# Rural Health Unit Decision Support System with Mapping

**Joan Hazel V. Tiongson, Marifel Grace C. Kummer**

***Abstract:*** ***In this highly challenging and demanding world, presence of data and technology are overwhelming. But at present, some institutions still engage in manual-type of operations like the Rural Health Unit of the Municipality of Solano, Nueva Vizcaya. Problems, issues and challenges encountered by the unitin the delivery of its medical servicesand the extent of compliance in ISO/IEC 25010 Software Quality Standards were identified. And with the uncontrollable availability of data, these can be handled and treated using data mining techniques to predict disease occurrences. In this study, the clustering and classification data mining techniques were utilized in order to predict disease occurrences of every barangay of the municipality at a given time. An efficient record management system along with a decision support system was developed to meet the challenges of the unit. It mainly features the disease-occurrence mapping to assist physicians and other health professionals in the unit in their decision-making tasks particularly in diagnosis, treatment and recommendations.In terms of ISO/IEC 25010 Software Quality Standards, the system gained a "very great extent" qualitative rating.***

***Keywords: Challenges, Clinical Decision Support System (CDSS), Data Mining, Electronic Medical Record (EMR), Health Information Technology (HIT)***

## I. INTRODUCTION

Data of all sorts that come from different sources are considered and are processed in this exceptionally testing and requesting world where information and innovation are overpowering. This simply happens in order to simplify every aspect of our lives like for communication, transportation, learning, and so much more. In this scenario, the healthcare industry is not exempted in this technology-driven community. It is one of the many sectors where data and technology are used in countless ways. Ubiquitous use of computer technology in medicine began in the early 1950s with the rampant increase in the use of computers worldwide [16]. This technological advancement led to health informatics or Health Information Systems which is a discipline at the intersection of information science, computer science, and health care. It concerns with the resources, devices, and methods required for optimizing the acquisition, storage, retrieval, and use of information in health and biomedicine.

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Information technology has been very helpful to the healthcare sector not just in the development of medical equipment and machines, discovery of new drugs but in the organization and improvement of electronic medical records (EMR). Medical records that consist of summaries of a patient's diagnoses, laboratory results and prescriptions would offer an overview of a patient's health status; permitting a more accurate diagnosis and improved patient care [9]. Also, this digitization of medical records would facilitate the easy sharing of information and collaboration between labs and specialists without the time and resource expenditure on physical transmission. Jones further stated that when these EMRs are properly maintained and implemented, EMR protocols can also help increase accountability and reduce malpractice. Electronic records would be easier and less time to consume to create and maintain. And they make life easier for medical accountants and reduce the chance of mistakes being made. Integrating electronic health record (EHR), healthcare providers are able to track clinical issues more effectively allowing them to easily identify areas of risk [8]. Processes can quickly and accurately be put in place in order to improve patient care. Drug prescribing patterns of individual clinicians including physician referrals for worst case scenarios could be carefully evaluated and compared to established standards. In fact, computer-based clinical support as part of an EMR has been shown to improve physician performance and patient outcomes. Electronic medical records (EMR) improve quality of care, patient outcomes, and safety [11]. With EMRs, there is improved management, reduction in medication errors, reduction in unnecessary investigations, and improved communication and interactions among primary care providers, patients, and other providers involved in care. Also, EMRs improve the work lives of family physicians despite some subjective concerns about implementation costs and time. EMRs have been demonstrated to improve efficiencies in work flow through reducing the time required to pull charts, improving access to comprehensive patient data, helping to manage prescriptions, improving scheduling of patient appointments, and providing remote access to patients' charts.Aside from the EMRs, the facilities, personnel, and technology create the capacity to provide health services. These structural characteristics are expected to influence the quality of health care services for they are the foundation upon which quality health care services are provided. Integrating EMR with detailed patient profiles and analytics functions allows clinicians to view not just which health conditions a patient is facing, but how their health has changed over time [14].

By having access to these insights, they can develop more targeted strategies for managing long-term illnesses and make personalized recommendations

The healthcare system in the Philippines has undergone dramatic changes in the last 20 years as the government has instituted various reforms and policies to provide easy access to health benefits for every Filipino [12].

The Department of Health (DoH) lists 1,071 licensed private hospitals, and 721 public hospitals. About 40% of hospitals in the country are public with well-trained doctors and around 10% are managed by the DOH while the rest are managed by local government units (LGUs) and other national government agencies. Nevertheless, healthcare system in the Philippines is of a high standard overall [2]. Filipino medical staff are expertly trained, but the facilities may not be as impressive as those found in high-end US or European hospitals. The quality of the Philippines' state-subsidized public healthcare, although good, varies widely between rural and urban areas. Private healthcare in the Philippines provides much more consistent care and facilities tend to be better equipped than public ones. Most hospitals provide efficient and affordable health services. Facilities, however, pale in comparison with those in high-end health institutions abroad. On a positive note, private hospitals in the country have better technical facilities than the public hospitals. Private hospitals thus, assure patients of higher quality service than public hospitals can provide.

Technology has made rapid advancements in the medical sciences field, ranging from electronic medical records to medical analytics. The application of ICT can improve the current state of health [6]. Moreover, health information technology (HIT) ultimately aims to help healthcare providers provide excellent care to their patient [1]. HIT does this by improving point of care areas along the patient – provider flow, from the time patient goes in the hospital to the time he/she went out and up to their home.

The RHU of Solano, Nueva Vizcaya provides medical services to an average of 80 – 100 Solanoans and to some citizens of nearby towns from 8: 00 in the morning to 5:00 in the afternoon from Monday to Friday. Considering the amount of data entering into the unit, the health professionals including the Municipal Health Officer experience slow processing and decision-making because of the manual recording. Management also find difficulty in accessing patient records for they are maintained in logbooks and forms. This form of storage by the unit compromises the security and privacy of patient information. Moreover, patient records may also suffer inaccuracies because of the absence of a central storage. On the part of the physicians, diagnosing disease tend to be of tedious work because they need to manually backtrack previous health records. Although different computers are present in the unit, they are basically used in generating communications and reports - - all contributing to delays of actionable programs and information. The developed system is a decision support system with mapping for the RHU of Solano, Nueva Vizcaya. This is designed mainly to assist physicians and other health professionals in the unit in their decision-making tasks. The system will be divided into two: (1) diagnosis and (2) treatment/recommendations.

The diagnosis will be provided by the system to help the physician's choices to improve the treatments. The patient's complaints will be data mined through the clustering and classification frameworks of data mining. Data gathered during diagnosis will be compiled and may be represented in if – then rules. In addition, classification data mining technique is also utilized to make a forecast of the memberships in a group for data instances like the age, gender, locality of disease occurrences and the like. In this manner, presentation of reports would be easier to interpret and understand.

On the other hand, the treatment/recommendation part of the system would now suggest what intervention would be applied by the health professionals to the patients. This includes drug prescription, therapy session or physician referral. Reminders, alerts, and recommendations for the unit head and the administration are also considered for careful strategic planning.

Customary statistical methods and data mining techniques will be used in order to calculate data patterns and to extract hidden patterns respectively. These techniques will be employed within the system for the purpose of mapping to monitor and report the diseases occurrences in every barangay of the municipality of Solano at a given time. This will aid the unit head in planning and strategizing different programs for the occurrences.

The researcher believes that this system is timely and relevant because of the present scenario of the healthcare industry. This decision support system will integrate clinical and patient information thus, providing support for administering patient care. Also, with the availability of data generated by the system, timely reports and actions will be provided resulting to effective processes and improved decision-making in the unit.

## II. AIM OF THE PAPER

### A. *Statement of the Problem*

This study sought to provide an efficient record management system and a decision support system relevant to the healthcare programs and services for the Solanoans.Specifically, this study further sought answers to the following questions:

1. What are the problems, issues and challenges encountered by the Rural Health Unit in the delivery of medical services?
2. What data mining techniques will be utilized in determining the disease occurrences?
3. What classification and clustering algorithms will be used in developing the system?
4. What system can be developed to facilitate the delivery of medical services in the Rural Health Unit?
5. What is the extent of compliance of the developed system to ISO/IEC 25010 Software Quality Standards in terms of:

a) functional suitability;
b) performance efficiency;
c) compatibility;
d) usability;
e) reliability;
f) security;
g) maintainability; and
h) portability?

6. What system enhancement can be recommended from this study?

**B.** *Framework of the Study*

The conceptual framework[7] summarizes the theory of what the study proposes to achieve, and the processes undertaken to achieve its purpose.

| INPUTS | PROBLEMS | CONCEPTS (Modules of Interventions) | USERS | OUTPUTS |
|---|---|---|---|---|
| Patient's Information Data | • Difficulty in data processing because records of patient are culled/ sifted from various source documents;<br>• Patient's records sacrifice confidentiality and security | • EMR Module (Database/ Records Management - storing, searching, updating, printing, viewing)<br>• Levels of access rights to system users | • Medical Technologist<br>• Midwife<br>• Nurse<br>• Physician | • Centralized database storage;<br>• Easy access of patient's record using EMR;<br>• Customized reports |
| Complaints, Consultation Record | • Tedious work in assessing condition;<br>• Difficulty in diagnosing given the various factors contributing to the ailment/ complaint;<br>• Time-consuming in backtracking previous health records | • EMR Module (Database/ Records Management - viewing, printing)<br>• Clinical Decision Support System (Actionable Information and Insight Features)<br>• Analytics Module (Alert Feature) | Physician | • Diagnoses and treatment of findings/ illness;<br>• Alerts, Reminders, Recommendations<br>• Customized reports<br>• Mapping |

**Figure 1. Conceptual Framework[7]**

It starts with particulars that need to be addressed and the corresponding appropriate modules of the Decision Support System (DSS) particularly the Clinical Decision Support System (CDSS) that would address the identified problem. With the DSS/CDSS emplaced, the level of access of users of the system is established. The ultimate output of the concept or theory of the study is the use of a system that would aid in the physician's decision-making on the diagnosis and treatment of an ailment/complaint. The proposed system has three main processes: first is the patient consultation where patient information, patient complaints and patient medical history are assessed. These relevant data and information are being recorded, stored and maintained in a central database to guarantee its security and confidentiality. Second part focuses on the different modules of intervention being provided by the system. The presence of electronic medical record (EMR) through the central storage is observed. This EMR contains the patient profile, patient complaints and patient consultation records in particular and will be accessible through the system. Moreover, records management like searching, storing, printing, etc. the easiest way is made possible. And most importantly, with a centralized data, an EMR is generated that will serve as the core source document past as well as current data for best intervention that will support the physician in her decision-making on the diagnosis and recommendations to obtain a better patient outcome. Also, the easy access of EMR would provide efficiency to the physician when compared to the usual patient record-handling of the rural health unit. Lastly, the DSS generates customized reports to present results as an aid in decision-making, program proposal preparation and most especially, actionable insights and recommendations. Users of the system will have different access rights that correspond to their respective tasks starting from data encoding, report generation up to system maintenance. Moreover, the ISO/IEC 25010 Software Quality Standards will be the basis in assessing and measuring the quality of the developed system in terms of user requirements. The ISO/IEC 25010 Software Quality Standardsprovides the leading models for assessing software product [5]. This is an important contribution towards establishing the delivery performance of software processes and proposed improvements.

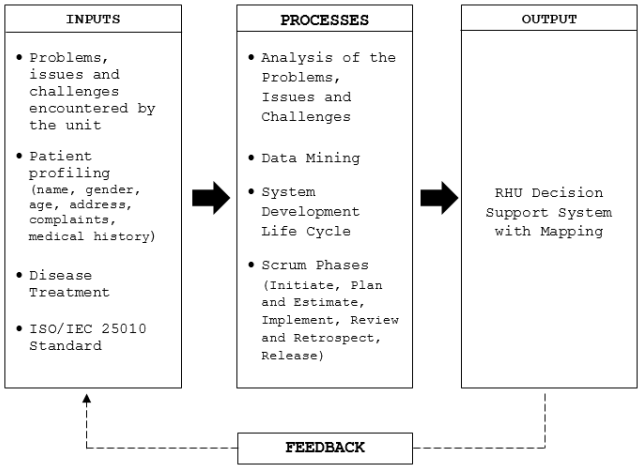


**Figure 2. Conceptual Paradigm of the Study**

The conceptual paradigm of the study is generalized into three parts: it starts with the presentation of problems, issues and challenges encountered by the unit. Patient name, gender, age, address, complaints, medical history are considered for the unit's patient profiling. These data sets provide important components for analysis and presentation. The top ten diseases causing morbidity and treatment are also included as part of the input. Different processes to be undertaken like analysis and data mining were conducted to be able to gather useful and relevant data for this study. In the course of system development, the Scrum phases will be applied in order to collect user responses and move forward with the development accordingly. Finally, by using the system, the RHU is now able to provide relevant healthcare services for the Solanoans in a very timely manner from prevention to treatment. Additionally, it will allow the physicians and administration to receive reminders and alerts about potential events before they happen and therefore make more informed choices about how to proceed with a decision. Reports are also readily available when needed .

## III. METHODOLOGIES

**A.** *Research Design*

This study designed and developed a decision support system for the RHU of Solano, Nueva Vizcaya. It uses a descriptive research method particularly interviews and questionnaire in order to gather data relevant to the conduct of the study and developmental research for the development of the system. The Agile Scrum methodology was also utilized in the system development. It relies on incremental development wherein each goal (sprint) is built into shippable product and are adjusted based on stakeholder and customer feedbacks. If there are any problems or changes, the scrum team can easily and quickly adjust product goals during future sprints to provide more valuable iterations. This way, stakeholders are happier because they get exactly what they want after being involved every step of the way.

This then encouraged the researcher to make use of Agile Scrum Methodology: Initiate, Plan and Estimate, Implement, Review and Retrospect, and Release.

**B.** *Research Methods*

To be able to gather pertinent documents and data for the study, the researcher started with a request letter seeking permission from the Office of the Mayor to conduct an interview to the concerned Municipal Health Officer (MHO). Upon approval of the letter, the researcher then approached the MHO and explained to her about the study and how it will be conducted highlighting the assurance that the data to be gathered will be treated with high level of confidentiality as stated in the letter to the mayor. The MHO then instructed the front line health workers to extend their services in order to help the researcher in gathering the needed data for the study. Direct observations were also noted to validate what were mentioned during the series of interviews with the Health Workers. The researcher personally witnessed the flow of transactions in the RHU. The researcher observed how the Individual Treatment Record (ITR)of every patient was filled out in order to get their profile, how these are being kept and retrieved when patients come back for a follow up check-up. Also, the researcher observed that other forms, logbooks, and cabinets were utilized in the RHU as forms of storage for several other reports of the unit. In addition, document scanning was used where the researcher went over the patient's Individual Treatment Record where the information on name, gender, age, address, complaints and medical history of patients are written. It is assumed by the researcher that all information written on the patients' ITR were personally and readily given as they consented to be interviewed by the health worker who was on duty. A questionnaire based on ISO/IEC 25010Software Quality Standards characteristics and sub-characteristics was considered in order to determine the overall performance of the system. Participants in the questionnaire were IT experts for they are knowledgeable on the technical side of the study. The researcher guaranteed that the involvement of the participants in this study is voluntary and that they are further assured that data and information gathered will be treated with utmost confidentiality.

**C.** *Data Analysis*

Qualitative approach through thematic technique and contextualization was used to analyze the answers of the respondents in the conduct of interview. These responses were consolidated to gather information of the problems, issues and challenges of the rural health unit as a basis in constructing an effective decision support system. Document scanning and observation checklist were used to collect and classify the symptoms of the common diseases based from the medical history of the patients. Through this, clustering was further used to analyze these symptoms in order to arrive at a specific diagnosis. The data collected from the ISO/IEC 25010 Product Quality Questionnaire were tabulated, summarized, analyzed and interpreted using descriptive statistics. The Likert-scale was used to easily get the mean result. Mean in which each item being averaged is multiplied by a number (weight) based on the item's relative importance. The result is summed and the total is divided by the sum of the weights. Frequency counting and weighted mean will be used for data analysis.

The table below presents how data will be treated using the said Likert-scale. Different graphical/pictorial models will also be used for the presentation of different results.

**Table 2. Likert-Scale for the Compliance with ISO/IEC 25010 Product Standard**

| Weight | Weighted Mean | Descriptive Rating |
|---|---|---|
| 5 | 4.20 - 5.00 | Very Great Extent |
| 4 | 3.40 - 4.19 | Great Extent |
| 3 | 2.60 - 3.39 | Moderate Extent |
| 2 | 1.80 - 2.59 | Little Extent |
| 1 | 1.00 - 1.79 | Very Little Extent |

## IV. RESULTS AND DISCUSSION

Based on the conducted interviews, observations and responses of IT experts using the ISO/IEC 25010, the following results were obtained:

**1. Problems, Issues and Challenges of the RHU**

With systematic and thorough interviews, observations and document scanning, the researcher identified the following problems, issues and challenges encountered by the RHU:

- slow processing and decision-making because of the manual recording of transactions;
- difficulty in accessing patient records for they are maintained in logbooks and forms which compromises the security and confidentiality of patient information;
- absence of a central storage;
- manually backtracking of health records tend to be of tedious work; and
- difficulty and delay in report generation.

The Rural Health Unit of Solano, Nueva Vizcaya at present practices a manual way of handling transactions such as patient profiling, record-keeping and retrieving. Patient records are stored in several areas sacrificing its confidentiality and security. On the physicians' part, there is tedious work in assessing patient's condition and difficulty in diagnosing for patient records are stored in several locations allowing the health front liners to spent time in backtracking previous health records. Computers are visible but only for reports and communication purposes only.

**2. Data Mining Techniques**

Data mining is a technique used in various domains to give meaning to the available data. In this study, clustering and classification data mining techniques were employed to determine disease occurrences of a particular barangay at a given time. Clustering techniques have been massively used in the healthcare industry for easy diagnosis and prediction of diseases [13]. This provides fast, adequate, reliable and less costly healthcare delivery to patients. In particular, clustering is a technique of grouping records on a database based on certain criteria where good clusters have a high degree of similarity between objects within a cluster and a high degree of inequality with other cluster objects. The clustering result is given to the end user to give an idea of what happens to the database. On the other hand, classification is a data mining technique that assigns categories to a collection of data. It uses rules to aid in more accurate predictions and better analysis.

Classification is one of several methods intended to make the analysis of very large datasets effective. Specifically, it uses mathematical technique like statistics to classify the data into different groups.

In this study, complaints raised by a particular patient will be inputted and stored in the database. The data will be mined using if-then rules resulting to a group of clusters recommending the possible disease outcomes of the patient.

**3. Clustering and Classification Algorithms**

Approaches of clustering and classification are generally used for predicting certain outcomes after giving meaning to the available data. These data, stored in database, are rich with hidden information, which can be used for effective decision making.

Clustering was defined as a technique of grouping records on a database based on certain criteria [15]. The clustering result is given to the end user to give an idea of what happens to the database. Clustering performs grouping of data without any particular data class.

In this study, the if-then statements are utilized and maximized that led to partitioning algorithm. The K-means clustering, which is one of the most widely used partitioning clustering algorithms, was employed in the development of this work. It was further revealed that the K-Means clustering classifies data in the form of one or more clusters [15]. It divides the data into groups and can accept inputs of data without class labels. This method partitions the data into clusters/groups so that data that have the same characteristics are grouped into the same cluster and data that have different characteristics are grouped into other groups. As such, it was pointed out that in medical domain, cluster analysis provides a systematic, formalized method for data exploration and defining groups with clinical similarities [10].

On the other hand, classification can be defined as a data-mining technique that assigns categories to a collection of data to aid in more accurate predictions and analysis [3]. It is one of several methods intended to make the analysis of very large datasets effective like medical data.

Specifically, this study made used of the decision tree algorithm. Decision tree is the most frequently used technique of data analysis [4]. Furthermore, classification methods like decision tree algorithms are widely used in medical field to classify the medical data for diagnosis [17]. Decision trees specify the sequence of attributes thus developing a set of prediction rules, usually an if-then statement. The construction of decision tree produces a sequence of rules that can be used to classify the data given its attributes. This algorithm creates a tree structure from the given data set where each node represents attributes to test or conditions and final leaf node represents the test results or classes. Initially all samples are on the single root node and then the remaining nodes are created based on the attribute partitioning condition. The decision tree is simple to understand and visualize, requires little data preparation, and can handle both numerical and categorical data which is fitted for medical databases.

**4. Rural Health Unit Decision Support System with Mapping**

This developed system is a decision support system that will facilitate in the delivery of medical services for the Solanoans. Also, it supports the unit's record management in terms of patient-profiling, record-keeping and retrieval. The system also generates reports in visualized forms that will aid the physician in its decision-making activities on better patient outcomes.

**5. RHUDSS Extent of Compliance with respect to ISO/IEC 25010 Criteria**

Table 3 revealed the summary of the software evaluation in compliance with the ISO/IEC 25010 Criteria.

**Table 3. Summary of the Software Evaluation in Compliance with the ISO/IEC 25010 Criteria.**

| ISO/IEC 25010 Characteristics Criteria | Criteria Mean | Qualitative Description |
|---|---|---|
| A. Functional Suitability | 4.73 | Very Great Extent |
| B. Performance Efficiency | 4.76 | Very Great Extent |
| C. Compatibility | 4.64 | Very Great Extent |
| D. Usability | 4.80 | Very Great Extent |
| E. Reliability | 4.77 | Very Great Extent |
| F. Security | 4.85 | Very Great Extent |
| G. Maintainability | 4.58 | Very Great Extent |
| H. Portability | 4.72 | Very Great Extent |
| **Overall Mean** | **4.73** | **Very Great Extent** |

Using the Likert-scale in evaluating the software product, it received an overall mean of 4.73 describing it as "Very Great Extent" in terms of the ISO/IEC 25010 Characteristics criteria extent of compliance.

The table further showed that security, usability and reliability received the top three (3) most rated criteria among the eight (8) ISO/IEC 25010 characteristics with a mean of 4.85, 4.80 and 4.77 respectively and described as "Very Great Extent". And this is further followed by responses in other criteria - system's performance efficiency, functional suitability and portability, compatibility and maintainability with a mean of 4.76, 4.73, 4.72, 4.64 and 4.58 respectively all marking with "Very Great Extent" descriptive rating.

## V. CONCLUSION AND RECOMMENDATIONS

The developed Rural Health Unit Decision Support System (RHUDSS) with Mapping served as an efficient record management system for the RHUof the Municipality Solano, Nueva Vizcaya. The central storage provides an easy access of data when it comes to patient-profiling, record-keeping and record-retrieval. In addition, the introduction of a decision support system to the RHU will be a great aid in the decision-making processes of the unit and the administration as a whole. The generation of customized reports in mapping disease occurrencesserves as tool in the delivery of relevant programs and services for the Solanoans. Anent this, developed system using the ISO/IEC 25010 Software Quality Standardscriteria is compliant with a "Very Great Extent" rating with respect to functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability.To further enhance the application, it is recommended to have a web-based application for easy access of data. Also, an inventory system on medical supplies can be integrated in the system. This is to help the health unit in terms of the status of availability of medicines and other medical supplies.

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