Design and Implementation of an Intelligent Information System Based on ASP.NET MVC Technology for Rational Deployment of Medical Equipment

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Design and Implementation of an Intelligent Information System Based on ASP.NET MVC Technology for Rational Deployment of Medical Equipment

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Abstract

Background: The problem of inappropriate deployment of medical equipment in hospitals is a significant issue in China. The purpose of the information system for rational deployment of medical equipment (MERDIS) is to inform judgements about the efficient and rational deployment of medical equipment in hospitals. For research needs, the basic information of 52 hospitals in Shanghai and other provinces are investigated. The deployment method based on clinical pathway and deployment method based on big data are designed to support the data analysis of the system. Through the analysis of macro data, the rational deployment plan of medical equipment in a certain hospital is given.

Result: Through the MERDIS system, it is convenient, accurate and intuitive to get the rational deployment plan and suggestions of different types of hospitals affected by different factors can be given conveniently, accurately and intuitively.

Conclusion: The design of the MERDIS system provides the development basis for the subsequent development of medical equipment macro data management. In the process of continuous improvement and supplement of data, the software model will become more and more accurate and reliable.

Keywords: ASP.NET MVC; SQL Server; rational deployment of medical equipment; big data.

Background

At present medical and health resources are still scarce resources in China, the problem of inappropriate deployment of medical equipment in hospitals is a significant issue. Irrational and excessive purchase or insufficient deployment of large-scale medical equipment is widespread. However, there are a limited number of studies on the deployment and utilization of large-scale medical equipment [1-7]. This paper aims to the design a system which provides a rational recommendation of medical equipment deployment by entering the basic information of a hospital.

There are multiple advantages in addressing and solving the problem of irrational deployment of medical equipment in hospitals. Such benefits include, among others: an increase in the utilization efficiency of medical equipment resources; improving the care and health of patients; reducing medical appointment waiting lists for diagnosis and treatment; and ensuring that newly established hospitals are adequately and efficiently equipped. As such, many benefits arise for patients, health practitioners and hospital management in establishing an effective medical equipment deployment planning system. This is particularly important in public hospitals where resources are limited and capital expenditure needs to carefully managed.

The deployment of medical equipment is typically the remit of the hospital equipment department. Indeed, there is a body of domestic literature on the methods of medical equipment deployment. However, such literature tends to be limited to a certain hospital and does not consider the hospital as a unit [1,2]. Furthermore, foreign research has an explicit focus on emergency medical equipment control methods [3]. Either for the special situation of medical resources allocation analysis [4,5], to solve this problem ethically [6], or for the allocation of scarce medical resources research. There is, therefore, a gap in the literature as it has not yet considered the potential role of detailed and complex statistical investigation in equipment deployment.

The information system for rational deployment of medical equipment, or MERDIS for short, is developed with Visual Studio2019. The main framework is ASP.NET MVC, its development language is C# and the database is SQL Server 2012. In order to provide data basis, this study investigated the basic information of 52 hospitals in Shanghai and other provinces, including the basic attributes of hospitals, diagnosis and treatment information and the current deployment of medical equipment. Among them, 20 hospitals also investigated the data of clinical pathway. The investigated hospitals include general hospitals, obstetrics and Gynaecology hospitals, children's hospitals, etc. The MERDIS analyses the above data in the database in two ways and gives the corresponding deployment value recording to the hospital parameters. The first way is to calculate the clinical pathway data of the exact hospital, then analyse the hospital's demand for certain medical equipment and calculate the theoretical minimum deployment value, and the corresponding formula is derived to calculate. The second way is to analyse the weight of each hospital parameter through big data, and give the recommended deployment value through the general rule of the medical equipment deployment of the hospital.

The deployment quantity of medical equipment should be directly affected by the frequency of usage of such equipment, and the frequency of usage of equipment is directly affected by the frequency of surgeries and visits in the hospital. At the same time, the level, built-up area and physician resources of the hospital cause the differences in the frequency of surgeries and visits in the hospital. The annual income of the hospital directly reflects the differences of the frequency of operations and visits among hospitals. Therefore, the deployment method can be designed base on the above different information. By collecting the above data, the different influence factors were analysed and processed. And then rational deployment plan of various medical equipment in different hospitals is provided to achieve the purpose of giving the rational deployment plan of medical equipment in hospital.

Implementation

Functional requirements analysis

The main users of MERDIS are the hospital equipment managers or the relevant personnel of the hospital procurement centre. Ordinary users have the authority of login, register, information enter, query deployment plan and other functions. On the basis of the functions of ordinary users, administrators have the authority of user information management, hospital information management, information check and modification. The information entered by users including: the basic influencing factors of the hospital; the deployment information of medical equipment; the clinical pathway information. **Fig 1 Usage case diagram of the MERDIS.** Each instance represents the functions that the user can realize, among which, the administrator can implement the functions implemented by ordinary users. The administrator has additional rights of information check and information management.is a usage case diagram of the MERDIS.

System Design and Architecture

The development environment of METDIS is Microsoft Visual Studio 2019, the development language is C# and the back-end database is Microsoft SQL Server 2012. The key technology which the system based on is ASP.NET MVC framework. ASP.NET MVC is a framework for building scalable, standards-based web applications using well-established design patterns and the power of ASP.NET and the .NET Framework. MVC-based framework is divided into three parts which are model, view and controller. This framework divides data and view independently and loose the coupling between modules. In this framework, the browser sends the client request to the front-end controller. The controller forwards the request according to the configuration file, and the back-end controller interacts with the processor mapper. After determining the view corresponding to the request, the data model is extracted from the database through the data interaction layer and processed. Finally, the model and view of the execution result are rendered, and the interface view with data is returned to the user. This mode fully applies each component in the whole operation process, and realizes the traits of dynamic modular update of the system (8).

Take data transmission, the deployment information of the hospital medical equipment which used for various analyses in the system is stored in the database, the client requests the deployment recommendation from the system in the browser, the controller receives the operation instruction, and sends the data output command to the database. The corresponding part of the data in the database is taken out through the data model, and then calculated by a series of algorithms in the controller. Finally, the recommended deployment quantity or theoretical minimum deployment quantity should be fed back to the user through the view (display layer). **Fig 2** is the diagram of MVC parts.

Function module design

The main application objects of MERDIS is medical equipment, and the main users are hospital staff. The target aim is to recommend and evaluate the deployment of medical equipment. For ordinary users, they should register before logging into the system. As the hospital data is highly confidential, for information security, the registration information should be checked by the administrator first, and then the users can log in to the system. After logging in, users can query deployment recommendation, query deployment evaluation and upload hospital information, medical equipment information, clinical pathway information. For administrator users, on the basis of the functions that ordinary users can achieve, they can process the user information and hospital information in the database. At the same time, the information check function is added, to check and approve the newly uploaded user information and hospital information. The abnormal information of users and hospitals are rejected or deleted, and only the normal data can be input into the database. **Fig 3** shows the functional flowchart of MERDIS.

Database design

The main entities of MERDIS including: users; hospitals; equipment; diseases. Each entity is a table in the database. The relational table between the hospital and medical equipment is “deployment” table, and the relational table between disease type and hospital is “DInfo” table, which is used to represent the frequency of diagnosis and treatment of hospital diseases. For disease types, equipment and hospitals, the relationship between the three came into being a table “CP”, which stores clinical pathway information. What’s more, in order to facilitate the representation and save storage space, “hospital-categories” table was set up for hospital classification, “equipment-categories” table was set up for equipment classification, and “daily work” table to record the daily workload of different types of hospitals for different types of equipment, “variables” table was set up to store calculation information. **Fig 4** is the database class diagram of MERDIS, through which we can intuitively understand the logical relationship between various table items in the database.

Deployment methods

deployment method based on clinical pathway

The basic information of the 52 hospitals surveyed includes the attributes of the hospital, category, the number of beds, the annual number of surgeries, the number of doctors, the annual medical income and the building area of the hospital. The information of clinical pathway includes the disease type, the medical equipment used in each pathway, the usage times of the equipment and the annual implementation times of the pathway. The annual demand of clinical pathway is calculated first. Based on the clinical pathway data of a hospital in the database, according to the capacity of the equipment, the annual clinical pathway demand of each kind of medical equipment in each hospital can be analysed out. Because the clinical pathway on file in the hospital cannot cover all kinds of diseases, the proportion of the operation volume of the clinical pathway in the total operation quantity can be calculated by according the annual operation quantity of the hospital. The actual operation quantity of the hospital is approximately replaced by the total amount of clinical pathway used divided by this proportion, so as to improve the accuracy of the theoretical minimum deployment value. The formula is as follows:

$$R_{p,q} = \frac{H}{\sum_{j=1}^{k} M_j} \cdot \left(\sum_{i=1}^{k} N_i M_i \right) \tag{1}$$

In the formula, “R”, “M”, “N”, “H”, “p”, “q”, “k” are integers greater than or equal to 1. And “M” is the annual usage times of the clinical pathway, “H” is the annual operation quantity of the hospital, “N” is the usage times of a certain kind of equipment to be studied in the clinical pathway (calculated according to the theoretical times of examinations), “k” is the total quantity of clinical pathways in the hospital, “$R_{p,q}$” is the annual clinical pathway demand of equipment “q” in the hospital “p”.

Next, the equipment capacity is estimated. Due to the influence of environment, work process, service life, maintenance times and other factors, the working capacity of medical equipment in the hospital is different. This method, according to clinical experience, estimates the average usage capacity of a certain type of equipment - "annual saturated working capacity" (calculated as "daily maximum workload × annual start-up days") in the form of "S".

Finally, the theoretical minimum deployment quantity of the equipment is estimated. For the equipment to be studied, the minimum theoretical deployment of the equipment can be obtained by dividing the annual clinical pathway demand “R” by the annual saturated working capacity “S”. As:

$$T_{p,q} = \frac{R}{S} \tag{2}$$

$T_{p,q}$ is the theoretical minimum deployment quantity of equipment “q” in the hospital “p”.

deployment method based on big data

In addition to the clinical pathway, this study also investigated the deployment of medical equipment in hospitals, including the quantity, grade, annual frequency of tests, annual income, service time, and maintenance cycle of certain medical equipment in each hospital. At the same time, nine independent variables such as the attribute of these hospitals, annual operation quantity, medical income, number of beds and built-up area were also investigated as the influencing factors of medical equipment deployment. Based on the big data of these hospitals, the recommended deployment plan of medical equipment in a hospital can be given on the premise that the medical equipment of all the hospitals investigated is rational deployed. The Least Square Method is used to calculate the multiple regression equation, and the regression coefficient is stored in the database after each calculation, so as to facilitate the next calculation.

Results

The system will obtain the corresponding user's information, including the name, the hospital where he/she works in and the user type after the user logs into MERDIS and then display the user information under the function bar of the home page. The top of the home page is the function bar. For ordinary users, there are new hospital information import, new equipment information import, contact and logout. On this basis, administrator users have user information management, hospital information management and information check. There are three main functions in the homepage: deployment recommendation, deployment evaluation and settings. The deployment recommendation is to query the newly established hospital's deployment plan of medical equipment by giving the basic information of this hospital. Deployment evaluation is to evaluate the current deployment of medical equipment in the hospital, and to analyse whether the deployment plan is rational and give suggestions. Users can click "home page" to return to the main interface during use.

Take the deployment of CT and MRI in a first-class hospital of Obstetrics and gynaecology as an example. The basic information and deployment of the two medical devices in the hospital are shown in **Table 1** and **Table 2**.

Table 1 Clinical data statistics of Shanghai First maternity and infant hospital in 2019

Hospital level	Hospital type	Operation quantity(times)	Annual clinical pathway usage(times)
first-class	maternity hospital	65108	11881

Table 2 Usage of CT and MRI

Equipment name	Total number of clinical pathways used	Annual operation days	Daily saturated workload (Times)
CT	2714	250	120
MRI	4182	250	40

According to the data in **Table 1** and **Table 2**, formula (1) can be used to calculate the theoretical annual clinical pathway demand of CT and MRI, and then formula (2) can be used to calculate the theoretical minimum deployment number based on clinical pathway.

For example, the minimum deployment number of CT:

$$R = \left(\frac{65108}{11881} \times 2714\right) / (120 \times 250) = 0.4958.$$

Table 3 Comparison of actual equipment deployment quantity and theoretical deployment quantity

Equipment name	R	S	Actual equipment deployment quantity	Theoretical deployment quantity
CT	14873	30000	1	0.5
MRI	22918	10000	1	2.3

From the data in the **Table 3**, it can be found that the number of CT deployment in the studied hospitals meets the demand of clinical pathway, and the deployment is more appropriate. The number of MRI deployment is lower than the theoretical demand, which cannot meet the medical needs of patients in hospital. And **Fig 5** is the deployment evaluation page of this hospital.

Discussion

Through the MERDIS system, it is convenient, accurate and intuitive to get the rational deployment plan and suggestions of medical equipment in the hospital. According to the frequency of clinical pathway on medical equipment and the working ability of the equipment, the theoretical minimum number of medical equipment deployment in different influencing factors can be calculated by the formula, and the recommended deployment quantity of medical equipment can be obtained through the calculation method of bigdata.

Due to the difficulty of data research, the current data of 52 hospitals is not enough complete and sufficient, and the deployment of medical equipment is only limited to large medical equipment. In the case of continuous data input and enrichment, the calculation model will become more accurate and expand the scope of medical equipment covered.

When the data tends to be complete and the number of statistical years increases, the function of forecasting the purchase quantity of equipment can be added in the later system version. By the annual average growth rate method, the annual growth rate of equipment deployment can be analysed, and the annual deployment quantity of the next year or even several years can be estimated according to the equipment deployment base at the end of the previous year (2). The formula is as follows:

$$R = \sqrt[n]{\frac{y_n}{y_0}} - 1 \quad (3)$$

The working capacity of different equipment is also different, as well as the same kind of equipment in different models and working environment. Later research can be closer to the direction of full cycle management of medical equipment, real-time monitoring of the use of medical equipment, increase the accuracy of statistics.

Conclusions

By providing the relevant basic data of the hospital, the system can feed back to users the medical equipment deployment suggestions based on big data of the hospital. If the detailed clinical pathway data of the hospital is provided, the theoretical deployment plan of medical equipment based on clinical pathway can also be obtained. Through MERDIS, not only the newly established hospitals can query the deployment of medical equipment, but also the existing hospitals can evaluate the current deployment of their own hospitals, which provides data theoretical support for the deployment of medical equipment in hospitals.

With the support of more than 50 hospitals' data, the relevant data calculated by the system model are true and reliable, which can be used by the evaluated hospitals.

The framework based on asp.net MVC perfectly constructs the overall structure of the system, which make the system functions from front-end view to back-end data are presented to users clearly. At the same time, SQL database is also the best choice for the large amounts data storage and processing.

Availability and requirements

Project name: MERDIS

Project home page: http://sourceforge.net/Home/Login

Operating system(s): Platform independent

ramming language: C#

License: Common public license 1.0

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due the confidentiality of hospital data but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

HZ participated in the study of deployment method and the design of software architecture. YY designed and compiled the software, and was a major contributor in writing the manuscript. HL investigated the data needed for the study, and participated in the research of the configuration method and the function design of the software.

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References

1. FENG Shi-ling, LIU Zhi-cheng. Preliminary Discussion on Clinical Pathway-

based Confi guration Method of Medical Devices. China Medical devices. 2014; 29(02): 47-49+112.

2. Xu Feng. The Principles And Evaluation System of Large Scale Medical Equipment Configuration Chinese Hospital Architecture & Equipment. 2019; 20(01):29-32.
3. Kaku Noriyuki,Nitta Masahiko,Muguruma Takashi,Hirata Yuichiro,Tsukahara Kohei,Knaup Emily,Nosaka Nobuyuki,Enomoto Yuki. Medical equipment deployment in pediatric emergency prehospital medical units in Japan. Pediatrics international: official journal of the Japan Pediatric Society. 2018;60(1).
4. Emanuel Ezekiel J,Persad Govind,Upshur Ross,Thome Beatriz,Parker Michael,Glickman Aaron,Zhang Cathy,Boyle Connor,Smith Maxwell,Phillips James P. Fair Allocation of Scarce Medical Resources in the Time of Covid-19. The New England journal of medicine. 2020;382(21).
5. Steven Teutsch,Bernd Rechel. Ethics of Resource Allocation and Rationing Medical Care in a Time of Fiscal Restraint - US and Europe. Public Health Reviews. 2012;34(1)
6. Krütli Pius,Rosemann Thomas,Törnblom Kjell Y,Smieszek Timo. How to Fairly Allocate Scarce Medical Resources: Ethical Argumentation under Scrutiny by Health Professionals and Lay People. PloS one. 2016;11(7).
7. Chun-xia Miao,Lang Zhuo,Yu-ming Gu,Zhao-hui Qin. Study of large medical equipment allocation in Xuzhou. Journal of Zhejiang University SCIENCE B. 2007;8(12).

8. ZHANG Suo-fei, XIE Ben. Analysis of Teaching Windows Programming from the Perspective of MVC Design Pattern, Educational Modernization. 2020;7(44):1-3.
9. Yu Qiang,Liao Xiaobin,Lin Jianbin. [Development of Modern Medical Equipment Management System Based on Web]. Zhongguo yi liao qi xie za zhi = Chinese journal of medical instrumentation. 2017;41(1).
10. Meredith A. Whitley,David S. Walsh. A Framework for the Design and Implementation of Service-learning Courses. Journal of Physical Education, Recreation and Dance. 2014;85(4).
11. Guisseppi A. Forgionne. An Executive Information System to facilitate army housing management. Journal of Decision Systems. 1997; doi:10.1080/12460125.1997.10511716.
12. David Sundaram, James Dong & Ananth Srinivasan. The Design and Implementation of a Flexible Web-based Decision System. Journal of Decision Systems. 2003; doi:10.3166/jds.12.159-176.
13. Shu-juan Dong. Basic data management and analysis system for new power energy based on MVC. International Journal of Ambient Energy. 2019; doi:10.1080/01430750.2019.1684999.
14. E. Althammer & W. Pree. Design and Implementation of an MVC-Based Architecture for E-Commerce Applications. International Journal of Computers and Applications. 2001; doi:10.1080/1206212X.2001.11441649.
15. Chenyuan Zhang, Wenjun Xu, Jiayi Liu, Zhihao Liu, Zude Zhou & Duc Truong Pham. Digital twin-enabled reconfigurable modeling for smart manufacturing

systems. International Journal of Computer Integrated Manufacturing. 2019; doi:10.1080/0951192X.2019.1699256.

16. Shouhong Wang & Hai Wang. Redesigning the Information Systems Analysis and Design Course: Curriculum Renewal. Journal of Computer Information Systems. 2014; doi:10.1080/08874417.2014.11645738.

17. Boris Jukic & Nenad Jukic. Information System Planning and Decision Making Framework: A Case Study. Information Systems Management. 2010; doi:10.1080/10580530903455221

18. Ross S. Purves, Paul Clough, Christopher B. Jones, Avi Arampatzis, Benedicte Bucher, David Finch, Gaihua Fu, Hideo Joho, Awase Khirni Syed, Subodh Vaid & Bisheng Yang. The design and implementation of SPIRIT: a spatially aware search engine for information retrieval on the Internet. International Journal of Geographical Information Science. 2007; doi:10.1080/13658810601169840.

19. Loris Belcastro, Fabrizio Marozzo & Domenico Talia. Programming models and systems for Big Data analysis. International Journal of Parallel, Emergent and Distributed Systems. 2019; doi:10.1080/17445760.2017.1422501

20. Alberto Fernández, Cristobal José Carmona, María José del Jesus & Francisco Herrera. A View on Fuzzy Systems for Big Data: Progress and Opportunities. International Journal of Computational Intelligence Systems. 2016; DOI: 10.1080/18756891.2016.1180820

Fig 1 Usage case diagram of the MERDIS. Each instance represents the functions that the user can realize, among which, the administrator can implement the functions implemented by ordinary users. The administrator has additional rights of information check and information management.

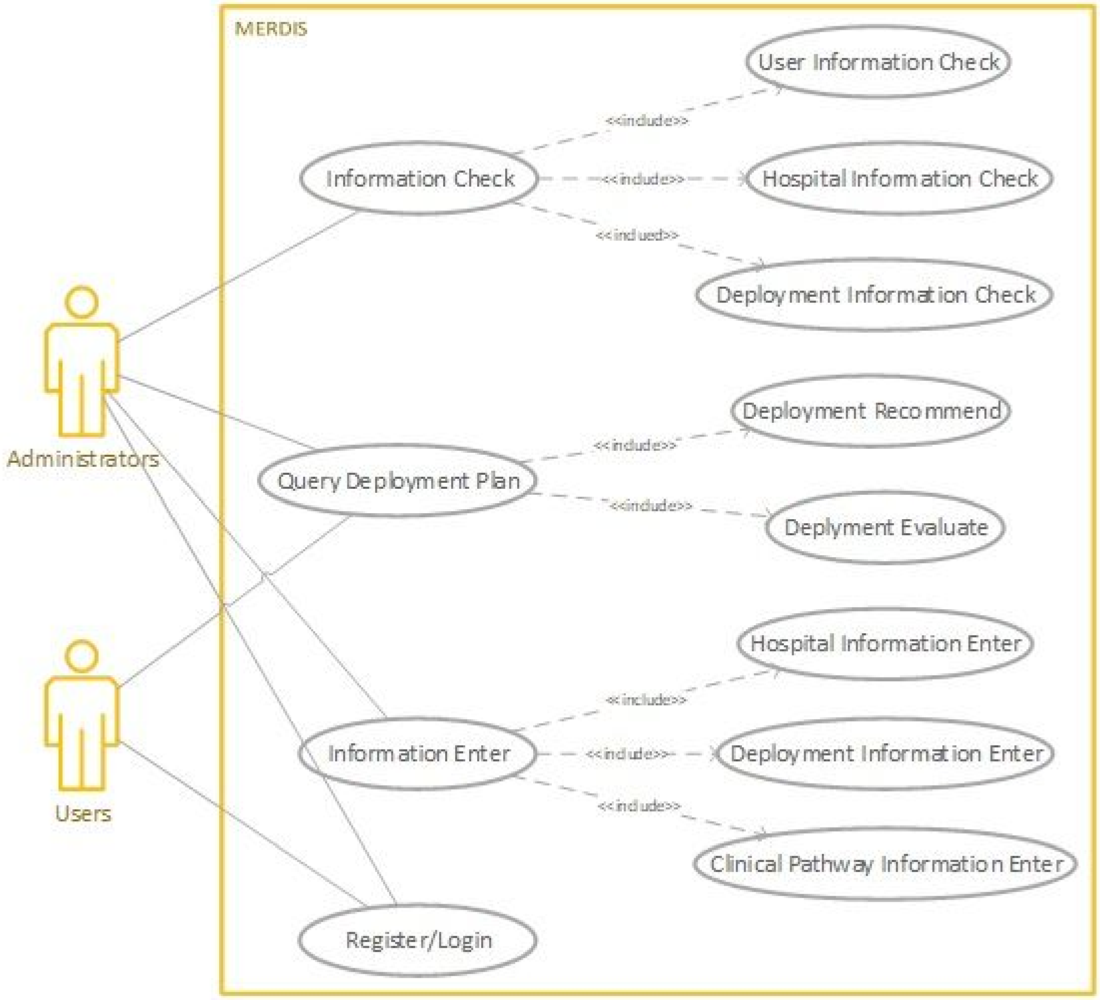
Fig 2 Relationship of MVC parts.

Fig 3 The functional flowchart of MERDIS.

Fig 4 Database diagram of MERDIS.

Fig 5 Deployment evaluation page.

Figures



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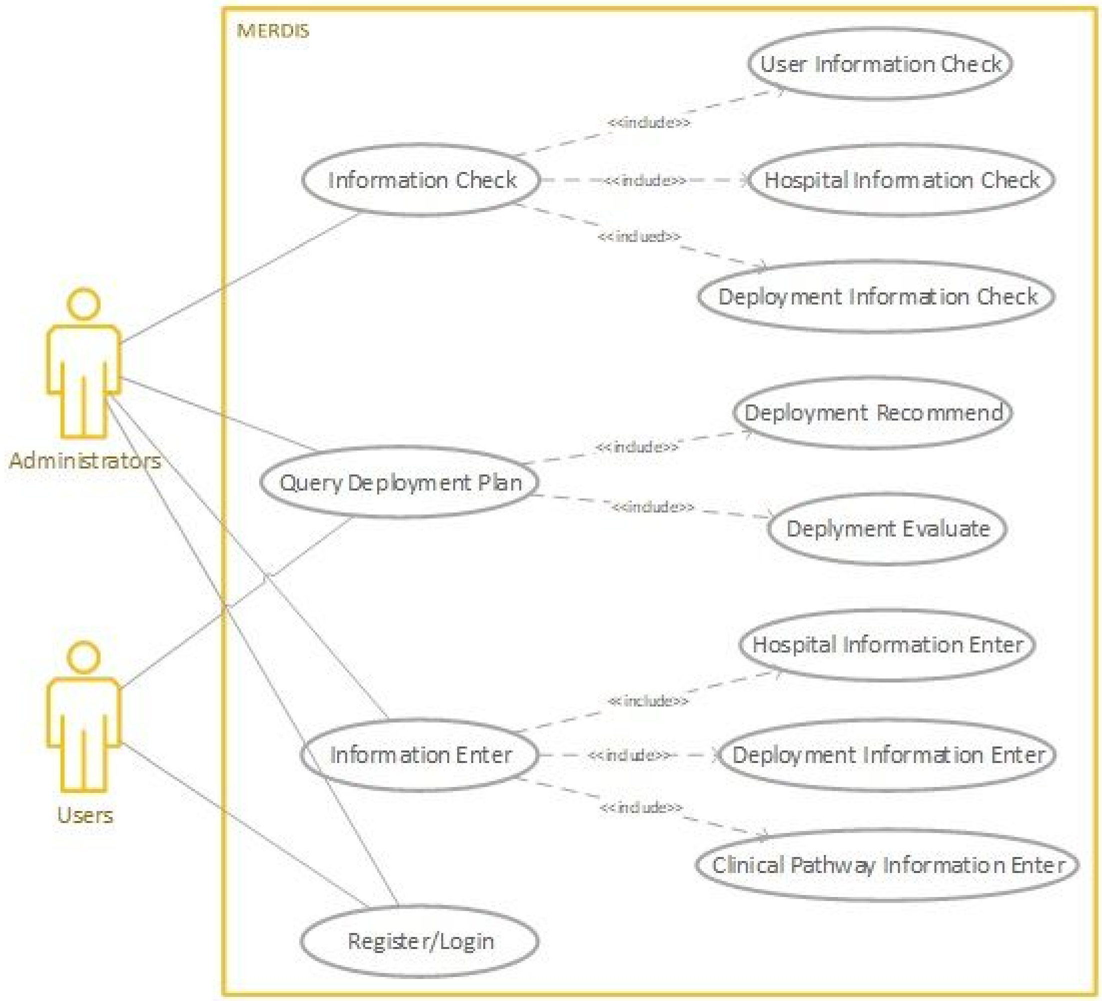

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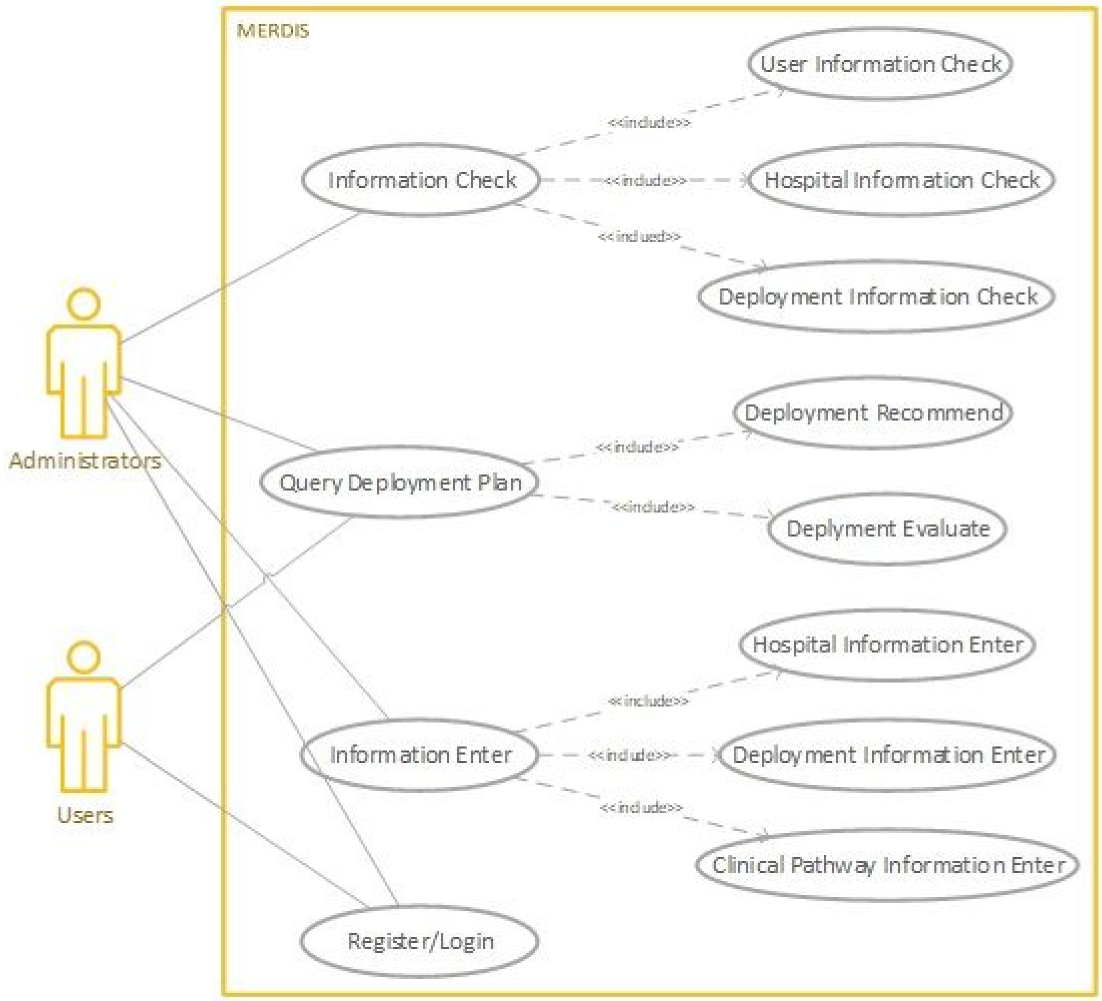

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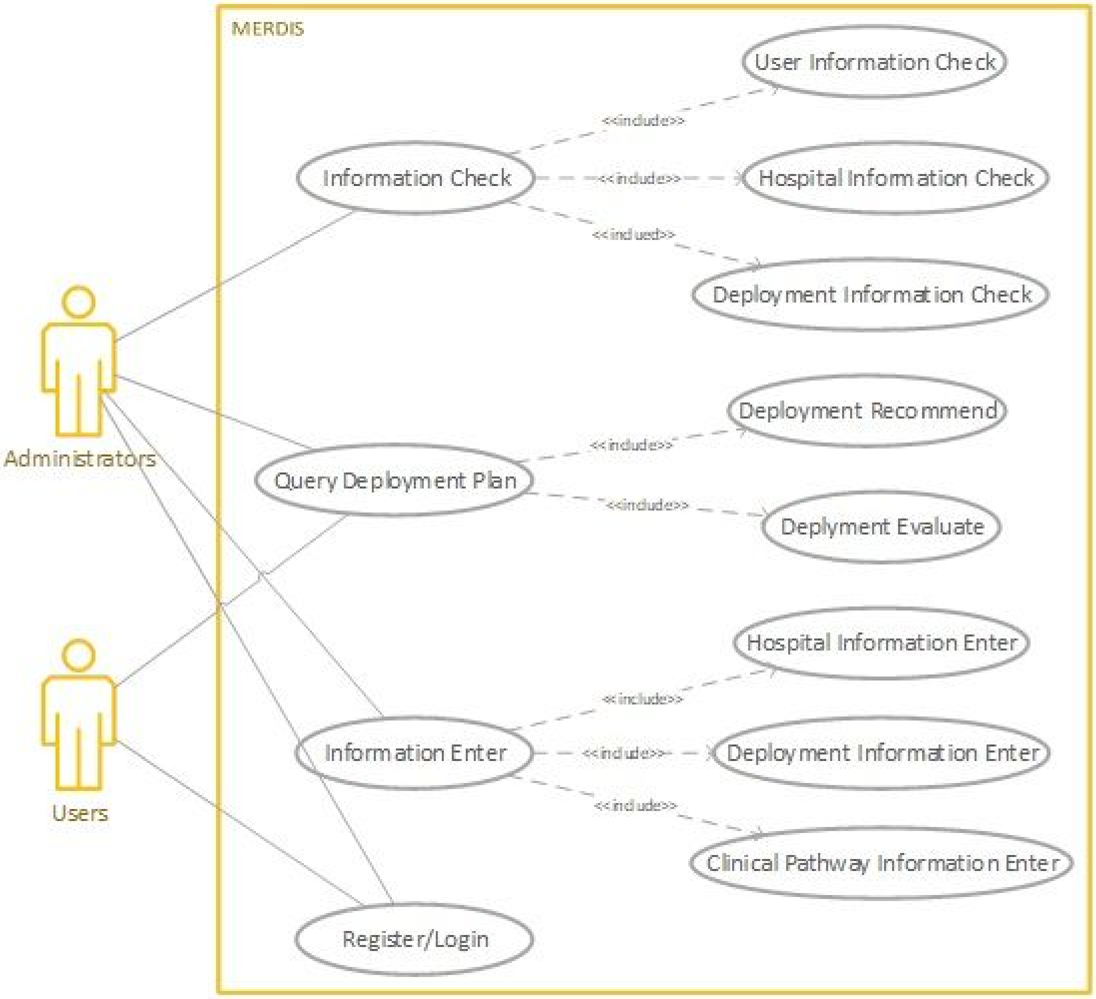

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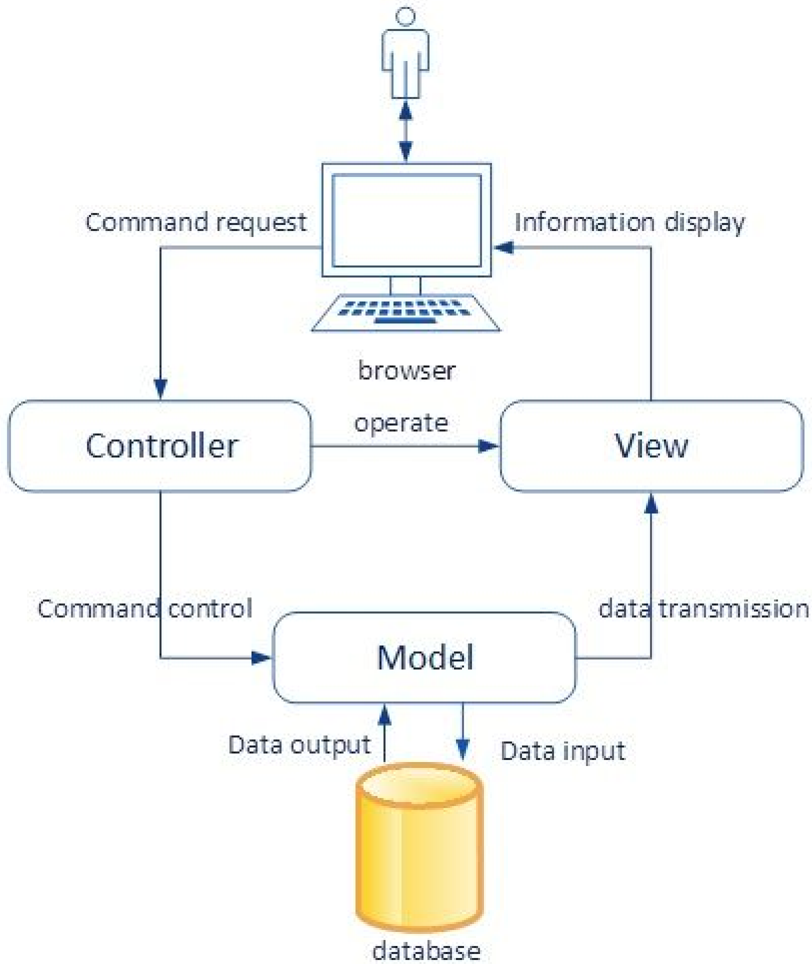

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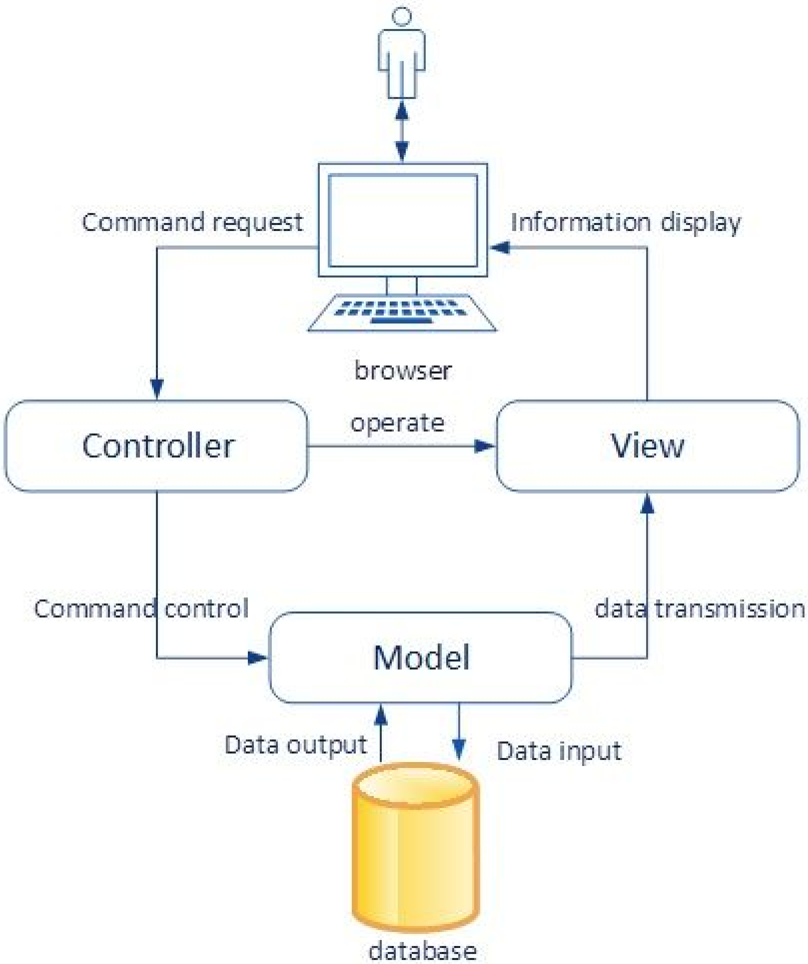

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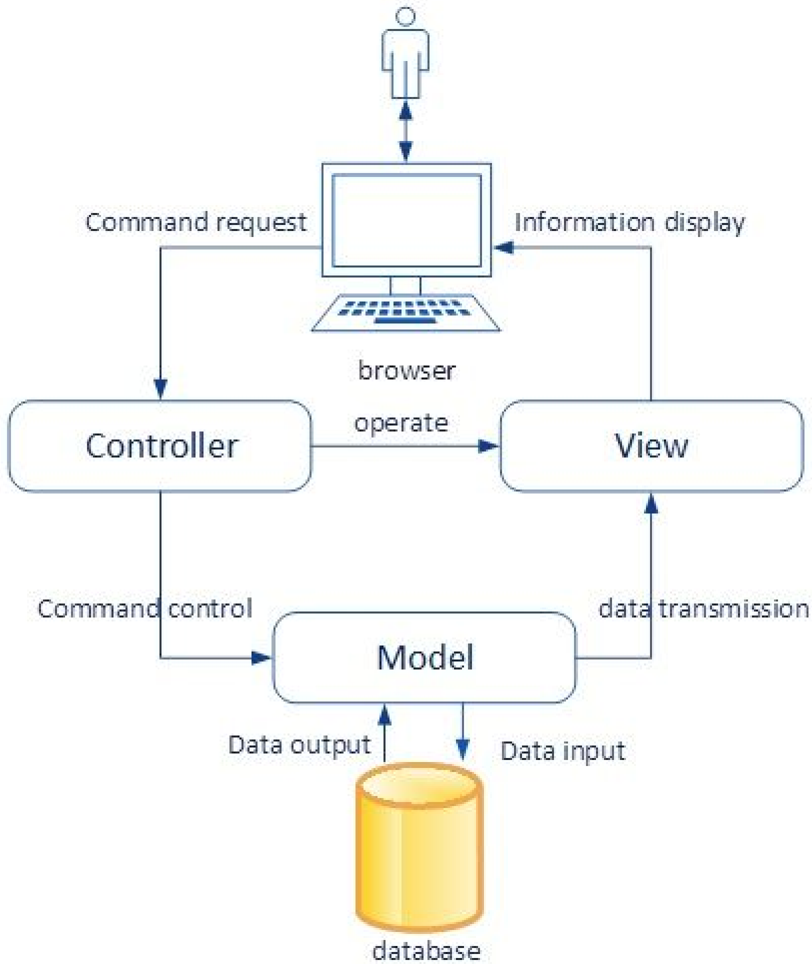

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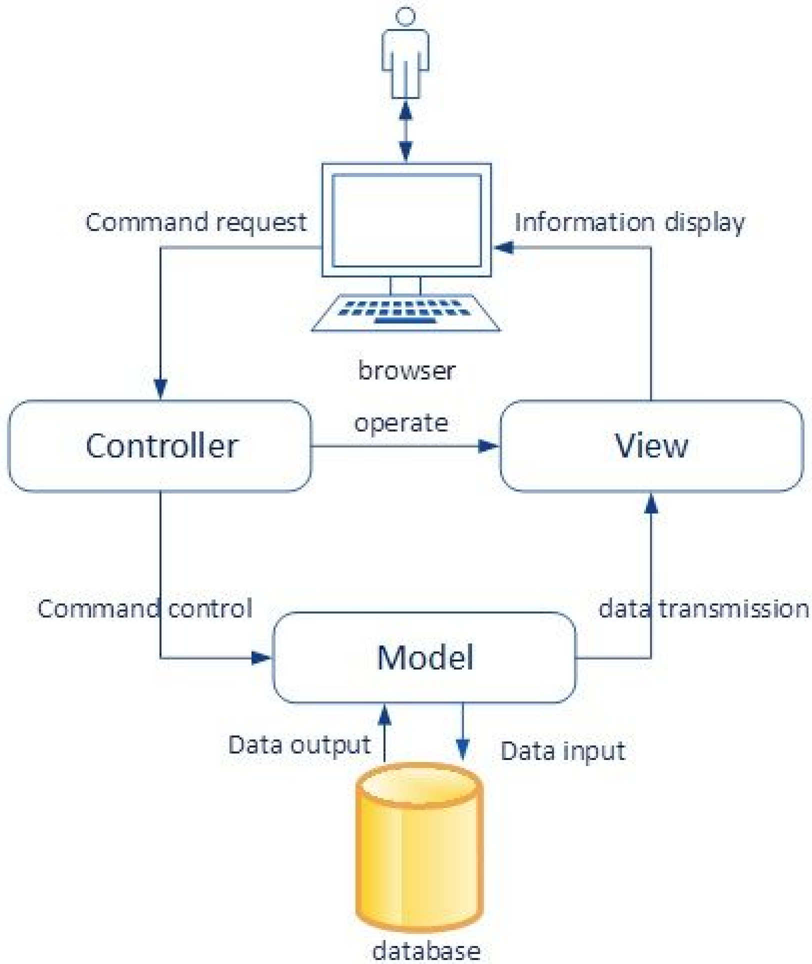

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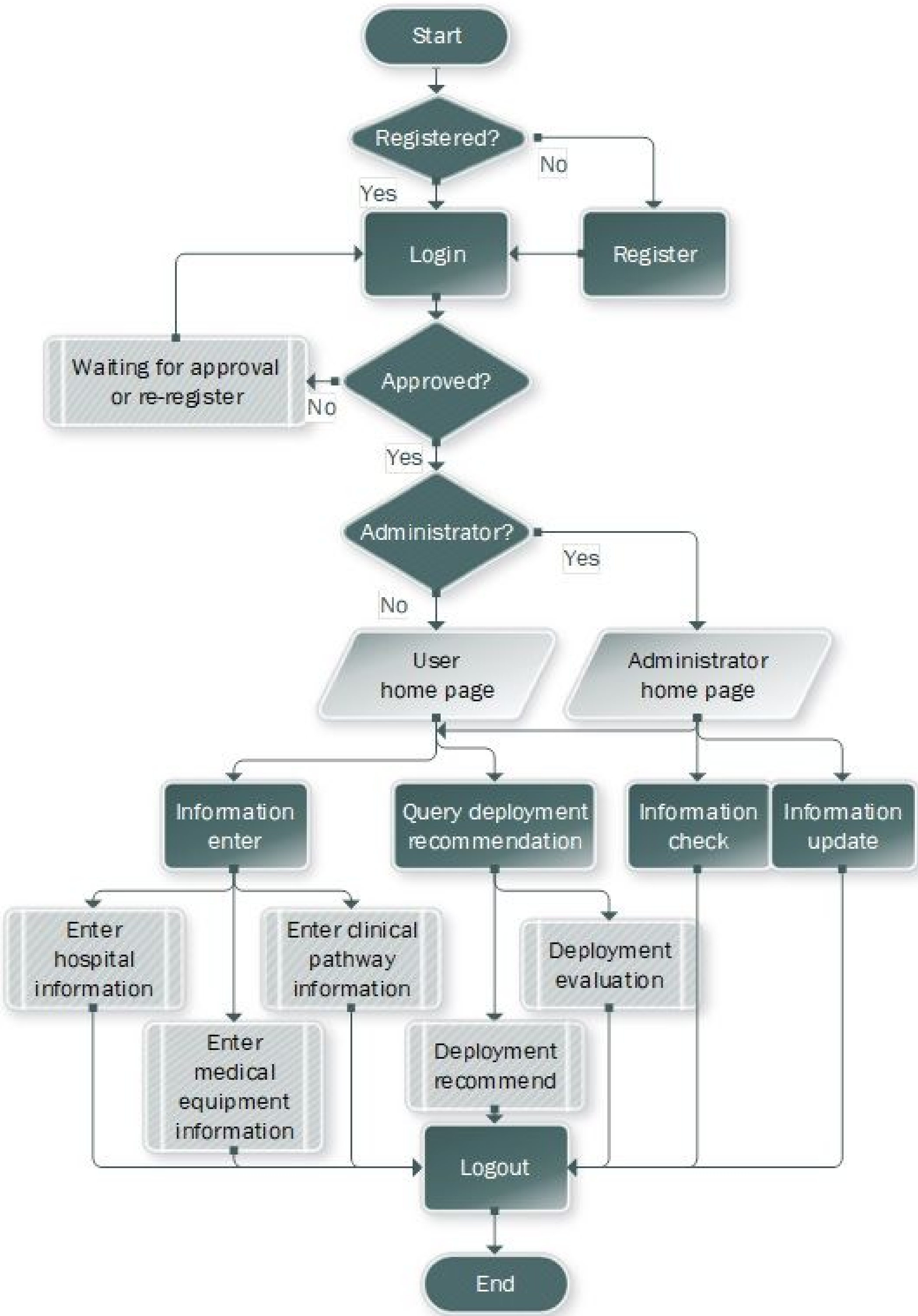

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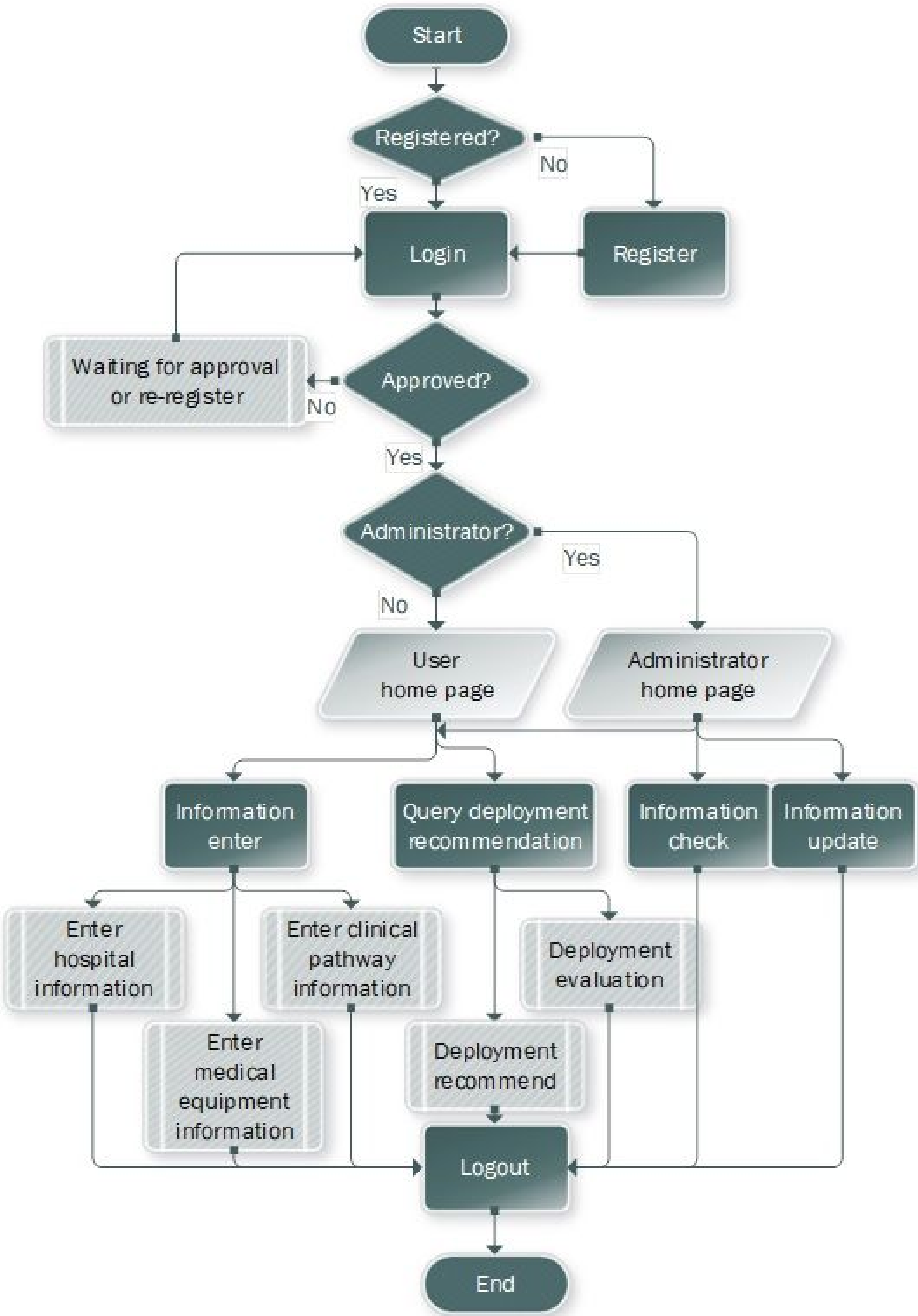

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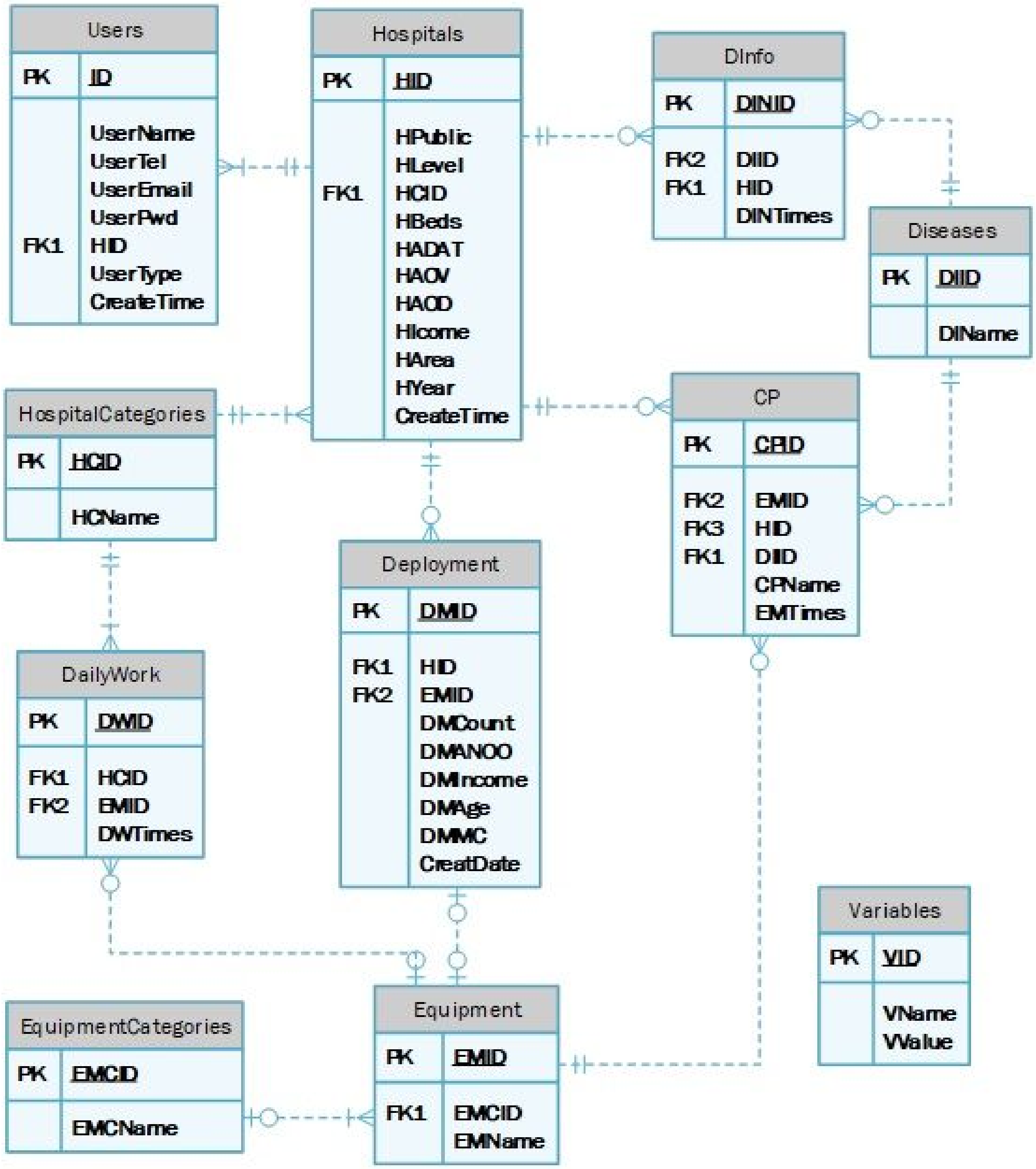

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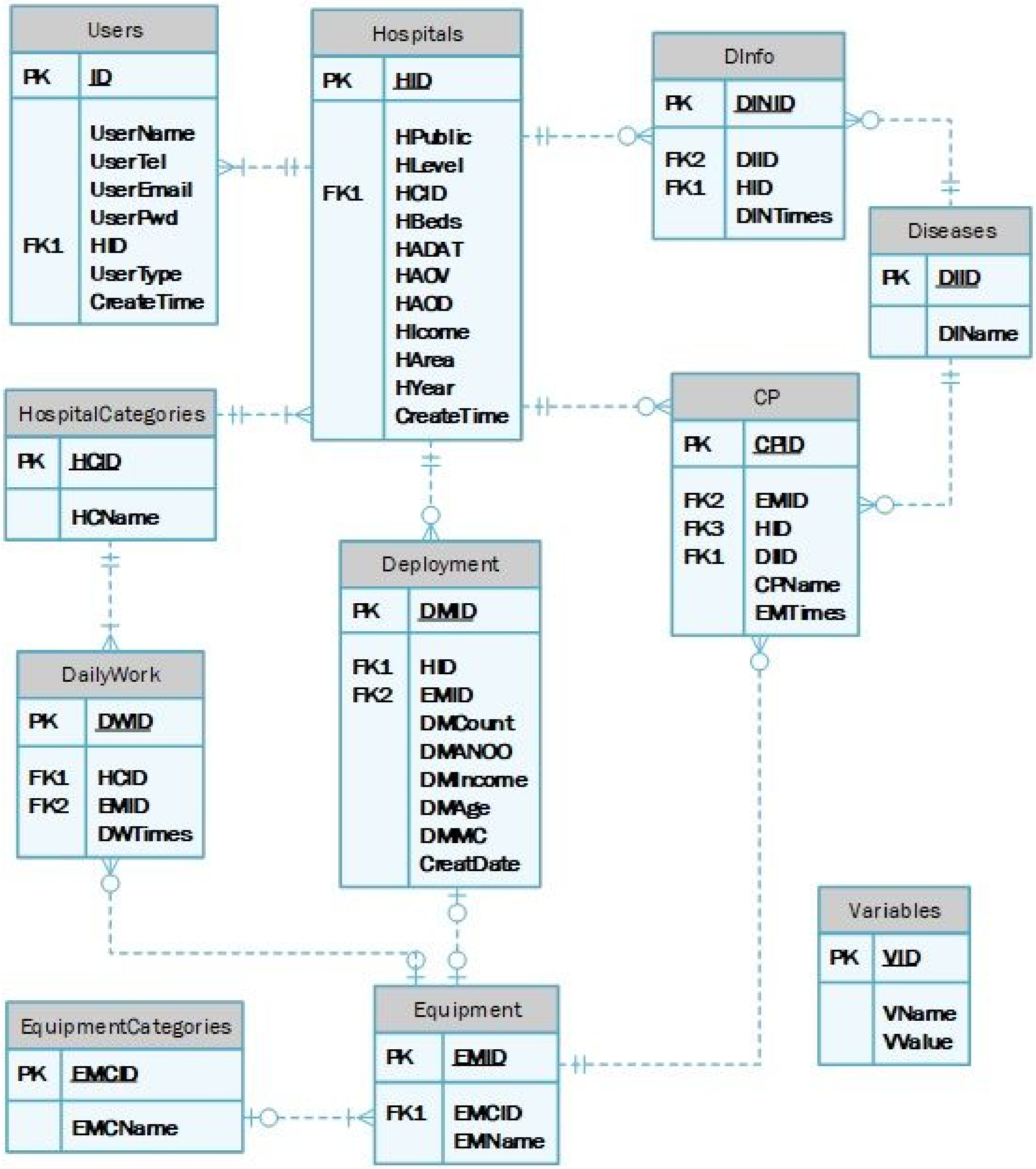

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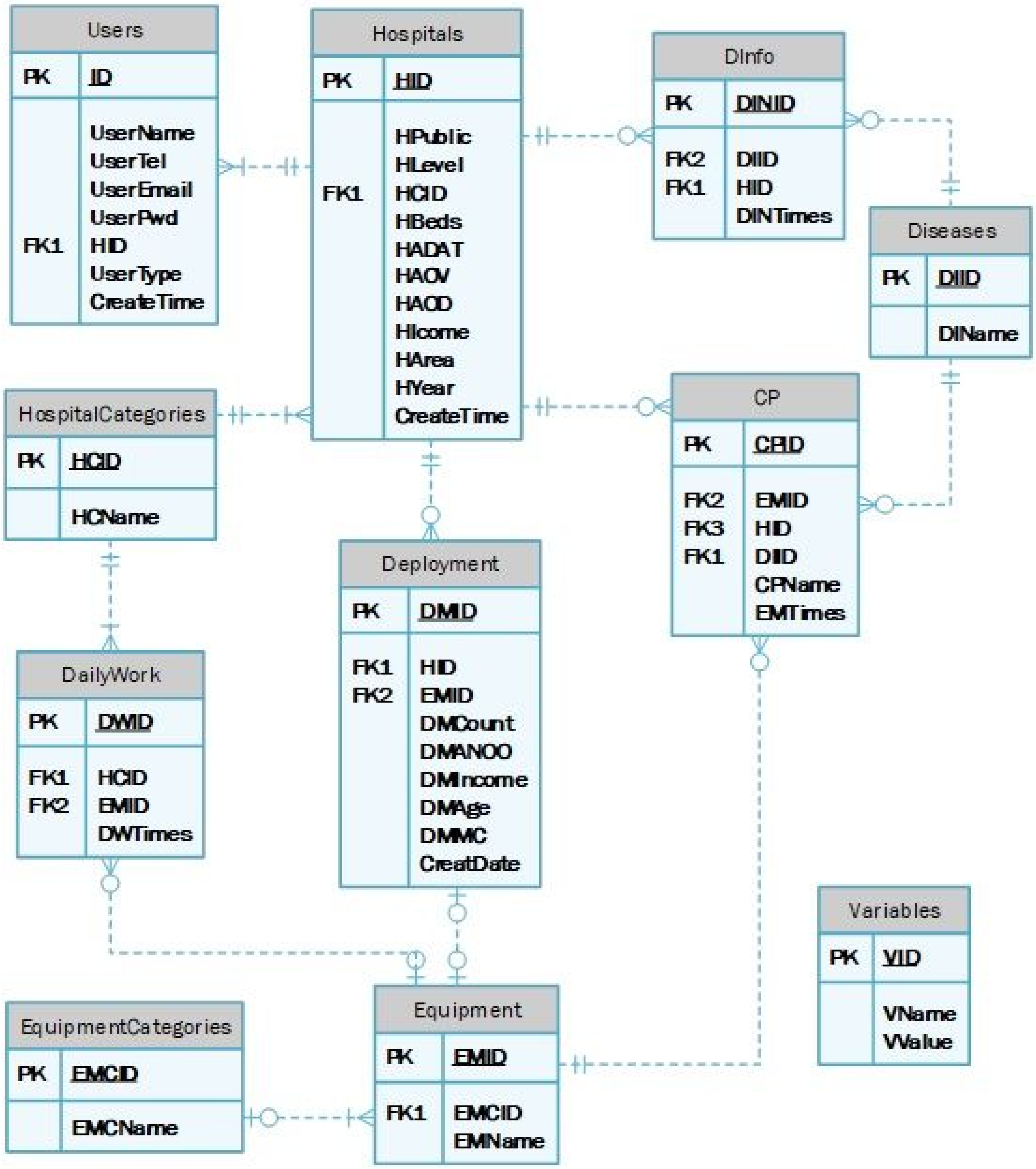

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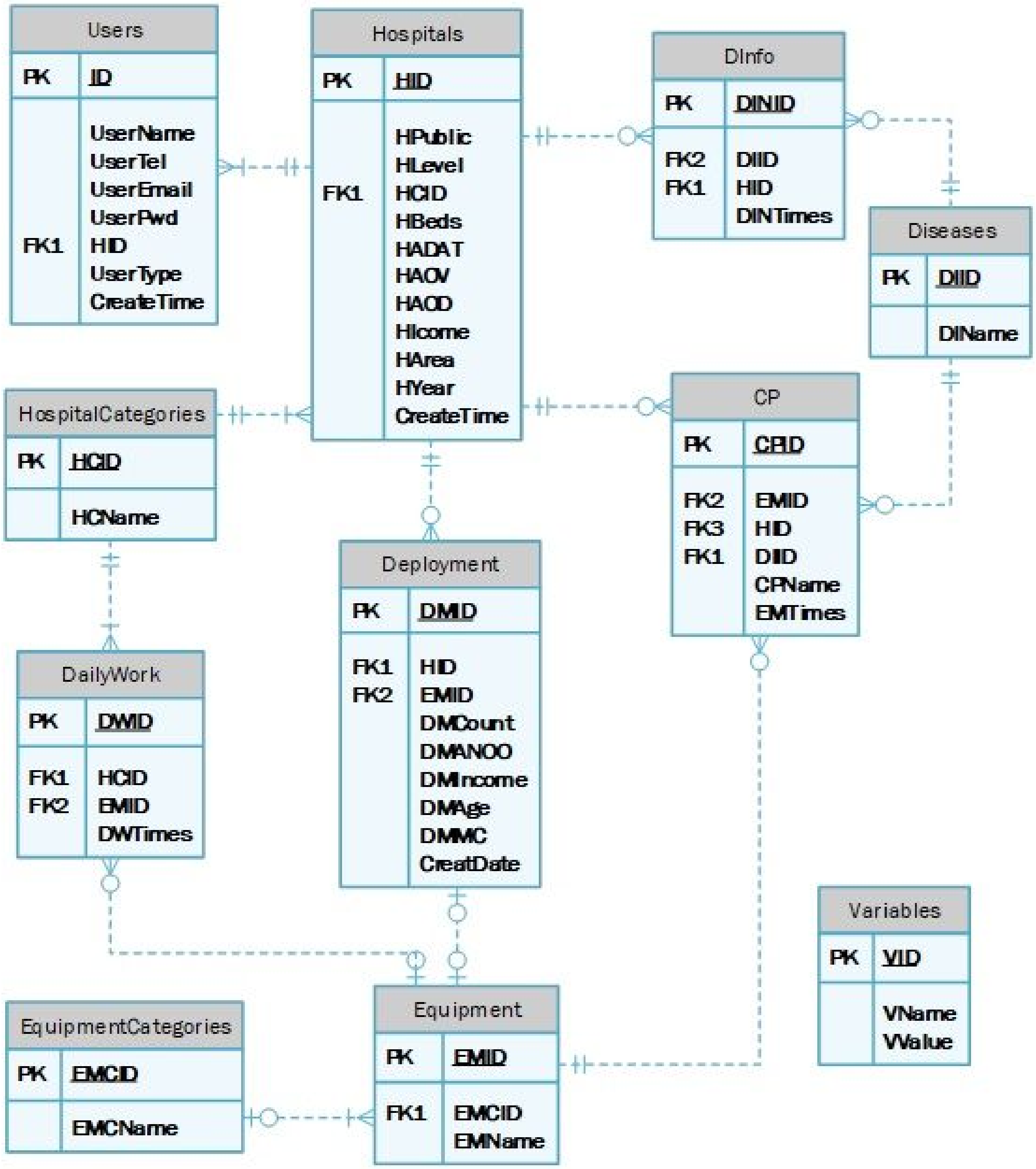

Figure 4

Database diagram of MERDIS.

Figure 5

Deployment evaluation page.

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