not the delivery should proceed or whether more loads should be added in order to increase usage.

V. SMART WAREHOUSE

A. Ali Baba's Smart Warehouse

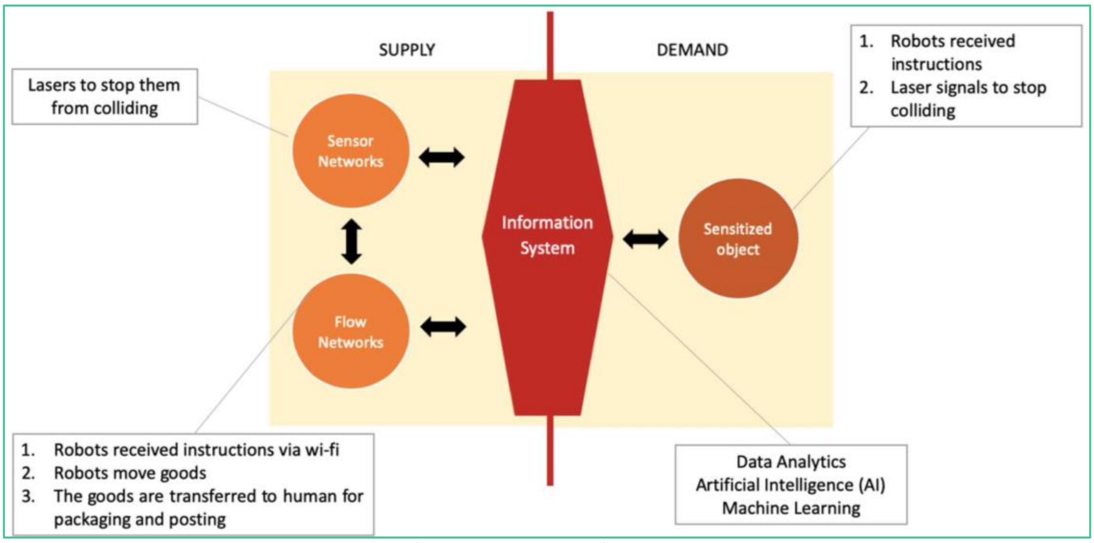


Figure 10: Energy Informatics Framework for Ali Baba Smart Warehouse

Ali Baba groups collaborate with a network of logistics providers dubbed China's smart logistics throughout the nation to accomplish responsive, scalable and flexible service to achieve cost efficiency for both supply and demand side. Thus, Ali Baba's smart warehouse is mostly managed by robots who are capable of lifting about around 1100 pounds or 500-kilogram products and spin 360 degrees on spot. The logistics business in China has seen significant transformation as a result of the package, pickup, and delivery completion rates that have been achieved via warehouse management.

The Flow Network (Robot) is as follows, based on the energy informatics architecture presented in Figure 10:

i) The robots got instructions through Wi-Fi and drive up to 3 miles per hour 5 kilometres per hour to the storage rack to pick up products and put them over to the shipping station.
ii) To complete the process of packing and shipping, products will be picked up by humans at a shipping station.

In addition, they contain collision avoidance laser sensors in the Sensor Network (Robot's Laser Sensor) that prevent these robots from running into one other.

However, IS offers an integrated solution by analysing information using Data Analytics, Artificial Intelligence and Machine Learning.

The Sensitized Objects (Robot's Signal / Data Receiver) determine the state of the robots. The robots got signal via instructions by Wi-Fi to automate efficiently to collect next commodities. They have a battery life of four to five hours. When the batteries are low, the docking stations will automatically dock for a five-minute recharge. Thus, after the work is done, the robots will return to await fresh orders.

B. *Auto-store Warehouse Robots*

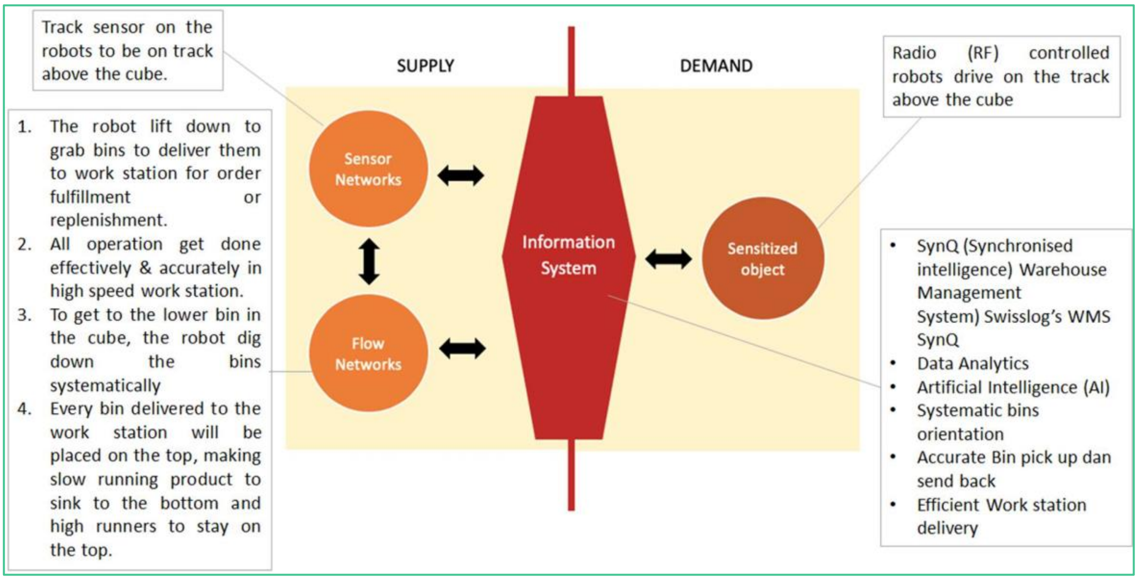


Figure 11: Energy Informatics Framework for AutoStore Warehouse Robots

AutoStore is a robotic storage device created by a firm called Hatteland. AutoStore is a game-changer in the field of warehouse administration. The major purpose for the product is to increase the quality of the internal logistics. In addition to being a green energy product, this system can decrease labor requirements, increase storage, and operate round the clock.

The Flow Network (Robot) is as follows, based on the energy information architecture depicted in Figure 11:

i) The robot lifts down to gather bins and transfer them to the work station for order fulfilment or restocking.
ii) All activities get done efficiently and precisely at high-speed workstation.
iii) To get to the bottom bin in the cube, the robot digs down the bins progressively. Every bin transported to the work station will be positioned on the top, causing a slow flowing product to sink to the bottom and high runners to remain on the top.

The Sensor Network (Robot's Track Sensor) receives and reports the status of a flow network so that the robots are on the correct cube track for pick-up and send-back operations during the transfer movements to humans for order fulfilment or replenishment at work station.

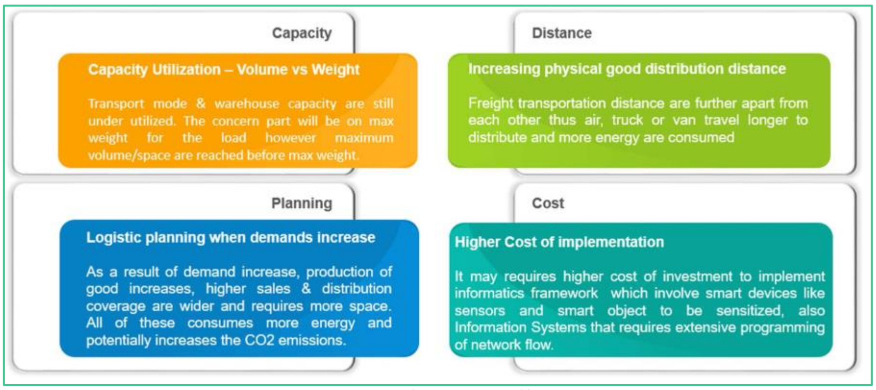
Information System (IS) will receive, analyze or interpret information and convey it to the sensitized object. The IS gives the following solution in freight transportation:

i) SynQ (Synchronized intelligence) Warehouse Management System) Swiss log's WMS SynQ
ii) Data Analytics
iii) AI
iv) Systematic bins orientation
v) Accurate Bin pick up and send back
vi) Efficient Workstation delivery

The Robot's Signal / Data Receiver will detect the input from IS and relay the status to IS. Here, robots will receive control signals using Radio Frequency (RF) to ensure that they are driving correctly along a path above the cube.

VI. CHALLENGES FOR ENERGY EFFICIENT LOGISTICS

More than merely decreasing your carbon footprint or the amount of packaging you use, "being green" is a way of life. In order to properly manage and eliminate trash, it is necessary to make environmentally-sensitive choices in the structure and execution of the supply chain, including the reverse supply chain. Businesses are in business to create profit for their shareholders, therefore any company that chooses to become green at any cost is being quite audacious. However, as fuel prices increase, economic and environmental concerns will merge even more, old fashioned operations management theory is directly relevant to carbon management. An effective carbon management strategy is one in which commercial ideas are applied to the environment, rather than the other way around. We may go into further depth regarding the challenges of ability, distance, preparation, and, of course, cost.



Capacity

Capacity Utilization – Volume vs Weight

Transport mode & warehouse capacity are still under utilized. The concern part will be on max weight for the load however maximum volume/space are reached before max weight.

Distance

Increasing physical good distribution distance

Freight transportation distance are further apart from each other thus air, truck or van travel longer to distribute and more energy are consumed

Planning

Logistic planning when demands increase

As a result of demand increase, production of good increases, higher sales & distribution coverage are wider and requires more space. All of these consumes more energy and potentially increases the CO2 emissions.

Cost

Higher Cost of implementation

It may requires higher cost of investment to implement informatics framework which involve smart devices like sensors and smart object to be sensitized, also Information Systems that requires extensive programming of network flow.

Figure 12: Challenges for Energy Efficient Logistics

Capacity utilization (load factor) is a significant criterion in analysing efficiency of freight transportation. Load factor may be described as a ratio of real weight of items to the maximum weight that can be carried on a fully loaded journey. Although certain stages of empty runs and load components below a particular percentage are unavoidable owing to the intricacy of optimization in trucking, those overall performance numbers advise that there is additional capacity that might be decreased. Maximum volume or space is thus reached before maximum mass. The optimization of capacity might lower the total number of kilometres pushed, which would relieve congestion and have a positive impact on both the economy and the environment.

One of the primary factors of energy usage and, as a result, CO2 emissions is the distance travelled. Freight transportation distances are wider away from each other hence air mode, truck or van journey longer for products distribution thus more energy needed. In addition, this increases the idle duration of vehicles and the amount of time it takes to return empty filled trucks or vans. It is also true that load variables have an effect on the distance versus GHG emissions per kilogram of product connection. There may be large emissions per kg km when small manufacturers or store owners drive their own trucks to wholesale marketplaces with low load factors, or tiny vans used by furniture merchants for modest loads to the customers' homes.

In addition, a framework of logistics and freight transport has to be built to be able to strengthen the harmonization and coordination of the numerous activities in supply chains to boost efficiency. Increased sales and distribution coverage necessitates more floor space as a result of the dynamic of increased competition and current consumption. All of this results in an increase in energy use and, thus, in CO2 emissions.

The design of an eco-friendly supply chain will undoubtedly cost more than normal. Investing in infrastructure, process automation and more efficient handling equipment undoubtedly will be a huge concern for a firm that has been working in conventional supply chain ways. However, a large amount of potential cost savings may be gained by its application in the long term. Making effective judgments by considering ecological sustainability may lead to successes of both aims at once: more efficient logistics and less emissions. Overall, a complete strategy must examine these costs in relation to other emission reduction initiatives in potential industries such as industry or power production.

VII. CONCLUSION AND RECOMMENDATIONS

A significant portion of our planet's greenhouse gas emissions are being generated by avenue freight transportation, which consumes a significant amount of energy. In order to increase the environmental sustainability of logistics, boosting energy efficiency in logistics is vital for environmental sustainability.

Sustainable organizations contribute to sustainable development by providing financial, social, and environmental advantages, according to the findings of a recent research. In fact, it helps to a decrease in pollution, visitor congestion and consequently it enhances the high-quality of life and also lowers health issues.

As a guideline we should adhere to green logistics operations which involve the environmental effect of alternative distribution methods, decreasing the energy use in logistic activities, minimizing waste and controlling its treatment.

Apart from that, logistics businesses need to equip Freight Transportation with the intelligent set up in the machine or system orientation through IS, to be power efficient with the optimization of loading space capacity usage, delivery extent and delivery distance. Warehouse owners must also follow IS as the enabler to an automated system which not only make warehouse operation more efficient but fewer labor, space and time required. Not less crucial than that, to conserve plenty of energy throughout the full orientation. End-user role regarding energy efficiency need to be enhanced and demand for further study to analyze internal and external expenses that effect the supply chain.

Some highlighted findings and major contributions are listed as follows:

1. The areas of transportation, storage, and packaging are all significantly impacted by logistics. Therefore, it has been provided a quality delivery of the goods, and as a result, the happiness of the consumers has increased.

2. According to the conclusions of a recent piece of study, sustainable organizations provide a positive contribution to the field of sustainable development by offering benefits in the areas of finance, society, and the environment.
3. Improving the energy efficiency of the logistics industry is one of the most important things that can be done for the environment in order to make the logistics industry more environmentally sustainable.
4. When evaluating the effectiveness of freight transportation, capacity utilization, also known as load factor, is an important metric to consider.
5. It has been found that the development of an environmentally friendly supply chain will surely come at an increased financial outlay. Investing in infrastructure, process automation, and more efficient handling equipment will surely be a significant issue for a company that has been functioning in traditional supply chain methods. This is because these areas are essential to improving overall efficiency.

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