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Hospital Logistics Management Using Industry 4.0 Techniques

Álvaro Junior Caicedo Rolon[1] , Wlamyr Palacios Alvarado[2] , Marvin Vladimir Dávila Perez[3]

[1] Faculty of Engineering, Universidad Francisco de Paula Santander Cúcuta, Colombia, https://orcid.org/0000-0002-3651-3364

[2] Faculty of Engineering, Universidad Francisco de Paula Santander Cúcuta, Colombia, https://orcid.org/0000-0002-4292-4178

[3] Faculty of Business Sciences, Universidad Francisco de Paula Santander Cúcuta, Colombia, https://orcid.org/0000-0002-6935-2413

Abstract

Industry 4.0 is the new revolution that combines advanced techniques of modern state-of-the-art intelligence in products, processes and services. The Internet is indispensable for this type of Industry 4.0 to work. In the logistics processes of pre-hospital care, it has taken much importance as it has helped these processes to be more productive by applying technologies such as; internet of things, Big data, simulation, in the cloud information that can be integrated with the use of mobile or portable applications through communication signals between them. The objective of the literature review article is to perform an analysis of how industry 4.0 has innovated the logistics processes of prehospital care to make decisions in operations of how to care for a patient in various situations before reaching a medical center, the methodology used is a literature review of scientific articles and books as a basis for research, in the results were found different applications that has the industry 4.0 in prehospital processes and that in this field of health is valuable to preserve the lives of people in emergency situations. In conclusion, we found technologies that are being used in different parts of the world in prehospital care and all the requirements it demands, in addition to the schemes in the processes in the step by step decisions to be efficient and effective in the care of patients who suffer an accident or illness.

Keywords: Prehospital care, Health 4.0, Industry 4.0, Logistics, Technology.

Introduction

Industry 4.0 has taken the initiative to integrate the Internet into machines and equipment with remote control features, thus giving way to the concept of Internet of Things (IoT) technology and Big Data as a tool to make new trends in industrial and social development. As an example are autonomous electric vehicles that can be addressed with different voice commands, sensory, data through the cloud and artificial intelligence such as augmented reality and cyber-physical systems Frank,et al;(2019).

The technologies that integrate Industry 4.0 converge physical, digital and biological systems, and employs the internet of things, Big data, 3D printing, artificial intelligence and robotics, cloud and fog information, cybersecurity and blockchain, etc. (see figure 1) Saturno,et al;(2018).

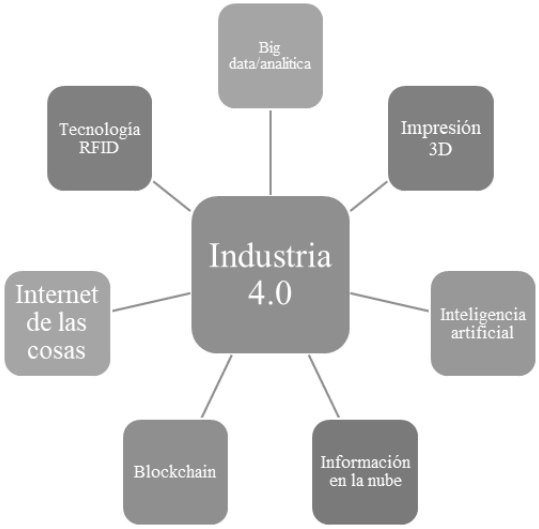

Figure. 1 Industry 4.0 technologies

Germany was the pioneer country in Industry 4.0 as an alternative to remain globally competitive thinking about manufacturing production that allows everything to be connected through the Internet of Things. thus achieving a transition to what we could today call smart cities or Smart cities creating countless opportunities and advances Witkowski,k;(2017)

4.0 technologies are the internet of things that include sensors, cell phones, and computer equipment linked together, allowing the sharing of information. Artificial intelligence, which is the programming of equipment to generate automatic responses according to certain parameters, including robotics. Information in the cloud, which are platforms that store important documents and files on the network and are available at any time anywhere. Big data which is data management and includes the analysis of these to determine results or answers Quintero,et al;(2019).

The digital information and communication technologies of industry 4.0 in the hospital sector are known as health 4.0 (H4.0); this approach in health is intended to change the way of assisting hospitals with four capabilities within the system: monitor, anticipate, respond and learn; with this technology manages to minimize the excessive dependence on human habituation skills and, in parallel, give new and greater opportunities for resilient performance in emergency Luz, et al;(2021).

Prehospital care is the medical care of the patient previously injured or with various complications of some disease, by a physician or other health person Donalds,(2017) Emergency medical services (EMS) personnel have logistical distributions at the level of a society, but they lack efficiency which makes injuries and other medical emergencies increasingly common becoming more frequent in the general population. Most people die in prehospital care, therefore, an expansion of prehospital care will be required in its processes with technology Jindal, et al;(2020),The major difficulties currently faced in prehospital emergencies are transportation difficulties due to traffic conditions and delays in hospitalization due to lack of available beds. Rescue operations can last many hours, which has a direct impact on patient survival and ambulance availability Dos Santos, et al;(2015).

With simulation technology it is possible to take into account different variables that appear in the pre-hospital care that goes from the first contact with the patient until the beginning of the hospital care or even surgery, these variables are divided into two steps. The first step is to define the patient transfer time. The second is to integrally choose the function of the chosen route from the original location of the

patient to the hospital, with this simulation method must find the fastest method using different technologies of industry 4.0. such as first diagnostics applications and routing systems.

The results of application in innovation for pre-hospital care show benefits where the main advantages supported by these Industry 4.0 technologies develop smart cities with pre-hospital emergency medical systems. In this way, first intervention and transfer times can be reduced, thus managing to reduce possible deaths due to delays and deficiencies in diagnoses before reaching hospitals. Derevitskiy,et al;(2017) this article seeks to give a clearer idea of the possibilities of application of industry 4.0 in prehospital care processes taking as a basis the main issues related to industry 4.0 technology and all its implications that demand in logistics processes such as applications, impacts and case studies applied in health entities worldwide.

Method

In order to describe the advances in Industry 4.0 in the logistics processes of pre-hospital care, this research was conducted based on a literature review of indexed and peer-reviewed publications in the last five years, i.e., between 2017-2022. The databases consulted were Science Direct, Researchgate, PubMed and Google Scholar, taking journal articles, conferences, textbooks, theses and case reports.

Figure 2 shows the contribution of documents from each database according to the selected references, PubMed is a specific database of articles published in the health sector, so the contribution to this research is evident. Science Direct, on the other hand, is a starting point because it has a large number of scientific articles from journals approved in Publindex, and they are open access.

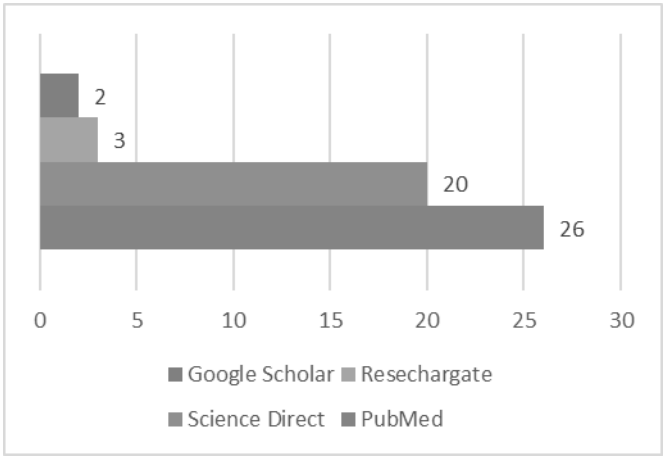

Figure 2. Databases consulted in the investigation

The search was carried out using the following keywords: industry 4.0, pre-hospital, emergencies, applications, internet of things; one or several terms in Spanish and English were combined, using the Boléan operators to be more precise in the results. After a quick reading, 50 articles were taken for the study of this research.

The methodology applied for the literature review contemplated the phases of review, detection, consultation, considering the summary, keywords, introduction and conclusions of the references. Information was extracted related to theoretical bases of industry 4.0 and application to prehospital care logistics processes, proposed and implemented programs and the impact of these Hernandez, R,(2014).

As shown in Figure 3, the bibliographic references contributed to the research were classified according to the years, and it is evident that the year 2017 has the highest scientific contribution, and the last 3 years between 2020-2022 contributed the same number of articles as shown in Figure 3.

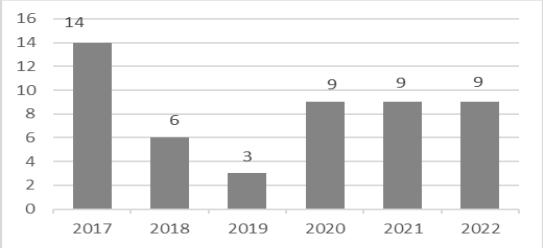

Figure 3. Research references by year of publication

Analysis of research information

In Industry 4.0, the internet of things is one of the main technologies where they use devices such as low-cost sensors where through a database they collect information needed for logistical processes of an operation using the internet. As for machine learning is essentially used to measure, archive data parameters in industrial processes, machine learning has a great impact on the detection of surveillance systems; classification models for health monitoring and fault detection Ahuett & Kurfess; (2018).

Industry 4.0 cyber-physical systems technology that combines statistical data, computer modeling and real-time data obtained from physical systems to model system response in different scenarios for real-time decision making, Despite the similarities, virtual reality and augmented reality are different technologies. Virtual completely separates the user from reality, while augmented reality allows to complement reality with digital projection through a device such as smartphones or computers Meindl,et al;(2021).

A. Industry health 4.0 (H4.0)

Innovations in hospitals are being made through the adoption of technologies that benefit not only the institution but also involve patients, healthcare technologies can improve operations in efficiency and competitiveness. It also improves the productivity of hospital providers by reducing the cost of hospital errors, such as readmissions and patient claims. In addition, information technology simultaneously reduces more accurate diagnosis by enabling physician-to-physician consultation Ancarani,et al,(2016).
B. Pre-hospital logistic care

With the advent of technological advances and the age of automation, Industry 4.0 has emerged to improve the prehospital industry and services. By incorporating Industry 4.0 technologies, the operational efficiency of public health systems and all their care networks is maximized to save human lives. The idea is to optimize the current healthcare system where unnecessary tasks or deficient methods can be eliminated or reduced through effective decisions such as prioritizing patients to receive first-class care.

In addition, the operational performance of the supply chain network can be improved through the coordination of the healthcare system using zero waste philosophy and advanced operations engineering analytical methods for logistic process decisions Fatima;et al;(2022).

Disease tracking is fundamental in measuring the quality of a complex prehospital intervention, which

is influenced by the quality level of the supplier who is in charge of supplying the technologies of the logistic process category, especially for emergency systems that depends on the special development in the prehospital environment according to its need. In this same sense, modern technologies are helping to minimize this limitation and increase reliability in the accuracy of documentation in databases. For example, electronic medical records with automatic records, have a higher accuracy in the collection of medical records Kottmann,et al,(2022).

Emergency medical services take the lead in the response and care of patients, many of whom are in life-threatening conditions. Such is the case of the global pandemic covid-19, which put the entire health system to the test, reflecting the shortcomings of the logistic systems for patient transfer, encouraging hospitals to adopt technological measures to reach a greater number of the affected population.[16]In this case, the structure of healthcare resources is optimized by formulating a new strategy for allocating medical logistic resources (see Figure 4) from large hospitals and redistributing them through a shared data network to small and medium-sized health centers Chu, et al.

EMS also has to handle calls from various situations, such as accidents, natural disasters, terrorism, epidemics, and patient transport from the logistical point of view to respond to difficult scenarios through logistical decisions.[18] Resource planning and utilization must be done efficiently to achieve a satisfactory response in each situation. Travel speed is a key parameter in operational decisions to address regional and area complexities, including terrain, prehospital incident response time, traffic flow and resource availability Olave & Nickel;(2021)

The most difficult issues in ambulance dispatching consist mainly in the identification of the different waiting points for dispatching, which are usually handled at a tactical level and in some cases must be solved in real time. In fact, EMS leaders often have to make decisions on vehicle allocation which are usually very quick decisions and even almost instantaneously, in order to maintain an adequate level of service Soriano,P;(2012).

C. Industry 4.0 applications in prehospital ***care logistics processes.***

Prehospital diagnosis is fundamental today in patients transferred to the health center in a timely manner, with this positively affecting mortality rates and decreasing the degree of complexity of the condition Iglesias & Nuñez ; (2019). In prehospital applications, telemedicine appears as personal remote medical care that includes data such as blood pressure, pulse, weight, and subjective health information, provided by the patient, transmitted electronically to the physician for personalized feedback of each patient procedure Murias, et al (2012).

In the event of an emergency, the process starts with a call to the operators, who in turn focus the solution according to the need described by the caller. In the case of health emergencies, the ambulance and paramedics are called, but the patient can be assisted from the line if the necessary technology is available to determine the medical situation he/she is experiencing, through artificial intelligence tools that can classify whether it is sepsis, a heart attack or cardiac arrest and provide resuscitation parameters to keep the patient alive while emergency personnel arrive Anthony, et al;(2021).

The first step when entering a primary care is to make or go through the TRIAGE, which is nursing staff that takes the data and signs of the patient in question, there is a collection of information that will be useful for the treating physician, but it has been shown that in emergency rooms this collection of information may not be accurate and have inconsistencies. Here the 4.0 technologies have explored making a triage through an application on smartphones, which allows the patient to fill out this information in an a priori way managing to be more assertive and faithful to the real Xie,et al;(2019).

In triage, patients are classified according to the severity of the emergency, and this is used to treat them, and according to this classification, patients are attended. The emergency severity index also allows predicting serious results in emergency patients with the objective of prioritizing patients with greater clinical risk, but sometimes these indexes are not assertive because they are based on obsolete algorithms and others are designed with new algorithms to gain precision in the results considering the new information systems Saberian;et al;(2022).

Primary care in medical emergencies at night is congested, since the availability of medical specialists is limited. Many patients go to the doctor for abdominal pain, cough or skin affections, some of these cases can be treated at home and some require medical observation, to depressurize the emergency service, mobile applications have been designed that offer answers to these types of ailments previously mentioned Verzantvoort;et al;(2018).

In pre-hospital care, telecare is based on a real-time synchronous system where patients and health professionals are required to be available at the same time and process patient data simultaneously, thus transfers from the point of patient encounter to the paramedics must be in contact with the physician sending instantaneous data information Follmann, et al; (2020). Remote monitoring and follow-up through telecare is an alternative treatment strategy, where possible the system should be able to automatically transfer data stored in databases, to outpatient clinics using shared system networks for real-time mobile wireless communications Sorensen,et al;(2013).

Such is the case of the mobile application "Enfermería APHMóvel", which allows feeding data to the system, viewing the patient's medical history, as well as the selection of diagnoses and viewing results and previous nursing interventions in all the logistic processes of mobile prehospital care. It also ensures the recording of patient information, providing indicators for service management and future medical logistic research Pizzolato,et al;(2020).

In an emergency, time is vital to save lives; it takes fractions of seconds to keep a patient alive. In response to this situation, applications have been designed to improve patient care times. In the area of cardiology, strokes or myocardial infarction are common in pre-hospital care, so the PULSARA application favors patient-centered care times Blandin,et al;(2022). Another mechanism that has been implemented in this type of emergency is teleconsultation with the specialist physician from the ambulance, to define the severity and the decisions to be followed regarding the intervention that should be performed or the patient should be taken to a more specialized care center Mazya,et al;(2020).

The acute ischemic stroke is a time-sensitive disease, i.e., the longer it takes the more complicated it is, so an application called FASTroke was developed to link the emergency medical service (ESM) with potential patients who may suffer this disease so that through notification they can receive timely care, preventing an unfavorable state of health Lee,et al; (2021).

One of the factors that affect emergency care is the speed at which situations occur and sometimes the diagnosis by medical personnel is not the most accurate due to lack of tests that cannot be performed on the patient because he/she is in a critical situation. In the vascular area aortic aneurysms represent a high mortality rate and the diagnosis is not simple, so in support of this situation a smart phone tool was created that helps the paramedic in emergency status to make a more accurate diagnosis Lewis,et al;(2016).

On the other hand, in the case of practicing tests and laboratories, waiting times for results are long, so it is vital to manage this information remotely through the internet of things, and cloud information, so that it is available to emergency personnel in short times and reduce the wait in the diagnosis and application of medical treatment Ehrler, et al;(2022). Emergencies require agility and even more so when

it comes to children, since it requires specialty and patience to interact with this type of patient. Children present emergencies due to cardiopulmonary arrest infrequently but without a high mortality rate Corazza,et al;(2020), this condition requires agile medical treatment, and the child population is more susceptible to medication errors. In response to this, an application for mobile devices PedAMINES was developed to reduce errors in the preparation of medications requiring intravenous injection, as well as to reduce preparation times and administration time Siebert, et al,(2022).

The transfer or arrival time is fundamental in pre-hospital logistic processes, Industry 4.0 technology allows us to have portable monitoring as is the case of the multivariable logistic regression model used in Japan that helps to control the oxygen of patients while they are being transported by ambulance to the nearest hospital. This technology helps to keep people alive in their resuscitation process, Sakai,et al; (2021).

Another problem that arises is the diversion of ambulances that increase patient transfer times that are aggravated by the lack of timely medical attention; on the other hand, it was found that avoiding diversions minimizes the amount of money lost due to additional trips, also increases in medical supplies applied to the patient and consequently by lawsuits due to lack of timely medical attention, thereby reducing revenues substantially for the hospital. For this reason, emergency communication system technology was developed in order to improve process performance such as ambulance dispatch management, decrease time lost in ambulance diversion and improve communication links between the ambulance and the hospital l Masri & Saddik; (2012).

Therefore, the aim is to evaluate the travel time from the point of departure to the nearest health center and also, if an ambulance is diverted while traveling and a new destination is established, this would imply that it is necessary to evaluate where the ambulance is in real time and calculate an accurate travel time from that point to the new destination. Thus, various systems can be used to estimate travel times through a linkage between geographic information systems (GIS) and prehospital care systems.

These systems provide real-time information on data such as traffic, decreasing transfer times, likewise through the feeding of databases can be estimated the average travel time duration of the most frequent places and thus be able to position ambulances in strategic locations so that these respond in less time Kergosien,et al;(2015).

When there is an emergency, the paramedic may encounter foreign patients who do not speak the native language and communication becomes complicated, which is why a digital tool was designed that allows the paramedic to communicate with a foreign language person in order to accompany the patient and approve what is practiced Noack,et al;(2020).

A phenomenon that occurs in the ambulance service is that it is generally a nursing professional who is at the service of the patient, but sometimes does not take action in the transfer from the emergency to the hospital, which means that time is lost in some treatment that can be applied on the way, which is why the remote accompaniment of doctors to the nursing professional in video arises, favoring the safety of health personnel in the ambulance and the participation of the patient in the situation Vicente, et al;(2021).

This situation also occurs between the transfer of the ambulance to the scene of the emergency, so it is suggested that direct communication between bystanders at the scene and paramedics, that is, not only to report the emergency but to serve as a bridge to know the status of those affected through video calls or videos shared by a social network, making the paramedic prepare their material and facilitate the correct diagnosis impacting the mortality of patients Sonkin,et al; (2022).

Any human being is exposed to experience a cardiac arrest at some point in life, without being warned, and timely attention to these episodes can save lives; but not all people are trained to perform resuscitation and medical personnel with little experience may not make the right pressure at the right time, which is why an application that has been tested in medical students was generated to guide the resuscitation process, guiding in real time the chest compression to be applied Metelmann,et al;(2021) .

In this situation, first responders are also prepared, and can go to provide cardiopulmonary resuscitation before an ambulance arrives, by means of notification through a mobile application indicating that a certain citizen requires first aid to ensure the patient's life Andeluis,et al;(2020). In the description of 4.0 technologies applied to pre-hospital care, we can highlight that the technology that provides more applications is the internet of things and merges with others such as artificial intelligence, information in the cloud and Big data, to create applications or resources that contribute to continuous improvement in aspects such as execution time, accuracy and assertiveness in diagnoses (see Figure 4 below).

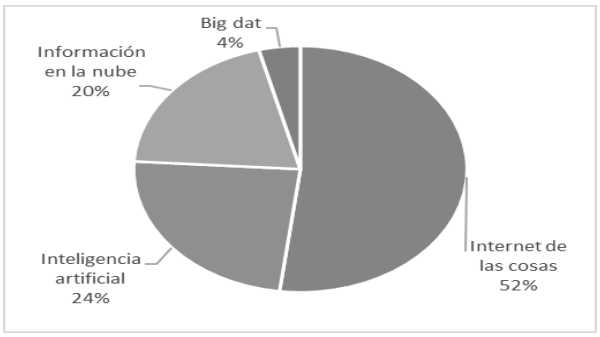

Figure 4. Application of Industry 4.0 techniques in the hospital sector.

Discussion

The applications and use of smart cell phones have increased the efficiency of data transmission in rural areas and difficult access for the health system improving in previous communication system based on radio waves in this way mobile cell phones enhanced the logistical process of care, however there are barriers to implement cellular technology in rural environments include travel time and all the necessary costs of trained personnel for installation and instruction of technicians who will attend medical emergencies.[45] There is also a limitation of smartphone technology is that certain functions are essentially dependent on a signal from the carrier's network (internet). So the lack of signal will prevent the use of the Global Positioning System (GPS) element of the application and communication with medical centers for patient transport would be lost Es & Crouch;(2015).

As for the professional training of paramedics, there are still shortcomings between face-to-face and virtual learning, such is the case of the results of a study which shows that those who learned to perform virtual cardiopulmonary resuscitation increased the rate of thoracic comprehension, but showed shortcomings in lower compression and less general skills that are gained with face-to-face training Nas,et al;(2020). This means that technology-mediated learning 4.0 still requires other tools to be enriched.

The health emergency restricted clinical practice in neonatal intensive care to the nursing student, so industry 4.0 was resorted to through a gamification program using immersive virtual reality to gain hands-on learning, and the result of this experimentation increased neonatal resuscitation knowledge, self-confidence, problem solving and learning motivation Yang & Oh ; (2022), which indicates that well-focused 4.0 tools in learning generate good results.

Medical personnel are still not completely confident in remote care when the paramedic or nursing staff exercise activities that are not their own, such as performing an ultrasound and passing the information to the specialist physician to determine the diagnosis. Although the healthcare personnel attending an emergency consider doing an ultrasound to be easy, the specialist physician considers it to be distracting them from the important emergency Eadie,et al;(2018). Remote care is effective when the emergency personnel perform the job they were trained to do and relay the information to the physician without intervening in their medical opinion.

Although smart glasses are on the market, their use is very limited, either because of the cost involved or because of the complex understanding of their use. In the case of healthcare there are studies of the use of smart glasses in pre-hospital processes to facilitate the collection and documentation of patient data, support decision making and greater knowledge of the situation they are experiencing; but barriers are presented in terms of reliability, privacy and hardware limitations Zhang,et al;(2022).

Conclusions

Industry 4.0 has permeated all sectors of society, enriching education and healthcare, offering innovative alternatives that improve service delivery and facilitate the work of healthcare personnel.

The Industry 4.0 tool that is most used in pre-hospital care logistics processes is the Internet of Things, since remote assistance between healthcare personnel or with the patient means that emergency times are reduced and errors are minimized in terms of diagnosis or medication formulation.

The use of technological means with the cell phone is becoming more and more frequent, and a doctor can monitor a patient from his cell phone, but it requires experience and a lot of confidence; there are still barriers in the implementation of these resources in the performance of medical personnel but these are temporary situations that can be modified with the constant use of technologies.One of the branches of medicine that benefits from 4.0 technologies is cardiology, since it favors the rapid intervention of health personnel in situations of cardiac failure.

Big data technology is a field little explored in pre-hospital care, but it would be necessary to generate significant changes in the logistic processes through data.as future lines of study to this research is the classification of the tools according to the area of knowledge and include the 5.0 technologies.

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