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Review on A Clinical Decision Support System for Risk Based Prioritization Using Soft Computing Technique

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Abstract— **.** The position of healthcare industry in India is poor in terms of – adoption of IT infrastructure and capability to harness its benefits. Both these factors entangle to form a catch-22 situation. The fundamental problem lies with either getting insufficient advantages or arousal of new loop holes in the IT solutions. In this paper initially conduct a literature review to have broad knowledge of Decision Support System Using Soft Computing Techniques and some Related work, they are used Clinical decision Support system. After that provide a architecture that provide the facility to analyze, mine and assess the data and for findings reflect what type of limitation and Problem of Clinical decision support system in Practice and Next do a comparative analysis on Decision Support System.

Index Terms— Decision Support System,ICU Information system, Soft Computing, Health care Environoment, Fuzzy logic, Nural network,HL7.

1.INTRODUCTION

The healthcare Industry is growing significantly as the surveys show for the developing countries and it consumes 10 percent of gross domestic product [Kaiser]. Information is a vital part of any industry, but it becomes an indispensable need for the healthcare industry as it is directly related to human lives. An effective management of this information is one of the key objectives satisfying the mission of any healthcare industry. When the issue is of 'information management' then Information Technology (IT) is the only benefactor. Though healthcare enterprises have started reaping benefits of this technology, yet a lot is left to adopt and adept related to this science. The aim of this work is to develop Clinical Decision Support Systems (CDSS) collect patient data from physiological monitors and other sources, providing clinicians with derived instructions and information to aid treatment planning. With advancements in telecommunication networks, CDSS functionality can be extended over distances, and accessed remotely.CDSS that features real-time continuous patient monitoring, high-fidelity analysis and incorporation of clinical guidelines for decision support. System outputs show successful aggrga-tion and analysis of continuous and periodic data, and automation of guidelines by recognizing deviation of patient's condition from normal states. Clinical decision support (CDS) systems provide clinicians, staff, patients, and other individuals with knowledge and specific information, intelligently filtered and presented at appropriate times, to enhance health and health care. The Institute of Medicine has long recognized problems with health care quality in the United States, and for more than a decade has advocated using health information technology (IT), including electronic CDS, to improve quality Federal Government promoted the importance of electronic medical records (EMRs), there has been a slow but increasing adoption of health IT. It must be remembered, though, that these health IT applications are a means to improve health care quality, not an end in themselves. Further, although EMRs with computerized provider order entry (CPOE) can improve accessibility and legibility of information, it is unlikely that there will be major improvements in the quality and cost of care from the use of health IT without proper implementation and use of CDS . As Studies Work done by many Authors it is pointed, that most of the framework are theoretical in Nature. They Lack Practical Guidance for method Selection. may existing framework lacks an Extensive Study of a wide Variety of method for CDSS development.

1.1 Analysis of Various Survey and their impact:

Various review presents a summary of the state of the art of CDS for clinicians. It includes background information on the types of CDS and focuses on the outcomes of deploying these CDS interventions. It also discusses the major issues and challenges of CDS implementation and evaluation. After reviewing what is known about implementing CDS, the impact from its use, and the knowledge gaps that remain, the review examines factors that can facilitate broader use of CDS, including the role of various stakeholders in influencing CDS adoption. The failure of the Decision support System has been Concerns of the Clinical from many years. Many Surveys have been done to investigate the projects failure statistics.

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Decision Support Systems that are implemented with the aid of Artificial Intelligence have the ability to adopt in new environment and to learn with time [3], [4]. Various methods are used to gather information used for the process of Decision making in Computer Aided Support Systems/ Expert Systems. For the diagnosis of pain, medical science need computer aided software that can collect the health related signals from patients and transform them in pain intensity [2]. Pain causes degradation in the life of patients and due to lack of the proper evaluation methods, sometime patient stops asking for further medication as the pain becomes worse [5]. Similarly the critical monitoring of the patient after operation needs accurate measurement of the medicine proportion as over dosage can sometime result into threats of life [1].The use of a Clinical Decision Support System to measure the intensity and diagnose the pain is much more efficient, effective and economical.

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propose a computable approach to represent medical rules by means of Fuzzy Clinical Decision Support Systems by preserving both accuracy and interpretability. Usually, prediction accuracy of these systems goes to overlook their linguistic interpretability and, in order to simultaneously optimize those conflicting properties, multi-objective evolutionary algorithms are adopted. The proposed approach has been tested on the Vertebral Column Data set, a recent medical database publicly available, with results that confirm the effectiveness of our method.

R Brian Haynes, Nancy L Wilczynski

CCDSSs that have been properly evaluated for clinical practice effects, a process of knowledge translation (KT) is needed to ensure appropriate implementation, including both adoption if the findings are positive and foregoing adoption if the trials are negative or indeterminate. the effects of computerized decision support for six clinical application areas: primary preventive care, therapeutic drug monitoring and dosing, drug prescribing, chronic disease management, diagnostic test ordering and interpretation, and acute care management; and to identify study characteristics that predict benefit. A decision-maker-researcher partnership provides a model for systematic reviews that may foster KT and uptake.

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focused on problems such as how people learn a new skill and how humans generate hypotheses about new situations e cognitive-based researches were to construct decision based on their past experiences[6][7]. Many prototype of decision support system based on CBR technique were built during this period: for example, Cyrus [8],[9], Mediator [10], Persuader [11], Chef [12], Julia [13], Casey, and Protos [14]. the U.S. Defense Advanced Research Projects Agency .These formally marked the birth of the discipline of Decision Support System using case-based reasoning.

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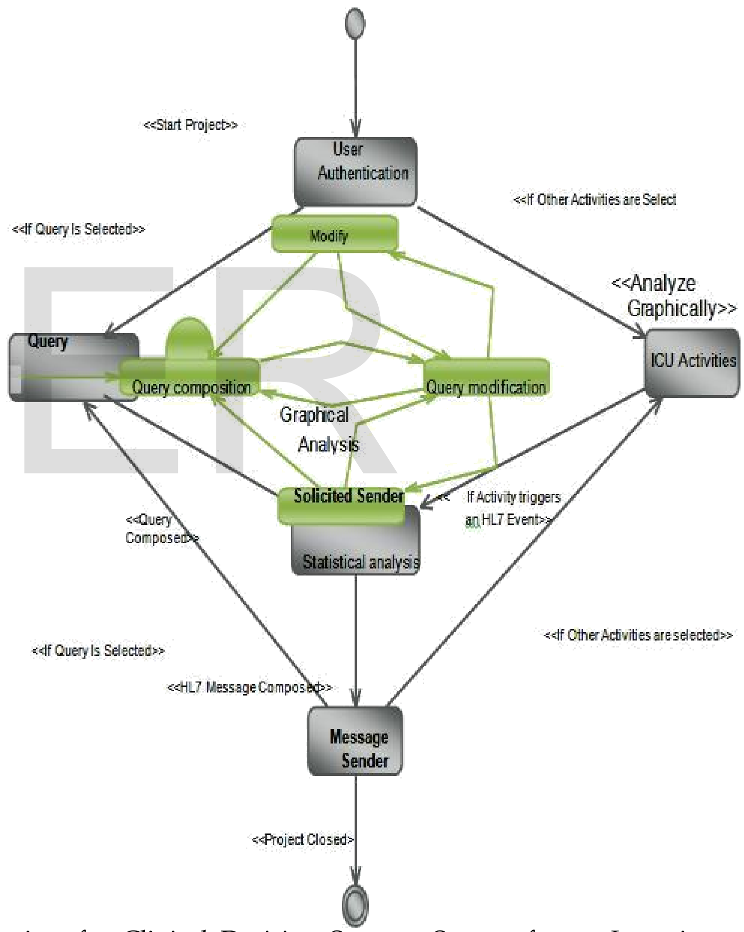

Figure.1 Comprehensive Software architecture of ICU Information System.(Adapted from impact 2013 IEEE by Faiyaz Ahamad ,Author)[39]

The aim of this work is to develop ICU is the specialized unit of a hospital for patients who require special medical care The system consists of two developmental phases: phase I for im-

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plementing the solution to communicative information system' and phase II for implementing the solution to the decision support system. So as to bring out the various features and perspectives of both the solutions, the whole system is elaborated with the help of the architectural views and process flow diagram figure 1.

The Importance of HL7 It may be argued that for many standards, which no sooner they conceive than they die their own deaths. Many research papers, scientific magazines, newspapers, market surveys are in favor of HL7. The facts in favor of HL7 are listed below **Table 1.1**

DOMAIN	ADOPTED STANDARD
Laboratory Results Names	Logical Observation Identifiers Names an Codes (LOINC)
Messaging Standards: General	Health Level Seven (HL7)
Messaging Standards: Retail Pharmacy	National Council for Prescription Drug Programs (NCPDP) SCRIPT
Messaging Standards: Connectivity	IEEE 1073
Messaging Standards: Image informationtoworkstations	Digital Imaging and Communications In Medicine (DICOM)
Medications	Federal Drug Standards
Interventions/Procedures: Lab	LOINC
Interventions/Procedures: Non-Laboratory	Systematized Nomenclature of Medicine, Clinical Terms (SNOMED CT)
Demographics	HL7
Immunizations	HL7
Lab Results Contents	SNOMED CT
Units	HL7
Anatomy	SNOMED CT for Anatomy
Diagnosis/Problem	SNOMED CT
Nursing	SNOMED CT
Financial/Payment	Health Insurance Portability and Accountability Act of Unit-
Clinical Encounters	HL7
Text-Based Reports	HL7

Table 1.1. Consolidated Health Informatics Domains and standards

The first desired and obvious result of such a scheme is that any modification in the standard can be made without touching the source code. One needs to fire queries for any changes. The number of queries required to change, append or delete HL7message component is shown Table 1.2

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The neurologist or neurointensivist may be called on for

ADDITION,	NUMBER OF	REASON
Simple or HL7/User De-	n1 = O(1)	One insert, delete or update query command for datatype description.
Composite Datatype having D simple components	n2 = O(D+n1)	One query command for compositedatatype description and D commands for the component descriptions.
Field which is referenced by S Segments	n3 = O(1+S+n2)	One query command for the field description, S commands for each referencing segment, and O(n2) commands because a field belong to some datatype.
Segment having F fields and referenced by M Mes-	O(1+(N*n3)+M)	One query command for thesegment description, M commands for referencing Messages and N*n3 commands for the related fields.
Message having S Segments each having F different fields	O(1+S+(S*F)+(S*F*n2))	One query command for message description, S commands for segment description, S*F commands for field description and S*F*n2 commands for respective datatype.

NOTE: The result is provided in the big-O notation which connotes the maximum value. Thecalculations are done with an assumption that the components or subcomponents don't exist at all or all need to be modified or deleted. In real case, only few subcomponents are needed to be appended or modified resulting in the drastic decrease of the queries required.

Table 1.2. Number of queries required to modify, add or delete an HL7 Message Component.

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consultation on an intensive care unit (ICU) patient with overt clinical convulsions, more subtle manifestations of subclinical or of no convulsive status, or occasionally on a patient misdiagnosed as being in status epileptics. This article addresses the diagnosis and management of such patients.

Algorithm for Clinical Seizure Activity in the Intensive Care Unit:

1.Immediate Actions:

i. Airway Breathing Solution give oxygen, start Intravenous, and send appropriate blood work including glucose, Antiepi-leptic drug levels, and toxicology screen if patient presents from outside of hospital; monitor Electro cardio gram.

ii. Administer Thiamine 100 mg IV if alcohol abuse or poor nutrition suspected and then D50W 50 mL IV (unless glucose level known and adequate)

iii. lorazepam 2–4 mg IV OR diazepam 20 mg PR; repeat lorazepam in 5 minute if seizures persist

Second Line Therapy to maintain adequate antiepileptic drug; levels:

2.Fosphenytoin (150 mg/min) or phenytoin (40 mg/min): 30 mg/kg IV with blood pressure and electrocardiogram monitoring OR

3. Valproate: 16–20 mg/kg IV OR

4. Levetiracetam: 500–2000 mg depending on renal function OR

5. Phenobarbital

Third-Line Therapy if seizures persist:

Intubate patient

I. Midazolam IV: loading dose: 0.2 mg/kg; infusion rate: 0.1 mg/kg/h OR

II. Propofol IV: loading dose: 3–5 mg/kg; infusion rate: 01–15 mg/kg/h

III. OR

IV. Pentobarbital IV: loading dose: 5–15 mg/kg over 1 h; infusion rate: 0.05–10 mg/kg/h OR

V. Thiopental IV: loading dose: 75–125 mg boluses; infusion rate: 01–5 mg/kg/h

2.RELATED WORK

Several studies have been conducted by health professionals and researchers to find out the characteristics of Decision Support System and what can be a good methodology in the design of a decision support system. A randomized and non randomized controlled trial exercise is used to evaluate the effect of CDSS compared to without a CDSS on practitioner performance:

i. Thermography (pain detection, diagnosis)

It talks about the use of thermography to disco genic the lumber disc herniation pain. It changes the pain into a color image form. It has a very high sensitivity of 89.5% and its results are very much correlated with clinical results. It is very much useful to diagnose the disc herniation, detecting the symptomatic level in multiple disc herniation and to predict the post operative courses in the lumbar disc herniation.

ii. Neural Network (Training the network, Avoidance of over dosage)

It focuses on the importance of monitoring the post operative patients to avoid any life threatening after affects because of the over dosage of morphine. One way to avoid it can be studying correlation between analgesia, the airway obstruction and hypoxia. Using the neural network it is observed that even without giving any prior information about category it is required to identify, still it is able to extract the relevant information from input data to generate clusters that corresponds to class.

iii. Knowledge Base (Rules, Recommendations, Implementation):

It focuses on the use of the adaptive guidelines extracted from the Knowledge base and to be used in the Delivery System for Clinical Guidelines. The patient test results serves as the input to the system and on matching the input against the defined rules, an optimal recommendation plan has been generated.

iv. Fuzzy Logic Rule Base (Data Mining, Disease Diagnosis):

The use of the Fuzzy Logic Rule Based classifier as a data mining technique in the diagnosis of diseases like appendicitis is very effective. It can accurately diagnose the severity and the type of appendicitis.

v. Laparoscope (Surgical Healing process, Enhancement of 3CCD)

It discusses the use of Laparoscopes that have certain benefits in surgical processes such as surgical incisions are small and healing process after the post operative pain is quick. Other than that it has some disadvantages such as it is very much technical in nature, it can loss the three dimensional assessment of anatomic structures. The research work on the enhancement of 3CCD camera using software algorithms to visualize is under process. Some injuries like common bile duct injury are very common complication of laparoscopic use.

vi. Interoperable System (Respiratory System, Safety Interlock)

This paper explains the need of an interoperable system that can continually monitor the patient on PCA system to detect evidences of deteriorating respiratory functions or critical states and suspend the medication delivery in case of over mediation. It activates safety interlock and activates the nurse call.

vii. Endoscopic Imaging System (Minimize Post- Operative Pain, Cost, Powerful Surgical Tool):

The use of the Clinical Decision Support Systems can be best observed in performing the medical operations today. Minimal invasive surgery is lower cost, fast healing process and minimizes the post operative pain. The two dimensional and three endoscopic imaging systems make it much more powerful. The use of the laser beam transendoscopically within body cavities is because of the development of reliable fiber or waveguide. The combination of endoscopy technique with the laser interaction creates powerful surgical tool. It has a long list of several WG's. The people participating in the survey are trying to have more flexible, high power and maximum reliability.

viii. iPCA (Post-Operative Pain Management)

Post Operative Pain is a very common complains of patients. Sometime this pain becomes so extreme that it causes more damage than the actual disease. There is a need of a Clinical Decision Support System that will enable us to continuously measure the level of pain in patient and help in its efficient management. It can be an integrated information system iPCA consisting of three main parts. Front for sensing the data, back for pain management database and data mining from systems and a middle integration network. The paper shows the feasibility of the approach in medical domain.

ix. Opioid-Sparing (Post-Operative Pain, Cost Effective):

The use of the medical opioids is an important component for the management of post operative pain but it increases the cost of health care. There is a need of cost effective technique for the management of post operative pain. A survey was conducted to compare the use of Opioid only with Opioid-Sparing and it is observed that the Opioid Sparing reduced the hospital cost.

x. Ketamine plus 2/3 Morphine (Post-Operative Pain, Stable Pain Score):

It compares the use of standard morphine dose to 35% lower dose plus a subanaesthetic dose of ketamine for the diagnosis of post operative pain. The patient suffering from tissues and bone cancer have severe pain during surgery. A randomized study of 10 months survey showed that the use of ketamine plus 2/3 standard dose of morphine results in more stable score of pain and shorter period of treatment.

xi Ketorolac (Stable Pain Score, Reduced Opioid Requirements):

It involves the study of stable pain score in children undergoing surgeries. It was observed that ketorolac provides the analgesia comparable to the meprindine and significantly reduced opioid requirements but is not associated with the reduction of post operative vomiting of length of stay and in management of acute surgical pain.

xii. Bupi Vaccine (Wound Inflation, Pain Score):

It is a study on the precision of wound inflation with bupi vaccine to wound at the end of the operation. A survey was conducted. The focus of survey was to divide the patients into three groups and then take their reading for 4 consecutive days after operation. It was observed that there exists no significant difference in the opioid requirement and the pain score between all three study groups.

xiii. Pattern Recognition (Pain Assessment, Sedation Level):

The use of pattern recognition technique using RVM learning in medical sciences is growing very rapidly. It is highly useful in diagnosis of pain and diseases in those patients that cannot communicate verbally. It is an extension of support vector machine algorithm and has the ability to distinguish pain from no pain.

This pain assessment system and automatic sedation system can be used along with the decision support system to figure out the level of sedation on a score 0-6. 0 represent unresponsiveness, 1 represents responsiveness with noxious stimuli, 2 represent responsive to touch or name, 3 represent calm and cooperative, 4 restless and cooperative, 5 agitated and 6 represents dangerously agitated.

From the above analysis it is evident that poor support system is the most prominent factor for the failure of the Decision support projects. So capturing Clinical requirement accurately is the major challenge that most of the researchers faced. Clinical Requirement plays a vital role in capturing requirement during Decision Making. Clinical Requirements is recognized as one of the most critical, knowledge-intensive activities of Decision making; poor execution of repository will almost guarantee that the final project is a complete failure. Since project failures are so rampant, it is quite likely that improving how the Clinical performs could have a dramatic effect on the success record of the Hospital.

Their review showed that:

1. Computer-based decision support is more effective than manual processes for decision support.

2. CDS interventions that are presented automatically and fit into the workflow of the clinicians are more likely to be used.

3. CDS that recommends actions for the user to take are more effective than CDS that simply provides assessments.

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4. CDS interventions that provide information at the time and place of decision-making are more likely to have an impact.

3. CDSS PROBLEM STATEMENT'S:

Evidence-Related

Lack of supportive research evidence ,Decision may not be able to draw an acceptable conclusion or judgment, Lack of supportive research evidence Decision may be infeasible to the clinical case, Inaccessible evidence at the point of care.

Clinician-Related

Lack of in-depth knowledge in the specific nature of evidence, Could not make full use of evidence to the specific type of a diagnostic problem, Failure to use the CDSS or non-acceptance of computerized recommendations, Could not efficiently manipulate evidence or adapt recommendations to accommodate the variance of diagnoses.

System-Related

Multiple requirements (e.g., billing and EMR) converge to stress clinicians for coding patient‟s disease with accurate diagnoses Throughput-oriented concerns may discourage the deliberate processes of analytic diagnostic thinking.

Table. 3.1 Problems and their Impact

PROBLEMS	IMPACT
Lack of supportive research evidence	Incomplete understanding of needs
Incomplete domain knowledge	Poor user collaboration
Inaccessible evidence at the point of care	Evidence could be not be reached
Multiple requirements	Misunderstanding of system purpose
Ambiguous requirements	Synonymous and homonymous terms
Poor usability or integration	Unnecessary design consideration
Lack of in-depth knowledge	Incomplete understanding of needs
Diagnostic strategies	More strongly than analytic research evidence
Failure to use the CDSS	Non-acceptance of computerized recommended
Motivational effect of the developer‟s	Good system performance

4. CDSS TECHNIQUES:

CDSS is considered to be a very vital activity in Soft computing engineering. It is a proven fact that improper elicitation of requirements leads to a project failure .So for the improvement in the Clinical industry's success the Decision Making process .

Rule-based systems. A rule-based system uses different expert knowledge bases in form of expressions that can be evaluated as IF-THEN rules (production rules). Neural networks. Artificial neural network is a non-knowledge-based adaptive CDSS that uses machine learning to learn from experiences and recognize patterns in clinical information.

Bayesian network. A typical knowledge-based decision-making system is the Bayesian network (a.k.a belief network or causal probabilistic network) that shows probabilistic relationships between sets of variables – diseases and symptoms, based on conditional probability according to Bayes theorem.

Logical condition. Logical reasoning makes decisions according to the value of a given variable. The results of a decision-making process are different if the value is within or outside of the set boundaries.

Data mining and machine learning. These methods are based on probabilistic decision-making according to the systems database. The ideal databases should be large and well constructed, so that they allow precise retrieval of patients similar to a current patient.

Genetic algorithm. As a non-knowledge-based method it uses iterative processes to rearrange itself and provide an optimal solution based on the patient data.

Guidelines for Selecting and Implementing Clinical Decision Support Systems:

Osheroff et al. offer practical suggestions for steps to be taken in the implementation of CDSS. The guidelines below address other issues such as those involved in selecting CDSS, interacting with vendors, and assuring that user expectations for CDSS are appropriate.[30]

Assuring That Users Understand the Limitations [31]

In 2010, Brannigan and Dayhoff highlighted the often different philosophies of physicians and software developers. Brannigan and Dayhoff mention that physicians and software developers differ in regard to how "perfect" they expect their "product" to be when it is released to the public. Physicians expect perfection from themselves and those around them.

Assuring That the Knowledge Is From Reputable Sources[32]

Users of CDSS need to know the source of the knowledge if they purchase a knowledge-based system.What rules are actually included in the system and what is the evidence behind the rules? How was the system tested before implementation? This validation process should extend not just to testing whether the rules fire appropriately in the face of specific patient data (a programming issue), but also to whether the rules themselves are appropriate (a knowledge-engineering issue). Sim et al. advocate the use of CDSS to promote evidence-based medical practice, but this can only occur if the knowledge base contains high quality information.

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Assuring That the System Is Appropriate for the Local Site
Vendors need to alert the client about idiosyncrasies that are either built into the system or need to be added by the user. Does the clinical vocabulary in the system match that in the EMR? What are the normal values assumed by a system alerting to abnormal laboratory tests, and do they match those at the client site? In fact, does the client have to define the normal values as well as the thresholds for the alerts? The answers to the questions about what exactly the user is getting are not always easy to obtain.

Assuring That Users Are Properly Trained
Just as the vendor should inform the client how much work is needed to get the CDSS operational, the vendor should also inform the client how much technical support and/or clinician training is needed for physicians to use the system appropriately and/or understand the systems' recommendations. It is not known whether the users of some CDSS need special clinical expertise to be able to use it properly, in addition to the mechanics of training on the use of the CDSS.

Monitoring Proper Utilization of the Installed Clinical Decision Support Systems
Simply having a CDSS installed and working does not guarantee that it will be used. Systems that are available for users if they need them, such as online guidelines or protocols, may not be used if the user has to choose to consult the system, and especially if the user has to enter additional data into the system. Automated alerting or reminder systems that prompt the user can address the issue of the user not recognizing the need for the system, but another set of problems arises with the more automated systems.

Assuring the Knowledge Base Is Monitored and Maintained
Once the CDSS is operational at the client site, a very important issue involves the responsibility for updating the knowledge base in a timely manner. New diseases are discovered, new medications come on the Overview of Clinical Decision Support Systems market, and issues like the threat of bioterrorist actions prompt a need for new information to be added to the CDSS.

Table.4.1.Parameters for Selecting the CDSS Technique

Parameters	Values		
Project Type	Clinical Critical Systems ,DSS		
Project Size	Small		Large
Identify Stakeholder	Market Need	Specific Organizational	
No of Stakeholder Participating	Single		Multiple
User Involvement	Low		High
Provide information when user is unsure what to do	High		
Budget Constraints	Low	Medium	High
Correct user‟s errors and/or recommend to plan	Low		
Quality concerns	Low		High

Depending on all the above attributes and values we select the appropriate CDSS techniques; these attributes may be independent or dependent on each other. These attributes will provide the more systematic and sequential approach to conduct Clinical process and application of right Decision technique. The study suggests that we require an effective guideline for selecting the Clinical requirement Technique. We require new ways and Techniques for CDSS to achieve high throughput and quality in Clinical Decision phase. Following are some suggestions for Effective CDSS Technique Selection. Using these parameters for selection, Instead of individual techniques, different combinations of techniques can also be analyzed in the same way. Parameters can be readjusted according to specific type of projects.

5.Evaluation of CDSS:

[33]Any evaluation of CDS should assess how the systems are used in practice and their impact on users. Systems that are "less than perfect" may positively impact users' decisions, and others that perform well outside the clinical setting may not be used in such settings, or may be overridden when implemented in a clinical environment. Also, as Carayon, et al. and Osheroff, et al. have emphasized, evaluations of CDS should assess the entire work situation and all stakeholders, rather than focus solely on system performance. Osheroff and colleagues use the acronym METRIC which stands for Measure Everything That Really Impacts Customers. The customers in CDS are in fact a diverse group of stakeholders which can include clinicians, patients, and the care delivery organization. There are a number of challenges in evaluating the impact of CDS. One of the reasons there are so few RCTs on the use of CDS is because an RCT is expensive and time consuming to conduct and cannot usually be undertaken without external funds. Part of the expense lies in having enough use of the system to have the power to detect an effect, especially for outcomes such as adverse drug events, which may be comparatively infrequent, hard to detect, and difficult to assess in terms of preventability. There are also very few evaluation studies outside academic medical centers. The non-RCT studies have tended to support the general results of the more rigorous trials—that CDS can be helpful to clinicians and can improve patient safety. However, for a variety of reasons, CDS is not always utilized, or is not implemented effectively, and hence the potentially positive impact on the quality of care is not always realized.[34]

6.CONCLUSION

The objective of my Review work "Clinical Decision Support System Using Soft Computing Techniques" are as follows:
Providing Preventive care Immunization, screening, disease management guidelines for secondary prevention .

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Provide Diagnosis Suggestions for possible diagnoses that match a patient's signs and symptoms .

Planning or implementing treatment guidelines for specific diagnoses, drug dosage recommendations, alerts for drug-drug interactions .

Develop a new methodology for improvements of Follow-up management Corollary orders, reminders for drug adverse event monitoring .
Hospital, provider efficiency Care plans to minimize length of stay, order sets Provides an efficient methods for Cost reductions and improved patient convenience Duplicate testing alerts, drug formulary guidelines

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A review of the studies in Appendix A suggests several notable tendencies:

As Appendix A shows, most studies are of specific changes in clinical performance that could affect patient care. As is evident from Appendix A, most studies use an experimental or RCT design. With only six multi-methods studies, plus three more using qualitative methods, methodological diversity is limited. Other approaches to evaluation [23,24]. Few studies involve field tests of a CDSS and almost none [21, 22])

Appendix A: CDSS Study and Finding

Authors	System	Study design	Findings
Bates et al. 2011 [17]*	Drug Alerts POE	Comparison of Medication errors before and after implementation, and also with and without team intervention	POE decreased rate of medication errors. Team intervention Conferred no additional benefit over POE.
Bates et al., 2010 [18]*	Drug Alerts POE	Comparison of medication errors at different time periods	POE decreased rate of medication errors
Berner et al. [25]+2010	Dx DSS	Comparison of physicians	Physicians' performed better on the easier performance cases and on the cases for which QMR on constructed cases could provide higher-quality information.
Berner et al. 1998 [27]+ grams'	Dx DSS	Comparison of pro performance than the others.	No single computer program scored better The proportion of correct diagnoses ranged from 0.52 to 0.71, and the mean proportion of relevant diagnoses ranged from 0.19 to 0.37.
Berg, 1997 [26]	Dx DSS	Case studies in clinical settings and drug detail	Actor-network theory is used to describe how system implementation changed both the system and work practices.
Bouaud et al., recom1999 [31]	Drug complain	physicians' agreement and com Recompliance with guide-	Clinicians agreed with 96% of the mendations and followed one of the mendations in 65% of cases.
Buchan et al., 1997 [19]	Dss compression	Guidelines Comparisons of pre scribing behavior change	Participation was followed by a favorable in clinical behavior which persisted for at least two years.
Friedman et Dx DSS al., 1999 [20]†	Dx dss	Comparison of physicians' Dx using dif-subjects'	DSS consultation modestly enhanced diagnostic reasoning ferent laboratory setting
Gadd et al,1998[28]	DSS Inter usibilty	Comparison of Perception of different were face.	Feature that improve perceived identify prototype the system through video observation survey

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Gamm et al., 1998 [29] patient	Drug Alert s POE	Computer Comparison of pre based and post-installation survey data.	Pre-installation, most respondents were moderately positive about the helpfulness and utility of computerization in their record did inter-views and practice. Post in-stallation experience fell observations. short of those expectations.
Jha et al., 1998 [13]* event (ADE)	Drug mon-itor	Drug Com-pare computer Alerts based ad-verse drug fewer moni-tor against chart re-voluntary report.	The computer-based monitor identified ADEs than did chart re-view but many more ADEs than did stimulated suggestions and user ac-ceptance
al., 1997 [21] physi-cian	Drug Alert s POE	physicians' agreement and com recompli-ance with guide-	observation and is-sues were identified. in-terviews concerning diag-nostic and treatmet guidelines in psychiatry

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