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## RESEARCH ARTICLE

# Integrating Emotional Requirements in Use-Case Point Model for Effort Estimation of Healthcare System

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**ABSTRACT** The software industry was greatly affected by the pandemic. The emotions and human behavior of software developers and users greatly affected the development of software systems. Accurate effort estimation is a key role in the success of any software project. Among many software effort estimation models, the use-case point (UCP) model is one of software development's maximum-used effort estimation models. So many research studies have addressed the effort estimation of software projects through the UCP model, but the effort estimation of specific quality and emotional requirements for the software system receives minimal focus. To fill this gap, we have proposed an extension to the existing standard UCP model. In the extended UCP model, we have introduced two new quality and emotional components. We applied the extended UCP estimation model to estimate the effort to build all types of software system requirements and analyze the influence of quality and emotional requirements on the effort estimation value. A real-time emotion-based healthcare case study was used by the authors to create and compare effort estimation models for estimating requirement-type efforts through UCP size. We have taken two more case studies named Internet banking system, and E-commerce application for further validation of our study. We found the mean magnitude of relative error (MMRE = 0.086), mean magnitude of error relative (MMER = 0.092), and mean absolute percentage error (MAPE = 8.6%). Our proposed methodology gives an 8.6% error, showing our model's accuracy. Expert opinions have also been taken to assess our study. Most industry experts validated our study by suggesting three additional human factors (social, cultural, and economic) that may impact the software project's effort estimation.

**INDEX TERMS** Requirements, emotions, use case point model, health care system, effort estimation, human factors.

## I. INTRODUCTION

The COVID-19 pandemic is regarded as a worldwide health catastrophe. Around the world, it affects numerous business sectors, and software development is no exception [1]. COVID-19 substantially impacts software development initiatives and professionals [2]. The development process

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events between January 2019 and April 2022 for 50 chosen open-source projects on GitHub demonstrate that 72.4% of projects were adversely affected by the COVID-19 outbreak [3]. Software developers' daily lives were disturbed by the COVID-19 epidemic and the ensuing lockdowns, which abruptly required them to work remotely from home [4]. Normal workday habits were severely disturbed by this adjustment, which impacted both productivity and well-being. Additionally, this epidemic will have a lasting impact

on the software sector because many IT firms now permit their staff to work from home whenever they like [5].

Safety-critical software systems are continuously changing due to the changing environment of workers. Accidents in safety-critical systems don't happen often, making them frequently insufficient to reveal safety trends or measure the system's instant safety performances. Such quantifications of system safety performance are required during system development or evolution to make safety design decisions or to satisfy regulatory requirements [6]. Developing software for safety-critical systems is expensive because of the required level of system reliability. Safety-critical systems are distinguished by the potential injury or fatalities that could come from an unplanned system failure [7]. Typically, software for critical applications is created by fitted procedural guidelines. The NASA STD-8719.13C, the DO-178C for the aviation industry, and the ISO/IEC 62304 for the medical industry are three of the most popular standards in this area [8]. The healthcare system is one of the safety-critical systems that has gained much attention from researchers due to its diverse nature.

Healthcare is one of the most crucial industries that requires the integration of cutting-edge technologies [9]. A healthcare system is a safety-critical software system that highly influences effort estimation methods due to high-risk assessment and specified standards factors. A traditional healthcare system is being transformed into a personalized healthcare system with an electronic health record (EHR) storage system [10], sophisticated data investigation algorithms, and multi-objective optimization approaches. The recent growth of telemedicine and e-healthcare systems has demonstrated the importance and necessity of these developments in healthcare organizations in the wake of the pandemic [11]. Healthcare and telemedicine are not the answers to all health-related difficulties. However, they can be exploited to solve many health issues without requiring patients and doctors to move about physically [12]. Due to the enormous number of people requiring medical support, the healthcare industry faces many difficulties [13]. Incorporating emotional intelligence is very necessary for artificial intelligence-based healthcare systems [14].

Emotions play a very important part in people's health. An emotion is a feeling resulting from someone's mood or reaction [1]. This phrase describes feelings like grief, rage, joy, fear, or astonishment. However, these concepts have little to do with consumers' emotional expectations of software. Research in psychology and neuroscience has shown how closely human cognition and emotion interact, including things like perception, attention, learning, and decision-making. People's daily lives depend heavily on emotions. Understanding emotional cues in contexts of daily life becomes a critical factor that affects how people communicate and behave verbally and nonverbally. The emotional states people are in also influence their body posture, speech intonation, and facial expressions. Nevertheless, the research

community continues to debate what constitutes an emotion. According to one of these definitions, emotion is the intellectual information derived from the assessment of internal and external events utilized to plan reactions and associate concepts and states with these supposed occurrences [15].

In software engineering, emotions play an important part in software effort estimation. Emotions can bias the estimation value. Integrating emotional aspects in the UCP method is significant as it addresses the hidden emotional view of the system. Integrating emotional requirements in the UCP method ensures that customers' emotions and experience regarding software services are satisfactory or not. The addition of emotional aspects in the UCP method can lead us to a more accurate effort estimation value. Risks can also be managed efficiently as emotional requirements also consider issues such as frustration and demotivation that can cause projects to be delayed. Incorporating emotional factors improves communication between different stakeholders, as all stakeholders know the major common emotional objectives of the project. Considering the emotional aspects of the users in producing software will make such systems that will meet users' functional, quality, and emotional needs. Due to the overconfidence of software developers, the effort for the system increases. Positive emotions resulting from past success can encourage software developers to build a project with the specified value. Negative emotions due to past failures can lead the developer to meet the project over budget and cost. Emotional requirements are necessary to build trust between patients and healthcare organizations. The absence of emotional requirements in healthcare systems can produce dissatisfaction among patients.

Quality attributes directly impact healthcare systems, like efficiency, accessibility, security and privacy, and adaptability. Healthcare resources should be used in such a way as to maximize efficiency. This includes reducing unnecessary tasks in the healthcare system and streamlining all the major processes. Accessibility of the healthcare system should also be ensured to facilitate the patients at all times. This can be done by providing alternative accessibility modes to patients, like telehealth and mobile streaming.

Human values and aspects greatly affect software development. Human factors play an important role in the success or failure of any software project. A major human factor influencing the effort estimation process is human behavior and values regarding any software system. These values are related to the emotional requirements of software systems. A lot of research has been done on the estimation of effort for software projects. Poor management can potentially drive-up software costs more quickly than any other factor, as Boehm noted in [16].

Inaccurate effort estimating is a key component of poor software development management, frequently resulting in software failure. Software engineers should, therefore, properly predict the time and effort required to accomplish any software project before they begin making plans for its

development. Accurate estimation undoubtedly contributes to more efficient software development management, lowering project failure risk. The effort estimation problem in software development projects has received extensive academic study. One of the most significant characteristics of project success is software effort estimation. Because of this, most methodologies for estimating software costs depend on effort costs, which determine cost estimates in terms of a person per month or software size. Due to this diversity, many software effort estimating (SEE) algorithms have been proposed in the literature. These methods were separated into four groups: algorithmic models (UCP analysis, functional point analysis, and constructive cost model; COCOMO), non-algorithmic models (expert judgment; price to win), machine learning techniques, and hybrid methods. In a thorough systematic review, Jrgensen and Shepperd [17] found 304 articles. Numerous researchers have studied the various estimating strategies and their accuracy issues. Over time, several models or variations have been developed and improved [8].

The creation of estimates, typically described in terms of money or hours, can be summarily defined as a series of tasks that must be completed [18]. Estimation anticipates the resources needed to complete the software development by analyzing the environment and the approach. By utilizing predetermined methodologies, tools, and techniques, software estimating allows us to determine software development effort and cost [19]. A good software estimating approach will result in the most efficient use of resources and enhance the standard of the finished goods to increase customer satisfaction.

Software requirements are gathered and documented using use case models and scenarios using the OOAD approach. The use case model (UCP) is a method for measuring a system's size. To determine the size of the system, each use case is given a numerical weight based on the number of transactions in the use case scenario. Additionally, weights are given to the system's users according to their kind. Unadjusted use case point (UUCP) size is the total of all user and use case weights. It is adjusted by a factor that denotes the impact of non-functional needs as determined by 13 technical complexity factors (TCF) and 8 environmental complexity factors (ECF). The equation below gives the formula for calculating the final modified UCP value:

$$UCP = UUCP * \left( 0.6 + \sum_{i=1}^{13} TCF_i / 100 \right) * \left( 1.4 - 0.03 * \sum_{i=1}^8 ECF_i \right)$$

A size measure that truly reflects the system's complexity can be derived by multiplying the UUCP size by a value that serves as an adjustment factor. Use cases establish the system's fully functioning scope, allowing us to make early estimates. According to Boehm's Requirement Specification milestone, the relative error of these estimations

may be between 30 and 50% [16]. Considering that the authors offer numerous enhancements, we decided not to create another improvement technique for the UCP approach. Instead, we suggest that projects be divided into several requirement types, with each requirement type's effort being estimated using the standard UCP size [20].

This research revolves around integrating emotional aspects into the use-case point method. The main research objectives (RO) of this study are given below:

**RO1:** Determining the impact of emotional aspects on the effort estimation value of the healthcare system.

**RO2:** Using different techniques to gather, validate, and measure the emotional aspects of the system for effort estimation value.

**RO3:** Extending the traditional UCP model by integrating emotional and quality aspects into the model and connecting these aspects with the technical and environmental factors of the traditional UCP model.

**RO4:** Validating extended UCP model by emotion-based healthcare system case study and experts' opinion.

**RO5:** Identifying human factors that can influence the effort estimation value of software projects.

The main motivation for doing research in effort estimation is its contribution to the success of any software project. Effort estimation is the key factor for the success or failure of any software project. Project planning, risk management, and cost estimation depend upon the effort estimation value. The wrong estimation will lead the project to failure. Effort estimation also greatly influences quality assurance, process improvement, and customer satisfaction. Much research has been done to find accurate estimations to develop projects better. This paper uses an effort estimation technique by extending the use case point technique to an emotion-based healthcare system. Some research questions will be answered and justified using our effort estimation technique. Those research questions are given below:

**RQ1:** Does the existing UCP model address the emotional aspects of the software project?

**RQ2:** Does the existing UCP model address the quality parameters of the software project?

**RQ3:** Can we connect our system's emotional and quality requirements with the UCP model's technical and environmental factors?

**RQ4:** What are the human factors other than functional, quality, and emotional, which can influence the effort for any software project?

According to these research questions, the key contribution of our paper is as follows:

- An extended UCP model addressed the emotional requirements and human values.
- The proposed extension to the UCP model focused on the quality parameters of the system.
- An extended UCP model connected emotional requirements with environmental factors of the UCP model and quality requirements with technical factors of the UCP model.

- Validation of the model through an expert opinion of 10 industry experts and a case study of a real-time emotion-based healthcare system. Social, cultural, and economic factors are other factors that can influence the software project.

The proposed model was applied to a real-time project titled a healthcare system to validate the proposed framework. We arrange the remaining paper as follows: Section II will define the literature review regarding effort estimation, use case point model, healthcare system, emotional models, and quality requirements. Section III will explain the main methodology. Section IV will address the UCP model implementation and results. Section V will explain the main threats to validity. In the last, section VI will give the conclusion.

## II. LITERATURE REVIEW

Effort estimation is not a new topic. It has been attracting the research community for the last decade. Many researchers have made many contributions to the estimation of different software projects. It has a straight consequence on the success of any project. The main motivation for doing research in effort estimation is due to its critical role in developing software systems successfully under the budget and schedule. The main purpose of doing research in effort estimation is to improve software projects' reliability, efficiency, risk management, and accuracy. The study [21] systematically studied effort estimation techniques from different perspectives. It suggested that the ensemble effort estimation model is the most suitable model for estimation. S. El Koutbi [22] discussed the trend of effort estimation research in the last decade. They observed a huge increase in research on effort estimation techniques. According to the study [23], effort estimation approaches are separated into two parts.

### A. ALGORITHMIC-BASED ESTIMATION METHODS

Those methods that use some algorithms or mathematical formulas to compute the software estimation are called algorithmic estimation methods. The main examples of algorithmic estimation methods are COCOMO 2, function point, Use case point, source line of code, and Putnam's model.

### B. NON-ALGORITHMIC-BASED ESTIMATION MODELS

Those methods that use historical data or observations for software estimation are non-algorithmic-based. These methods are separated into expert judgment, analogy, and machine learning methods.

There are also other methods used to model the objects like graph theory and software modeling by different variable objects. Graph theory consists of graphs that connects different objects to show the relationship among them. Software modeling like unified modeling language (UML) is also used to model the objects to show different types of relationship among them. Every method has certain conditions for usage. No method can fit all conditions. The best-used method that approximately fits all conditions is the use case point model.

In this paper, we are using the UCP model from a different perspective. Karner [24] proposed a use case point model for effort estimation of a software project. The use case point model is based on the use case components of the system's functional requirements. Technical and environmental factors also impact the use case point value. The use case model has different limitations, such as ambiguities in natural language requirements, cost estimation, and uncertain classification of use cases and actors. Different researchers have modified the use case point model to remove these limits. These modifications are adapted use cases, enhanced use cases, extended use cases, and others [25], [26]. Wang presented the idea of extended use case point method by using Bayesian network and fuzzy sets [25]. Mohagheghi et al. discussed the method of adapted use case point. In his method, he assumed that all the use cases belong to the complex class and all the actors belong to the average class [26]. Ochodek et al. proposed a method for using case point values by omitting the values of UAW [27]. He used all the classifications of Karner. Silhavy [28] described an algorithmic approach for UCP estimation. This method used the least square method to improve regression coefficients. In a study [29], silhavy discussed six different LR-based models for UCP estimation. He observed that LR-based UCP estimation models have performed better than other models. AdamUCP method was defined by Hoc [30]. This method used gradient descent to optimize the regression coefficients. Silhavy developed an actor and case size estimation method. In his method, he only used actors and used case values for UCP estimation [31]. The study used different clustering techniques for UCP estimation [32].

Prokopova discussed three clustering techniques to resolve the issues in UCP estimation. He introduced distance metrics for UCP estimation [33]. Preetam presented a survey report on UCP estimation for software cost estimation of different projects [34]. The authors concluded that the UCP method mainly depends upon the number of transactions and weights. The study [35] discussed the divide-and-conquer approach with the help of a case-based approach. This approach gives structural simplicity and efficiency to systems. Robiolo addressed an approach for early estimation of software projects by use case transactions and entities [36]. Jha et al. made UCP estimation values based on six environmental factors. Authors assigned values to these factors according to experience and observations [37]. The study [38] presented a log-linear regression approach based on the use case point value to estimate the effort. The author concluded that this approach is very useful for larger projects. The study [39] addressed the fuzzy model tree for effort estimation based on the use case point value. Authors find better results in his approach. Naasif et al. addressed an artificial neural network model based on UCP value to estimate the effort [40]. The authors used PRED and MMRE criteria for evaluation.

Integrating emotional aspects in software development is a crucial task. Kashumi [41] discussed the importance of emotional intelligence while handling requirements changes

in the software development process. The study emphasized the importance of emotional intelligence on team productivity, goals, and values. Emotional intelligence may impact the project planning and effort estimation value. Another study [42] discussed the impact of emotions in agile software development. The study focused on developing a tool to gather emotional requirements and integrate them into agile project management, including risks and effort management. Kashumi [43] discussed the influence of emotional requirements changes in agile teams and its long-lasting impact on software project management metrics like effort estimation, cost estimation value, and risk management. The study [44] discussed emotion-oriented requirement engineering by taking a survey from 201 software practitioners regarding the impact of emotional requirements changes on project management. The study discussed that changes in emotional requirements cause technical and social challenges that affect software project management activities.

Meenakshi proposed [45] enhanced the UCP model by assigning five types of weights to the actors and use cases. The study compared the accuracy metrics of different projects. The study [46] focused on the influence of non-functional requirements on the effort estimation value. Benrahman [47] used the UCP method to find the effort accuracy of health surveillance applications and found an improvement in effort estimation value. The study [48] used the PERT model with the UCP method to remove the subjective assessment of complexity factors of the UCP method. Hussain [49] calculated a software project's effort value using the UCP and class point methods. He found that the UCP method estimates the effort value more efficiently than others. The study [50] introduced merging the use case point method to reduce the complexities of the traditional UCP method and find better results. The study [51] used regression models to identify those technical and environmental factors that have a greater influence on effort estimation value. Park [52] proposed a linguistic analysis method based on the sentiment analysis method to extract use cases from requirement specifications and then apply the UCP method to those use cases. The study [31] proposed an actor and use cases size estimation method to calculate the effort value. That method is independent of the traditional UCP method.

There are many research gaps in the above literature studies. Most literature studies discussed different UCP methods and their applications on smaller and larger projects. None of the literature has used UCP in another perspective for effort estimation of critical software systems like healthcare systems. All previous research studies used functional aspects of software systems to estimate the effort. Quality and emotional aspects were missing in those studies. It produces a research gap and emphasizes us to analyze these two aspects and integrate those aspects into the effort estimation model. The integration of these two aspects will produce a great impact on the effort estimation value. Our proposed extension will fulfill the research gap by connecting quality requirements with the

technical factors and emotional requirements to the environmental factors and analyze the effect of quality, emotions, and human values on the effort estimation value. In critical software systems, effort estimation plays an important role. The wrong estimation will cause project failure, which will cause serious damage to the project. The healthcare system is one of the most common safety-critical software systems. Researchers have made many innovations in the development of healthcare systems in the last decade. The emotional aspect of the healthcare system is a very underestimated topic. Emotions play an important part in developing healthcare systems. The study addressed the fact that emotions play an important role in providing care.

The study [53] developed an emotional healthcare system based on machine learning and sentiment analysis. The users can access that system through their smartphones. The authors addressed that this system provided more patient care and usefulness. Samira et al. discussed emotion detection in Hollywood movie clips using a multi-layer cognitive structure [54]. The study developed an emotion recognition system using IOT that can be used as a smart healthcare system [55]. Hossain et al. developed an emotion-based medical framework using 5G technology [56]. The study [57] examined all emotion-related factors for a software project. Emotional models can represent emotional requirements. The study [58] discussed an emotional model that explained emotion in six different manners. There is also a neutral category showing the absence of emotion. The study [59] addressed an emotional model focusing on the emotion elicitation process. Ojha proposed an emotional model that used general rules to evaluate emotions rather than customized rules [60]. Osuna et al. analyzed different emotional models from a software engineering perspective [15]. The study [61] analyzed 67 emotional models to investigate different emotion theories best suited for model development. Emotional requirements are also connected with the quality of the system. The study [62] addressed the quality factors in their system for emotional information processing. Quality factors also greatly impact the project's emotional and functional requirements; many attributes define the quality of the system, like portability, scalability, security, and performance. Emotional requirement engineering is very different from traditional requirement engineering. Traditional requirement engineering mainly focuses on the functional and non-functional requirements of the system. In contrast, emotional requirement engineering focuses on stakeholders' emotional needs and behaviors [43]. Emotions change from person to person. Emotional requirement engineering focuses on stakeholder's emotions in different contexts [63]. Observations and survey techniques are very useful for gathering emotions from the stakeholders. Emotions are connected with technical and environmental factors defining stakeholders' positive and negative emotions. Emotional requirement engineering focuses on multidisciplinary fields, including psychology, design, and human-computer interaction [64].

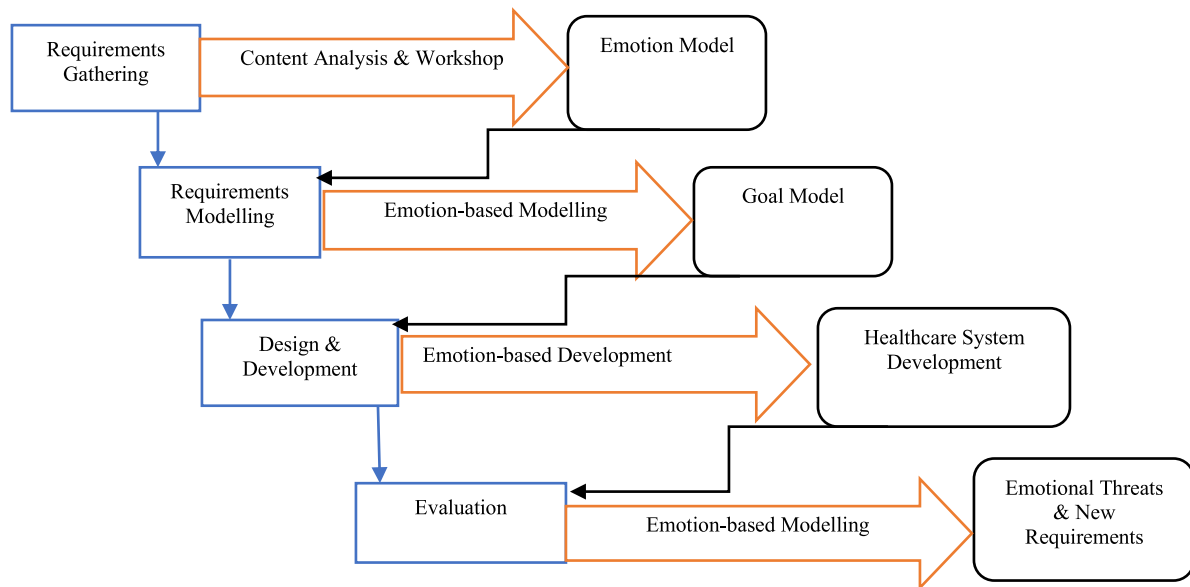


FIGURE 1. Emotion-based development process.

The emotional requirements-based development process can be represented in FIGURE 1.

Effort estimation is very crucial in safety-critical systems [65]. The study [66] addressed the necessity of including quality attributes to develop emotional models of any system. The inclusion of quality attributes will improve the performance of emotional models. Not all quality attributes are necessary to develop an emotional model of the system. Reusability and scalability are necessary for emotion-based systems [67]. The construction of emotional models and quality models for the healthcare system is not an easy task. Healthcare systems are one of the most important critical systems. In our research study, we will focus on the emotional and quality aspects of the healthcare system. Researchers have put a lot of effort into developing healthcare systems in the last decade. The study [68] proposed a methodology to incorporate emotional intelligence in software systems. Widya et al. developed a requirements elicitation methodology to build health systems [69]. The study [70] proposed a user-centered approach to developing a healthcare system by involving users in the development life cycle. Many challenges come when we estimate the healthcare system's effort and size. The main difficulty for estimation is emotional theories and quality aspects that influence the healthcare system. Our study will deal with all these kinds of aspects.

The major novelty of this paper is to get the emotional requirements of the stakeholders and check which emotional requirements can be connected with environmental factors. Many studies used environmental factors in effort estimation techniques. However, all those studies focused on the environmental factors related to the system's functional requirements. Introducing the emotional requirements in software engineering is an emerging area. Our main focus is to see how the stakeholders' emotions are connected with the

environmental factors of the system. Other studies focused on all environmental factors. However, our proposed study focuses only on those environmental factors that have some relationship with the emotions and behaviors of stakeholders. When we assign the weights according to emotional requirements and environmental factors, the accuracy value will be changed compared to traditional studies.

### III. METHODOLOGY

We have proposed a framework to see the UCP model in an extended manner. Normally, the UCP model is used to find the size and effort for the system's functional requirements. We have proposed a framework focusing on the technical and environmental factors influencing the UCP model. We have connected those factors with the quality and emotional requirements of the system. The proposed framework is given in FIGURE 2 below:

In the above-proposed framework, we can see the extension of the UCP model. We have developed three models in this framework. UCP model normally focuses on the functional model of software systems. However, our study has proposed two additional models, quality and emotional. The main reason for proposing a functional model in our study is its ability to define the scope and complexity of software projects. The quality model is directly related to the quality of the software project. The main reason to add a quality model to our proposed study is its ability to define the quality of the software project, which will be useful for software effort estimation. The emotional model is a less discussed topic in the effort estimation area. The major objective of adding an emotional model in our proposed study is its high impact on the effort value. Human values have a great impact on effort estimation. The emotional memories and incidents regarding past projects can also affect the project's performance. The

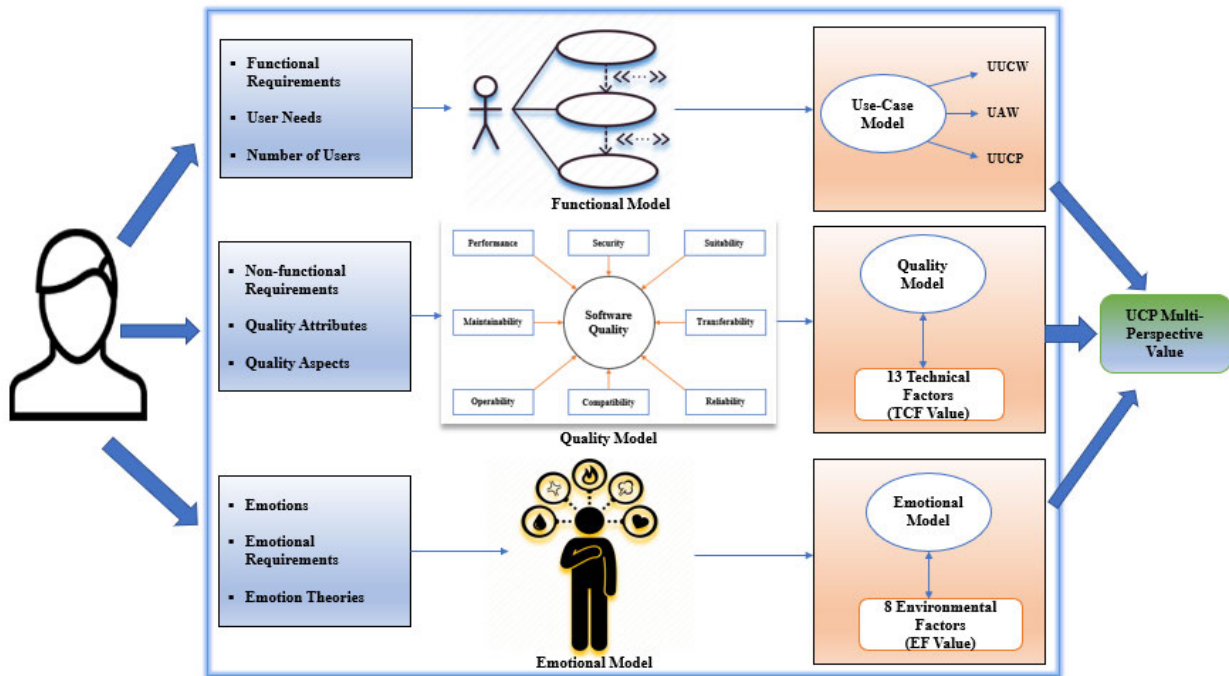


FIGURE 2. Proposed extension to UCP Model.

emotional needs of users from the system may also impact the effort estimation value. Integrating these three models in our study is very important to ensure that the effort estimation value is based on all the services the system should provide with better quality and the emotional needs of the users and developers.

There are many ways to gather functional requirements from the users. However, not every method can be suitable for gathering emotional requirements. According to a study [71], workshops and interviews are the best techniques to elicit emotional requirements. Our proposed study gathers emotional requirements from a joint application development workshop (JAD). JAD is a workshop of 20 to 30 people. All stakeholders are present in this workshop. We have elicited emotional requirements in the JAD workshop and cross-validated it after conducting interviews with all stakeholders. In the JAD workshop, story cards were distributed to all stakeholders, and all stakeholders wrote their functional, quality, and emotional requirements on the cards. As all stakeholders were present in the workshop, the chances of changing the requirements are very low. The main participants that attended the workshop are given in TABLE 1 below.

The requirement engineer gathered all these requirements, and the scribe documented them. We have 8 stakeholders in this system. By using JAD, we get all functional requirements presented by FRQ, quality requirements presented by QRQ, and emotional requirements presented by ERQ from 8 stakeholders for the patient administration module of the healthcare system.

After elicitation, we validated those requirements. There are many ways to validate the software requirements. Emotional requirements are often validated by quantitative and qualitative methods. Our proposed study uses a questionnaire and survey technique to validate our emotional requirements. All stakeholders filled out the questionnaire form and gave feedback regarding their emotional, functional, and quality requirements. The questionnaire contains questions related to all types of requirements, and participants are asked to rate the importance of requirements on a scale of 1 to 5. The requirements for those who got 3 or more scores will be included in the system. The remaining requirements will be deducted from the system. After taking a survey from all the participants, we got the validated requirements that will be included in the system.

To extend the UCP method, we integrate emotional requirements into the UCP model. Emotional requirements can be integrated into the UCP model by adding another emotional complexity factor in the weight calculation phase. But this can disturb the value of effort estimation. As we addressed emotional, quality, and functional requirements, we extended the UCP using another method. After elicitation and validation of emotional requirements, we classify the emotional requirements into three classes (positive, negative, and neutral emotions). After classification, we integrate emotional requirements into use cases. Emotional requirements also fall under the category of quality requirements, but we deal with these requirements as a separate entity. We used emotional and quality-only requirements to calculate technical and environmental factor values for the UCP method.

**TABLE 1.** Participants of the Jad Workshop.

Serial No.	Workshop Participants	Responsibilities
1	Facilitator	Team member 1 (TM1) is the project manager of an organization. He also conducted an overall session of a joint application development workshop. Coordination with different workshop participants is also a major responsibility of TM1.
2	Scribe	Team member 2 (TM2) is a requirement engineer of an organization. TM2 documented all the requirements.
3	Executive Sponsor	The company is a sponsor of the JAD workshop. The company afforded all the expenses of the workshop.
4	Observer	Team member 3 (TM3) is an observer of the workshop. He is observing all the activities of the workshop.
5	Full-Time Participants	Doctor, Nurse, Lab Technician, Receptionist, Billing Clerk, Customer/ Patient, Pharmacist, IT Administrator

We have not included quality and emotional requirements in the unadjusted use case point calculation process. Including emotional and quality requirements in finding the values of technical and environmental factors will help us find the real effort estimation value. By observing 13 technical factors and 8 environmental factors, we map between quality requirements and technical factors and emotional requirements and environmental factors. Each quality and emotional requirement is mapped to its relevant technical and environmental factor and gets the weight of the same factor. After assigning weights to quality and emotional requirements, these requirements will help us find the value of UCP, which will be useful for estimating the value of effort. Integrating emotional and quality requirements in the UCP model gives better and more efficient results.

The major components of our framework are the UCP model, emotional requirements, functional requirements, non-functional requirements, technical factors, and environmental factor values. Environmental and technical factor values are connected with emotional and quality requirements. Environmental factors like motivation and customer experience are directly connected with people's emotions. These factor values can contribute to the improvement of effort estimation value. By improving the requirements elicitation process, we can gather all types of requirements from stakeholders and find effort with more accuracy.

Accurate technical and environmental factors values are also useful in improving the effort estimation process. The use-case model explains all the functional requirements of the software system. Use-case is the simplest way to show the functional requirements of the system. The use-case model will detail the number of actors and functions included in the system. In the UCP effort estimation model, the use-case functional model finds the unadjusted use-case weight, unadjusted actor weight, and unadjusted use-case point value. In previous research, technical and environmental factors can be computed by observing the impact of those factors on functional requirements. Our proposed framework connects those factor values with the quality and emotional models of the system.

The quality model explains all the non-functional requirements of the system. In our framework, we have built a quality model that will help compute the technical factor value for the UCP effort estimation model. UCP model has 13 different

technical factors. These standard technical factors assess the quality of the software project. These factors have a direct impact on the system's quality. Among 13 factors, we will analyze only those relevant to our system. We will connect the project's quality requirements with only those technical factors that impact the healthcare system's quality. We will assign weights to those technical factors according to our system's demand.

The emotional model describes all the emotion theories and requirements a user wants from his system. The environment has a direct effect on the emotions. In our proposed framework, we have connected the emotional requirements of the software system with the environmental factors to compute the environmental factor value for UCP effort estimation.

The motivation models will be used to summarize and quantify the functional, quality, and emotional requirements elicited during the workshop. The patient's primary functional objective self-management health encapsulates all of the goals elicited and represents the application's intended use. All participants wanted to attain self-management of health and feel robust, in control, and capable while doing so. According to the workshop, the objective of Self-Manage Health is divided into five smaller objectives. All functional (rectangle shape), quality (cloud shape), and emotional goals (heart shape) of self-management health can be represented in FIGURE 3 below.

A motivational modeling workshop was held as part of the study to gather requirements for digital decision assistance in the healthcare system. The initial goal models that the authors produced based on the findings of the feasibility study project completed up to that point served as facilitators in the workshop. The goal model shown in FIGURE 4, which is the overarching goal model for decision assistance in healthcare, was created from the workshop results. The goal model starts by presenting the top objective, "Decisions Support in healthcare," along with the emotional goal that indicates how decisions in healthcare should be supported: individually and emotionally. The roles of the patient, doctor, nurse, lab technician, IT administrator, billing clerk, and pharmacist are important for reaching the highest-level objective. The goal model for decision support in the healthcare system can be represented in FIGURE 4.

In the project team's talks, it was underlined that providing decision help to achieve the sub-goal "Stay healthy" can

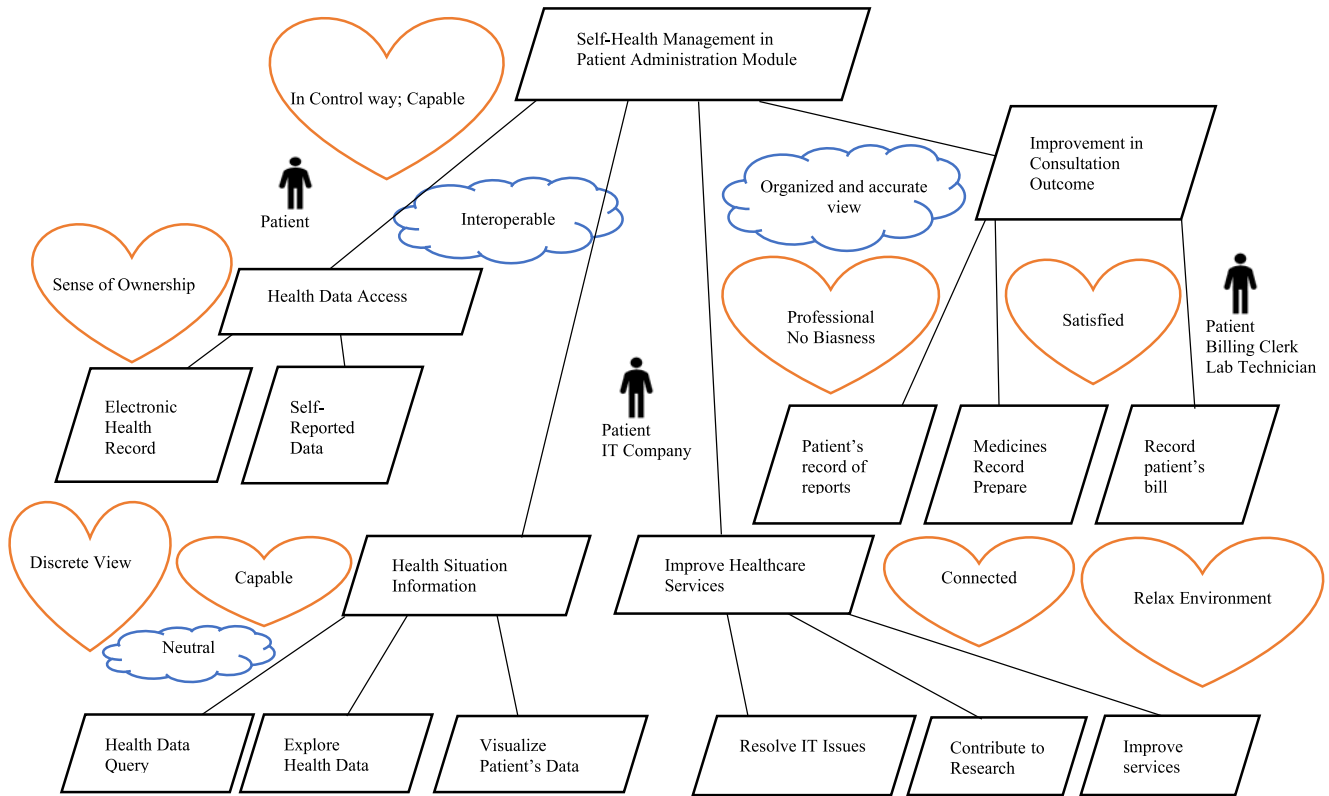


FIGURE 3. Goal model for Self-health management in healthcare system.

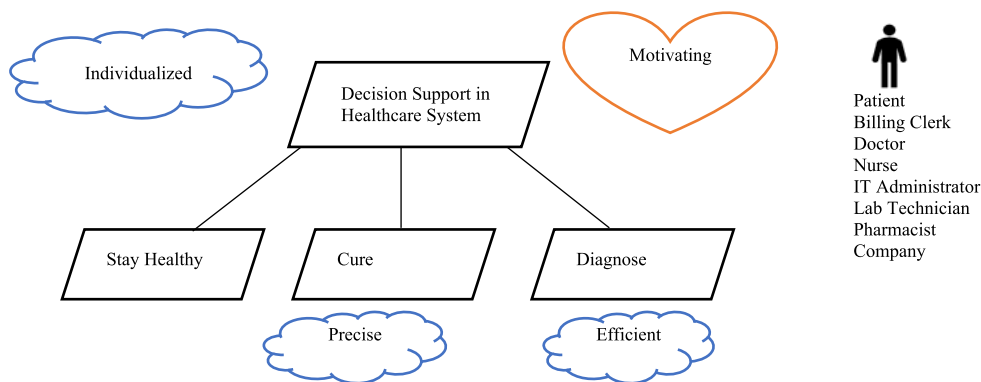


FIGURE 4. Goal Model for Decision Support in Healthcare System.

result in the majority of healthcare cost savings. This sub-goal is directly related to the emotional aspects of the healthcare system. In response to this, we expanded on the “Stay well” sub-goal in FIGURE 5.

The above three motivational goal models are useful tools to express and quantify emotional goals. These models show the emotional, quality, and functional goals of the system’s major objectives. These three models help us to analyze the connectivity of all three goals with each other. There are numerous ways to quantify emotional requirements. Several indicators and metrics can be used to quantify and measure emotional requirements like user surveys, emotion

recognition tools, sentiment analysis, engagement metrics, questionnaires, behavioral indicators, interviews, and customer satisfaction scores. Using one or a combination of these indicators helps quantify the emotional requirements of the stakeholders. We have used a combination of surveys and questionnaires from the stakeholders to measure and quantify the emotional requirements.

UCP model has 8 different environmental factors. These standard environmental factors assess the environment and user’s interaction with the software project. The standard UCP model has environmental factors that greatly influence the system’s environment and are relatable to the system’s

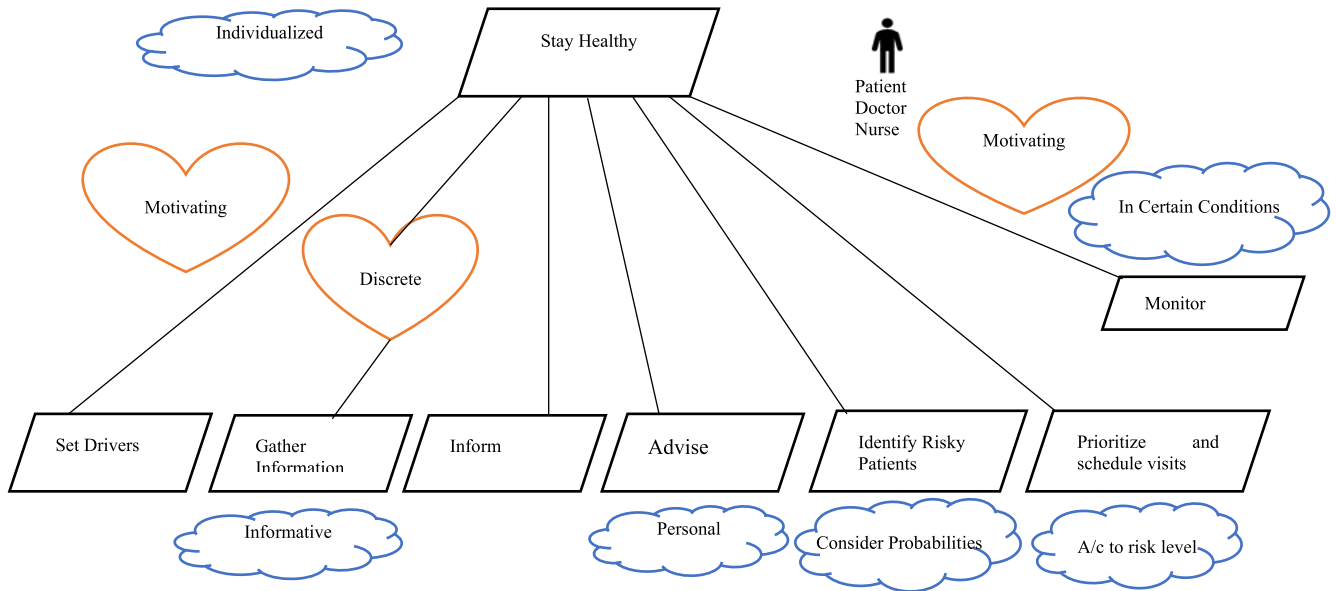


FIGURE 5. Goal model of stay healthy sub goal.

functional requirements. We connected those factors with the users’ emotional needs and values in our proposed study. Among 8 factors, we will analyze only those relevant to our system. We will connect the emotional requirements of the project with only those environmental factors that impact the environment and the user’s interaction with the healthcare system. We will assign weights to those factors according to our system’s emotional requirements.

We have different data sources to connect emotional requirements with environmental factors of the UCP model. One of the main data sources is customer feedback and past project data. Emotional and sentiment analysis of customers is also a powerful data source for emotional requirements. Environmental factors have a direct connection with the emotions of the stakeholders. We can connect emotional requirements with relevant environmental factors. Cultural, physical, and social environments greatly influence people’s emotions and behaviors. Environmental factors like motivation, stability, good experience, and accessibility provide positive emotions to the stakeholders. We can connect these environmental factors with emotional requirements and find weights easily. Environmental factors and emotions are not directly relatable. However, environmental factors have a great impact on the emotions of the stakeholders. The emotions of the stakeholders vary according to external and internal factors. Internal factors may include functionalities and quality of the system. External factors include environmental factors, cultural factors, and social factors. Environmental factors influence people’s emotions in both positive and negative manner. For example, motivation is an environmental factor that does not directly relate to emotions. Motivation is useful for customer satisfaction, which will indirectly cause positive emotions for a stakeholder. Our proposed framework’s major component is extending

the current UCP model. Through this extension, we have gathered the healthcare system’s quality parameters and emotional requirements, made connections with technical and environmental factor values, and assigned weights according to their impact. The major contribution of our proposed study is to see another view of the UCP model by connecting it with the emotional aspect of a software system. The next section will apply all these processes and frameworks to a real-time healthcare system.

#### IV. CASE STUDY AND RESULTS

##### A. HEALTHCARE SYSTEM OVERVIEW

A healthcare system is a software system that handles all patient health operations. For this study, we have considered all types of requirements (functional, non-functional, emotional) to estimate the effort needed to build a healthcare system. The main modules of the healthcare system are defined as follows:

**DOCTOR MANAGEMENT SYSTEM:** The doctor management system handles all the operations related to doctors. This system will manage all the information of doctors, their designated hospitals, and patients.

**NURSE MANAGEMENT SYSTEM:** The nurse management system handles all the operations related to the nurse. This system will handle all the information of nurses, patients’ history, and their designated hospital’s information.

**LABORATORY MANAGEMENT SYSTEM:** This system will manage all the vitals of patients. The laboratory management system will handle all the lab reports and patients’ history.

**HUMAN RESOURCE MANAGEMENT SYSTEM:** Human resource management will handle all the operations related

**TABLE 2. Selected requirements from Emotion-based Healthcare system.**

Req. No.	Description	Category	Req. No.	Description	Category
R1	Doctor's Profile	FRQ	R38	Precision in Doctor's Details	QRQ
R2	Patient Allocation	FRQ	R39	Patient's Health Details	QRQ
R3	Messages Section	FRQ	R40	Nurse Efficiency	QRQ
R4	Patient's information for the doctor	FRQ	R41	Accurate diagnosis by Nurse	QRQ
R5	Doctor's Notification	FRQ	R42	Lab Technician Efficiency	QRQ
R6	Associated Hospitals Information	FRQ	R43	Probabilities in Lab Reports	QRQ
R7	Settings Update	FRQ	R44	Receptionist Accessibility	QRQ
R8	Treatment Procedures	FRQ	R45	Patient's Details Security	QRQ
R9	Vitals Access Section	FRQ	R46	Patient's Details Easiness	QRQ
R10	Patient's Weight Information	FRQ	R47	Patient's Data Installation	QRQ
R11	Patient's Blood Pressure Information	FRQ	R48	Patient's Details Organization	QRQ
R12	Patient's History Accessibility	FRQ	R49	Patient's Details Privacy	QRQ
R13	Test Reports Accessibility	FRQ	R50	Portable View of Hospitals	QRQ
R14	Diagnostic Lab Reports	FRQ	R51	Accurate View to Pharmacist	QRQ
R15	Blood Sample Information	FRQ	R52	System Reliability Issues	QRQ
R16	Lab Technician Accessibility	FRQ	R53	Parallel Processing of Patient Details	QRQ
R17	Lab Technician Profile	FRQ	R54	Patient's GUI should be user-friendly	ERQ
R18	Receptionist Account	FRQ	R55	Motivation for Patient's Care	ERQ
R19	Add Patient's Details	FRQ	R56	Ownership of Doctors	ERQ
R20	Receptionist Accessibility to Vitals	FRQ	R57	Nurse Motivation towards Her Tasks	ERQ
R21	Procedures Accessibility to Billing Clerk	FRQ	R58	Time for Making Reports	ERQ
R22	The patient's History Visible to the Billing Clerk	FRQ	R59	Connectivity of Patients with Lab Technicians	ERQ
R23	Immunization Accessibility to Clerk	FRQ	R60	Easy to use Patient Details by HR	ERQ
R24	Patient's Appointment Visibility	FRQ	R61	Patient's Details Consistency	ERQ
R25	Patient's details Accessibility	FRQ	R62	Patient Motivation for System	ERQ
R26	Patient's Profile	FRQ	R63	Empowerment of Patient	ERQ
R27	Record all Procedures of Patients	FRQ	R64	Patient Capability for Using Data	ERQ
R28	Patient's Data Update	FRQ	R65	Patient Connectivity with Stakeholders	ERQ
R29	Medication Visibility in Patient's Profile	FRQ	R66	Patient's Medication History View	ERQ
R30	Immunization Accessibility to Pharmacists	FRQ	R67	System Issues Information	ERQ
R31	Patient's Procedures	FRQ	R68	Time Frame for Resolving Issues	ERQ
R32	Allergies and Precautions Information	FRQ	R69	Environment Friendly	ERQ
R33	Patient's information accessibility to IT admin	FRQ	R70	System Stability	ERQ
R34	Patient's Details Upgrade by IT Admin	FRQ			
R35	Doctor's Visibility by IT Admin	FRQ			
R36	Billing Details Visibility to IT Admin	FRQ			
R37	IT Network Issues	FRQ			

to recruitment and customer dealing. The main responsibility of this system is to make the connection between doctor and patient.

*ACCOUNTS MANAGEMENT SYSTEM:* The account management system will handle all patients' bill information. It will also handle the payment and salaries of hospital staff.

**TABLE 3.** Information regarding Use-case transactions and weights.

Complexity of Use-Case	Total Transactions	Weight of Use-Case
Simple Use-Case	$\leq 3$	5
Average Use-Case	4 to 7	10
Complex Use-Case	$>7$	15

**PATIENT MANAGEMENT SYSTEM:** The patient management system will handle all the information of patients. Patient information, doctor appointment, and patient's previous history will be managed by this system.

**PHARMACY MANAGEMENT SYSTEM:** This system tracks the patients' records of the prescribed medications. It will handle all the information about patients' medicines and their payments.

**IT MANAGEMENT SYSTEM:** This system will handle all the issues that arise in the healthcare system. This system will resolve all the queries relevant to the system.

In this system, we have elicited more than 100 requirements. After analysis, 70 requirements are selected from the healthcare system (37 functional requirements (FRQ), 16 non-functional or quality requirements (QRQ), and 17 emotional requirements (ERQ)). The functional requirements represented by the use case help find the value of unadjusted use-case weight (UUCW) and unadjusted actor weight (UAW). These two values are helpful to find the value of the Unadjusted use-case points (UUCP). Non-functional requirements (quality requirements) can be used to find the value of the technical complexity factor (TCF). Emotional requirements can be used to find the value of environmental factors (EF). TCF and EF values are useful for finding the final value of the use-case point (UCP). Requirements are represented by R1, R2, R3...Rn identifiers. TABLE 2 shows all the requirements, categories, and technical and environmental factors.

### 1) UCP ESTIMATION

The use of case points (UCP) estimation method is applied to all the functional requirements of the healthcare system. It is given in the following sections. UCP estimation method contains four steps, which are as follows:

#### *a: CALCULATE UNADJUSTED UCP*

First, we will find unadjusted use case weight (UUCW). The standard UCP method defined three types of use-case and set weights to every type (5,10, and 15). These weights provide standardization to effort estimation across all types of projects. Unadjusted use case weights can be found by the number of transactions every use case performs. There are three types of use-case complexity in standard use-case point methodology. Those types are simple, average, and complex. These types are based on the number of transactions in each use case. As in the doctor's profile, there are only three transactions: login, logout, and view profile. Due to 3 transactions, the doctor's profile comes under the category

of simple use case, and we assign 5 weights to that use case. Likewise, patient allocation requires many transactions like patient registration, doctor reservation, scheduling, and appointment, etc., so this use-case comes under the category of average use-case, and we assign 10 weights to that use-case. The treatment procedure requirement contains many transactions, so this comes under the complex category, and we assign 15 weights to that use case. Due to the many requirements, we write only the number of transactions in Table 3 according to the nature of the requirements. To reduce the complexity of the proposed approach, we discussed only the total number of transactions of each use case and assigned weights according to the standard UCP method. The standard use case weights according to the number of transactions are given in TABLE 3.

Based on the system use case, and several transactions, the functional requirements of the healthcare system are characterized into three groups simple, complex, and average. These requirements are given in TABLE 4.

We can find unadjusted use-case weight (UUCW) according to the above values. UUCW can be calculated by finding the number of total transactions that happen in a specific use case. If transactions are very small, like 3, then we categorize those use cases in simple categories and assign the weight of 5. If transactions are average, like 5 to 10, then we categorize that use case in the average category and assign the weight of 10. And if transactions are very large, like more than 10, then we categorize them in complex categories and assign a weight of 15. The calculation of UUCW is given in the TABLE 5.

UUCW for the functional requirements of the healthcare system will be as follows:

$$UUCW = (5 * 16) + (10 * 14) + (15 * 7)$$

$$UUCW = 80 + 140 + 105 = 325$$

Now, we will find the unadjusted actor weight to find the unadjusted use-case point value. We categorized actors as simple, average, and complex. The classification of actors, their types, examples, and weights, are given in TABLE 6.

To find the weights of the actors, we have also divided the actors into three categories. Those categories are simple, average, and complex. Complex actors are those actors that interact with the system from an application programming interface. In our case study, all actors interact with the system from an interface, which is why all actors are complex. The actors of all use cases are considered complex as all the healthcare system users will interact with the system through a well-defined GUI. Unadjusted actor values (UAW) can be calculated as presented in TABLE 7.

$$UAW = (1 * 0) + (2 * 0) + (3 * 37)$$

$$UAW = 111$$

**TABLE 4. Categorization and complexity of functional requirements.**

Req. No.	Description	Category	No. of Transactions	Use-Case Complexity
R1	Doctor's Profile	FRQ	2	Simple
R2	Patient Allocation	FRQ	5	Average
R3	Messages Section	FRQ	2	Simple
R4	Patient's information for doctor	FRQ	3	Simple
R5	Doctor's Notification	FRQ	2	Simple
R6	Associated Hospital Information	FRQ	3	Simple
R7	Settings Update	FRQ	10	Complex
R8	Treatment Procedures	FRQ	8	Complex
R9	Vitals Access Section	FRQ	3	Simple
R10	Patient's Weight Information	FRQ	3	Simple
R11	Patient's Blood Pressure Information	FRQ	6	Average
R12	Patient's History Accessibility	FRQ	4	Average
R13	Test Reports Accessibility	FRQ	4	Average
R14	Diagnostic Lab Reports	FRQ	4	Average
R15	Blood Sample Information	FRQ	4	Average
R16	Lab Technician Accessibility	FRQ	2	Simple
R17	Lab Technician Profile	FRQ	2	Simple
R18	Receptionist Account	FRQ	2	Simple
R19	Add the Patient's Details	FRQ	4	Average
R20	Receptionist Accessibility to Vital	FRQ	4	Average
R21	Procedures Accessibility to Clerk	FRQ	6	Average
R22	Patient's History Visible to Clerk	FRQ	4	Average
R23	Immunization Accessibility to Clerk	FRQ	4	Average
R24	Patient's Appointment Visibility	FRQ	3	Simple
R25	Patient's details Accessibility	FRQ	3	Simple
R26	Patient's Profile	FRQ	2	Simple
R27	Record all Procedures of Patients	FRQ	8	Complex
R28	Patient's Data Update	FRQ	6	Average
R29	Medication Visibility in Patient's Profile	FRQ	3	Simple
R30	Immunization Accessibility to Pharmacists	FRQ	4	Average
R31	Patient's Procedures	FRQ	8	Complex
R32	Allergies and Precautions Information	FRQ	5	Average
R33	Patient's information accessibility to IT admin	FRQ	3	Simple
R34	Patient's Details Upgrade by IT Admin	FRQ	8	Complex
R35	Doctor's Visibility by IT Admin	FRQ	3	Simple
R36	Billing Details Visibility to IT Admin	FRQ	10	Complex
R37	IT Network Issues	FRQ	10	Complex

The unadjusted use-case point value (UUCP) is the sum of UUCW and UAW. The value of UUCP is given below:

$$UUCP = UUCW + UAW$$

$$UUCP = 325 + 111 = 436$$

#### *b: CALCULATE TECHNICAL COMPLEXITY*

Technical factors are directly connected with non-functional (quality) requirements. In the UCP model, we have 13 standard technical factors that are helpful to find the technical

complexity of the system. To validate our proposed framework, we took a healthcare system case study in which we have 16 quality requirements. To calculate the technical complexity of our system, we follow four steps that are given below:

- We analyze each quality requirement of a healthcare system and find its relationship with any technical factor of the UCP model.

TABLE 5. Calculation Of UUCW.

Complexity	Weight of Use-case	Total Number of Use-cases	Product
Simple use-case	5	Number of Simple Use-case (NSUC) = 16	5 * NSUC
Average use-case	10	Number of Average Use-case (NAUC) = 14	10 * NAUC
Complex use-case	15	Number of Complex Use-case (NCUC) = 7	15 * NCUC
<b>Unadjusted Use-case Weight (UUCW)</b>			<b>5 * NSUC + 10 * NAUC + 15 * NCUC</b>

TABLE 6. Classification of actors and weights.

Complexity of Actor	Examples	Weight of Actor
Simple Actor	A System with a defined API	1
Average Actor	A System cooperating through a Protocol	2
Complex Actor	A user cooperating through GUI	3

TABLE 7. Calculation of Uaw.

Complexity of Actor	Weight of Actor	Number of Actors	Product
Simple Actor	1	Number of Simple Actors (NSA) = 0	1 * NSA
Average Actor	2	Number of Average Actors (NAA) = 0	2 * NAA
Complex Actor	3	Number of Complex Actors (NCA) = 37	3 * NCA
<b>Unadjusted Actor Weight (UAW)</b>			<b>1 * NSA + 2 * NAA + 3 * NCA</b>

TABLE 8. Connection of quality requirements with technical factors of UCP.

Req. No.	Description	Category	Technical Factors
R38	Precision in Doctor’s Details	QRQ	Throughput Performance Objective
R39	Patient’s Health Condition Details	QRQ	Easy to Use
R40	Nurse Efficiency	QRQ	End User Efficiency
R41	Accurate diagnosis by Nurse	QRQ	Special User Training Facilities
R42	Lab Technician Efficiency	QRQ	End User Efficiency
R43	Probabilities in Lab Reports	QRQ	Easy to Change
R44	Receptionist Accessibility	QRQ	Provide Direct Access to Third Parties
R45	Patient’s Details Security	QRQ	Includes Special Security Objectives
R46	Patient’s Details Easiness	QRQ	Easy to Use
R47	Patient’s Data Installation	QRQ	Easy to Install
R48	Patient’s Details Organization	QRQ	Distributed System
R49	Patient’s Details Privacy	QRQ	Includes Special Security Objectives
R50	Portable View of Hospitals	QRQ	Portable
R51	Accurate View to Pharmacist	QRQ	Provide Direct Access to Third Parties
R52	System Reliability Issues	QRQ	Complex Internal Processing
R53	Parallel Processing of Patient Details	QRQ	Concurrent

- After a deeper analysis, we find a strong relationship between our quality requirements and 13 standard technical factors. We connect each quality requirement with the relevant technical factor. Each technical factor has its standard weight.
- After making an association between quality requirements and technical factors, we find the frequency of

technical factors for our system. The frequency shows the existence of that factor in the system. The frequency ranges from 0 to 5.

- After assigning the value and weight, we find the impact of every quality requirement. The impact can be found by multiplying the weighted value with the frequency of that factor. The sum of all impacted quality requirements

**TABLE 9. Technical factors with their weights according to quality requirements.**

Factor	Description	Weight	Rated Values (0 to 5)	Impact Value (I = W * RV)
TF1	Distributed System	2	1	2
TF2	Throughput Performance Objectives or Response Time	1	1	1
TF3	Efficiency of End User	1	2	2
TF4	Internal Processing Complexity	1	1	1
TF5	Code Reusability	1	0	0
TF6	Installation Easiness	0.5	1	0.5
TF7	User Friendly	0.5	2	1
TF8	Portability	2	1	2
TF9	Changeable	1	1	1
TF10	Concurrency	1	1	1
TF11	Include Security Objectives	1	2	2
TF12	Direct Accessibility to Third Parties	1	2	2
TF13	Need Special User Training Facilities	1	1	1
<b>Total Technical Factor Value (TFactor)</b>				<b>16.5</b>

gives us the value of the Technical cumulative factor (TCF), which will help us determine the system's technical complexity.

In the table below, we have linked the quality requirements of our healthcare system with technical factors. Accordingly, our standard technical complexity factors and their weights are given in TABLE 8.

Technical Factors with their weights according to the quality requirements are given in TABLE 9.

Technical Complexity Factor (TCF) can be calculated using the given formula:

$$TCF = 0.6 + (0.01 * TFactor)$$

Some of the technical factors are assumed in this system. The technical complexity factor value of the healthcare system is given below:

$$TCF(\text{Healthcare System}) = 0.6 + (0.01 * 16.5)$$

$$TCF(\text{Healthcare System}) = 0.76$$

### c: CALCULATE ENVIRONMENTAL COMPLEXITY

Environmental factors are directly connected with emotional requirements. In the UCP model, we have 8 standard environmental factors that help us to find the environmental complexity of the system. In the healthcare system, we gathered 17 emotional requirements. To calculate the environmental complexity of our system, we follow four steps that are given below:

- We analyze each emotional requirement of a healthcare system and find its relationship with any environmental factor of the UCP model.
- After a deeper analysis, we find a strong relationship between our emotional requirements and 8 standard environmental factors. We connect each emotional requirement with the relevant environmental factor. Each factor has its standard weight.
- After making an association between emotional requirements and environmental factors, we find the frequency of environmental factors for our system. The frequency

shows the existence of that factor in the system. The frequency ranges from 0 to 5.

- After assigning the value and weight, we find the impact of every emotional requirement. The impact can be found by multiplying the weighted value with the frequency of that factor. The sum of all impacted emotional requirements gives us the value of the environmental factor value (EF), which will help us determine the system's environmental complexity.

In the table below, we have linked the emotional requirements of our healthcare system with environmental factors. According to that, our standard environmental complexity factors and their weights are given in TABLE 10.

TABLE 11 presents environmental factors with weights according to ERQ.

Environmental complexity factor can be found by using the given formula:

$$EF(\text{Healthcare}) = 1.4 + (-0.03 * EFactor)$$

$$EF(\text{Healthcare}) = 1.4 + (-0.03 * 18)$$

$$EF(\text{Healthcare}) = 1.4 - 0.54 = 0.86$$

### d: CALCULATE USE-CASE POINTS (UCP)

UCP for the healthcare system is given below:

$$UCP = UUCP * TCF * EF$$

$$UCP = 436 * 0.76 * 0.86 = 284.9$$

The value of UCP shows that approximately 285 hours will be spent to make the healthcare system. As the total UAW of 37 FRQ is 111 and all requirements have the same actor weight, the UAW for each requirement will equal 3. TCF and EF values for each requirement should be the same because these two factors have an equal impact on all the requirements. We will find the UCP value for three classes based on use-case complexity: simple, average, and complex. TABLE 12 shows the UCP values of each category.

UCP value shows time in hours. TABLE 13 shows the UCP value of all functional requirements of the healthcare system.

Estimated effort can be found in the UCP and PF products. PF is the productivity factor, which is the ratio of the number

of man hours per use case point based on past projects of the same domain. If there is no historical data, software industry experts suggest that the number should be between 15 and 20. The ideal value of PF suggested by industry experts is 20. As we are dealing with a patient administration module of a simple healthcare system that stores only personal health records, the number 20-man months is a feasible number. The formula to find the estimated effort is given below:

$$\text{Estimated Effort} = \text{UCP} * \text{PF}$$

$$\text{Estimated Effort} = 285 * 20 = 5700 \text{ Person Hours}$$

Now, we will find actual effort for the healthcare system. Actual effort can be computed using the formula Actual Effort = count of workers \* time occupied by each worker. Person Hours (PH) is the unit of effort. After finding the estimated effort, we find the magnitude of the relative error value to show the deviation of our estimated value from the actual value. It is the most commonly used absolute criterion for effort estimation. The MRE value nearer to zero is the more precise the related estimation. The formula to find MRE is given below:

$$\text{MRE} = \frac{|\text{Actual Effort} - \text{Estimated Effort}|}{\text{Actual Effort}}$$

The estimated effort value is 5700 person-hours. The actual effort value of the healthcare system observed in the software industry is 3.25 years. If we convert these years into hours, we can say that the actual project effort is 6240 person-hours. We can find the MRE value by putting these values in the above equation.

$$\text{MRE} = \frac{|6240 - 5700|}{6240} \quad \text{MRE} = 0.086$$

So, the above MRE value is 0.086, which shows that our relative error magnitude is close to zero. It means that our estimation is accurate and precise. If we find the percentage of MRE, then it will be 8.6%. We can increase the accuracy of the UCP model by refining the UCP calculations. Accurately identifying actors' use cases and their weights can increase the accuracy of the UCP model. The analysis of historical data regarding effort estimation will also help improve accuracy. We can also increase accuracy by observing all the major risks in our healthcare system. Using automated tools for effort estimation can also reduce ambiguity and improve the UCP accuracy value. The calculation of other UCP effort estimation parameters, the mean magnitude of relative error (MMRE), the magnitude of error relative to estimate (MER), the mean magnitude of error relative (MMER), mean absolute error (MAE), root mean squared error (RMSE), mean absolute percentage error (MAPE), median relative error (MdRE) and the prediction percentage (PRED (x)) is given below.

$$\text{MMRE} = \frac{1}{N} \sum_{i=1}^N \text{MRE}$$

As in our study,  $N = 1$ , so MRE and MMRE will be the same.

$$\text{MER} = \frac{|\text{Actual Effort} - \text{Estimated Effort}|}{\text{Estiamted Effort}}$$

$$\text{MER} = \frac{|6240 - 5700|}{5700} \quad \text{MER} = 0.094$$

If we find MER value in percentage, then it will be 9.4%.

$$\text{MMER} = \frac{1}{N} \sum_{i=1}^N \text{MER} \quad \text{As } N = 1, \text{ so } \text{MER} = \text{MMER}$$

The formula is given below to find the mean absolute error (MAE).

$$\text{MAE} = \frac{1}{N} \sum_{i=1}^N |\text{Actual Effort} - \text{Estimated Effort}| \quad \text{As } N = 1, \text{ so}$$

$$\text{MAE} = |6240 - 5700| = 540$$

$$\text{RMSE} = \sqrt{\frac{1}{N} \sum_{i=1}^N (\text{Actual Effort} - \text{Estiamted Effort})^2}$$

$$\text{RMSE} = 540$$

The formula for the mean absolute percentage error is given below.

$$\text{MAPE} = \frac{100}{N} \sum_{i=1, \text{so}}^N \frac{|\text{Actual Effort} - \text{Estimated Effort}|}{\text{Actual Effort}} \quad \text{As } N$$

$$\text{MAPE} = 100 * 0.086 = 8.6$$

$$\text{PRED}(x) = \frac{k}{n}$$

where  $x$  = selected range of maximum MRE (MER);  $n$  = the total number of projects;  $k$  = number of projects in a set of  $n$  projects whose MRE (MER)  $\leq x$ . For example, PRED (20) = 30 shows that 30% of the projects drop within the 20% error range. Estimation accuracy is directly proportional to PRED (x). PRED (x) is useful for dealing with multiple projects. Many factors contribute to MRE for effort estimation. Uncertainty and complexity of the project are the major factors. MRE value can be changed if we have historical data. Time is also a big constraint in MRE value. Technology change also greatly influences MRE value. We can enhance prediction accuracy by analyzing the past data of related projects. We are dealing with only one project (the healthcare system), so we cannot find the value of MdRE.

## V. VALIDATION AND DISCUSSION

If we are dealing with multiple projects ( $N > 1$ ) then we can see the effectiveness of mean magnitude of relative error (MMRE), the magnitude of error relative to estimate (MER), the mean magnitude of error relative (MMER), mean absolute error (MAE), root mean squared error (RMSE), mean absolute percentage error (MAPE), median relative error (MdRE) and the prediction percentage (PRED (x)) parameters. We take two more case studies to show the effectiveness of the proposed extended UCP model and the results of various effort accuracy parameters. Those case studies are shortly defined below.

**INTERNET BANKING SYSTEM:** The Internet banking system is a web-based application that provides users with

**TABLE 10. Connection of emotional requirements with environmental factors of UCP.**

Req. No.	Description	Category	Environmental Factors
R54	Patient’s GUI should be user-friendly	ERQ	Object Oriented Experience
R55	Motivation for Patient’s Care	ERQ	Motivation
R56	Ownership of Doctors	ERQ	Motivation
R57	Nurse Motivation towards Her Tasks	ERQ	Motivation
R58	Time for Making Reports	ERQ	Application Experience
R59	Connectivity of Patients with Lab Technicians	ERQ	Object Oriented Experience
R60	Easy to use Patient Details by HR	ERQ	Familiarity with the Software Project Model
R61	Patient’s Details Consistency	ERQ	Stable Requirements
R62	Patient Motivation for System	ERQ	Motivation
R63	Empowerment of Patient	ERQ	Motivation
R64	Patient Capability for Using Data	ERQ	Lead Capability
R65	Patient Connectivity with Stakeholders	ERQ	Object Oriented Experience
R66	Patient’s Medication History View	ERQ	Object Oriented Experience
R67	System Issues Information	ERQ	Application Experience
R68	Time Frame for Resolving Issues	ERQ	Application Experience
R69	Environment Friendly	ERQ	Familiarity with the Software Project Model
R70	System Stability	ERQ	Stable Requirements

**TABLE 11. Environmental factors with their weights according to environmental requirements.**

Factor	Description	Weight	Rated Values (0 to 5)	Impact Value (I = W * RV)
EF1	Familiarity with the Project Model	1.5	2	3
EF2	Experience of Application	0.5	3	1.5
EF3	Object-oriented Language Experience	1	4	4
EF4	Capability of Lead Analyst	0.5	1	0.5
EF5	Motivation towards Project	1	5	5
EF6	Requirements Stability	2	2	4
EF7	Part-time Staff	-1.0	0	0
EF8	Complex Programming Language	-1.0	0	0
<b>Total Environmental Factor (EFactor)</b>				<b>18</b>

**TABLE 12. UCP Value Of Each Functional Category.**

Values	Simple	Average	Complex
UAW	$(16 * 3) = 48$	$(14 * 3) = 42$	$(7 * 3) = 21$
UUCP	$(80 + 48) = 128$	$(140 + 42) = 182$	$(105 + 21) = 126$
UCP	$128 * 0.76 * 0.86 = 83.6$	$182 * 0.76 * 0.86 = 118.9$	$126 * 0.76 * 0.86 = 82.3$
UCP per requirement	$83.6 / 16 = 5.2$	$118.9 / 14 = 8.4$	$82.3 / 7 = 11.7$

all the banking services online. These services include money transfers, account details, withdrawals, E-statements, and bill payments. The main stakeholders of this system are the users, banks, third-party users, and internet service providers. All calculations relevant to weights, UAW, UUCP, TF, EF, UCP, and MRE are given in TABLE 14.

**E-COMMERCE APPLICATION SYSTEM:** E-commerce is a web-based application that is made for online shopping. The major features of an e-commerce application are that it allows you to shop, make online payments, avail yourself of discount vouchers, and send gifts. The main stakeholders of this system are the users, banks, third-party users, and internet service providers. All calculations relevant to weights, UAW, UUCP, TF, EF, UCP, and estimated effort are given in

Table 14. We have presented only calculations of these two case studies as all the processes are the same as in the above healthcare system case study. These values and calculations are based on the study [45].

After calculating the estimated effort, we find all effort estimation parameters that are discussed above in the healthcare system case study. In the healthcare system case study, the value of N was 1. We will find all effort estimation parameter values for N = 3 as we add two more case studies. Calculations of effort estimation parameters for all three case studies are given below in TABLE 15.

TABLE 15 presents the values of MMRE, MMER, and MAPE, which are very low. We can see the mean absolute percentage error, which is only 8.6%. This means that projects

**TABLE 13.** Individual UCP values of all functional requirements.

Req. No.	UCP	Req. No.	UCP	Req. No.	UCP
R1	5.2	R16	5.2	R31	11.7
R2	8.4	R17	5.2	R32	8.4
R3	5.2	R18	5.2	R33	5.2
R4	5.2	R19	8.4	R34	11.7
R5	5.2	R20	8.4	R35	5.2
R6	5.2	R21	8.4	R36	11.7
R7	11.7	R22	8.4	R37	11.7
R8	11.7	R23	8.4		
R9	5.2	R24	5.2		
R10	5.2	R25	5.2		
R11	8.4	R26	5.2		
R12	8.4	R27	11.7		
R13	8.4	R28	8.4		
R14	8.4	R29	5.2		
R15	8.4	R30	8.4		

**TABLE 14.** Calculated values related to UCP extended model of two case studies.

Projects	Actors	Use-Cases	Actual Effort	UAW	UUCW	UUCP	TCF	ECF	UCP	Estimated Effort
Internet Banking System	3	9	3693	11	112	123	1.145	0.59	83.09	3350
E-commerce Application System	4	11	3501	14	132	146	1.02	1.085	161.5	3231.5

**TABLE 15.** Effort estimation parameters values of all case studies.

Projects	MRE	MMRE	MER	MMER	MAE	RMSE	MAPE	PRED (20)
Healthcare System	0.086	0.086	0.094	0.092	384.1	400.67	8.6	30
Internet Banking System	0.092		0.102					
E-commerce Application System	0.08		0.08					

have only 8.6% wrong effort estimation value, which shows the effectiveness of our proposed extended UCP model in all types of projects. In the next section, we will do a comparative analysis of the proposed effort estimation with existing literature. We have included an expert team in our assessment to make our estimation more effective.

Before selecting an expert team, we ensure that the team should be domain experts capable of providing healthy feedback regarding the proposed methodology. The team should know the scope of the methodology. We have categorized all stakeholders who are keenly interested in the UCP model. We have also included those stakeholders in our expert panel. We have made a selection criterion for experts. The experts should have experience in software and project management activities. Experts should have knowledge of UCP and

relevant effort estimation methods. The panel should have experience in working on projects where UCP is involved. After recruiting expert members, we conducted training sessions to ensure that all expert members had the same understanding of the UCP model and other effort estimation techniques. After training, an expert panel evaluated the proposed extended UCP model according to accuracy metrics. The expert panel evaluated the proposed extended UCP model and suggested other human factors that can influence the effort value. Based on experts' suggestions, we will make improvements to our extended UCP model in the future. The rigorous analysis of experts and their information is given in TABLE 16.

This team comprises five project managers and 5 IT architects with vast experience in effort estimation. All project

**TABLE 16. Suggested human factors by industry experts.**

Factor No.	Suggested Factors	Factors Types	Impact on UCP Model Values
1	Social Factors	Education Political Affiliation Health Religion	Environmental Factor Value (EF Value)
2	Cultural Factors	Language Barrier Set of Traditions Set of Laws posed by Community	Functional Value (UUCP Value) Environmental Factor Value (EF Value)
3	Economic Factors	Tax Rate Inflation Rate Exchange Rate Labor Wages Policies Imposed by Government	Functional Value (UUCP Value) Technical Factor Value (TCF Value) Environmental Factor Value (EF Value)

managers and IT architects are certified and having experience of more than 5 years. All expert team members are asked to access our proposed framework and list the other additional factors that can impact the software system. All new factors rather than functional, technical, and environmental factors have been discussed among industry experts, who give their opinions on them. Experts asked many evaluation questions (EQ), and experts gave their reviews regarding the proposed methodology. These questions are relevant to the theoretical foundations, empirical validation, practical application, scalability, and usability of the proposed methodology. The comprehensive expert reviews regarding our proposed methodology are given below.

**EQ1:** Is the foundation of the proposed study relevant and supported by existing literature?

**Expert Reviews:** According to the expert reviews, the proposed study deals with one of the major challenges of project management: effort estimation. The foundation of the proposed research is relevant to the most commonly used effort estimation UCP model. A lot of literature is available regarding the proposed methodology. The theoretical foundation of the proposed study is strong.

**EQ2:** Are the assumptions taken in this study applicable and relevant to the proposed method?

**Expert Reviews:** The experts analyzed all the assumptions taken in the study and found them useful in computing the effort estimation value. Experts observe that the actor and use case weights are accurate and useful for the proposed extended UCP model.

**EQ3:** Is the proposed extended UCP model easy and understandable or not?

**Expert Reviews:** The UCP extended model is easy to understand. It is the extension of the previous standard UCP model. This model focused on the emotional and quality aspects of the system. UCP model only focused on the functional requirements of the system. However, the UCP extended model includes emotional and quality requirements in the system.

**EQ4:** Can any human factors influence the effort estimation value in the UCP extended model?

**Expert Reviews:** Experts analyze that many human factors can influence the effort estimation value in the proposed UCP extended model. Experts suggested some social, cultural, and economic factors that can be shown in the TABLE 13.

**EQ5:** How does the proposed extended UCP model work in some case studies?

**Expert Reviews:** The experts analyzed the implementation of the extended UCP model in the healthcare system case study. The results of the healthcare system case study show the effectiveness of the proposed UCP extended model. Experts suggested including cultural and social factors in the calculation of UCP value. It may influence the UCP effort value. In the future, we will accommodate these factors in the UCP model.

**EQ6:** Is the proposed methodology efficient as compared to existing UCP models?

**Expert Reviews:** This methodology is efficient and unique compared to existing literature. The major uniqueness of the proposed study is the emotional aspects that the authors added to the UCP model. No study has been reported to address the emotional requirements of the system. Including emotional and quality requirements in the UCP model makes the UCP model more efficient and reliable than other existing methods.

**EQ7:** What are the major pros and cons of the proposed study?

**Expert Reviews:** The major advantage of the proposed extended UCP model is its capability to address quality and emotional requirements and their connection to technical and environmental factors. The inclusion of these requirements in the UCP model gave real-time effort value. These requirements also cover the software system's hidden emotional and quality aspects. The major disadvantage of the proposed methodology is emotional requirements elicitation and validation. As emotions can be changed at any time and emotional requirements validation is a crucial task, there may be chances of requirements errors that can cause inaccurate effort value.

**EQ8:** Is the proposed methodology usable and flexible for other projects?

**Expert Reviews:** According to expert reviews, the proposed UCP extended model is easy and understandable.

**TABLE 17. Potential biases in expert opinion.**

Serial No.	Potential Biases	Description
1	Overconfidence Bias	Sometimes, experts are overconfident regarding the knowledge and understanding of some models. Due to overconfidence, their predictions regarding the model are not reliable.
2	Selection Bias	Selection bias is a common bias that exists in the expert opinion method. Sometimes, experts are chosen based on some relationship or affiliation. This can cause inaccurate evaluation.
3	Confirmation Bias	Experts favor or dislike some methodology due to their previous experiences or beliefs. The evaluation of the proposed methodology can be compromised due to his bias.
4	Availability Bias	Sometimes, experts depend on available literature to decide on a methodology. Inaccurate literature information can lead to poor evaluation.
5	Cultural Bias	The cultural background of experts may also influence their perceptions and understanding regarding any model.
6	Conflict of Interest Bias	Experts could have some professional or financial conflicts with other experts or organizations. For example, if an expert can benefit from the methodology, he can support the methodology.

It can be used by any project manager or software developer. Experts suggested that the proposed methodology can be applied to other domains. However, it will be more useful for safety-critical software systems.

**EQ9:** Does the proposed methodology create risks and meet the standards and rules?

**Expert Reviews:** According to expert reviews, no major risks occurred in the proposed methodology. However, only one risk of improper requirement elicitation process may exist. This risk can be mitigated by training requirement engineers regarding the system environment and proposed UCP methodology. The experts analyzed all the standards and regulations in the proposed extended UCP model and found that all weights and structures follow the UCP standard model.

**EQ10:** Is the proposed methodology flexible to change or update any new requirements?

**Expert Reviews:** The experts observed the methodology and analyzed that the authors used the JAD workshop and questionnaire techniques to elicit and validate requirements. These techniques are best suited for handling changes in requirements. So, this methodology is suitable for handling new changes in requirements.

Out of 10 industry experts, 1 expert (project manager) rejected our proposed framework of the UCP extension model. 2 industry experts (1 IT architect, 1 project manager) have accepted the changes. Those changes are the additional human factors that should be included in the UCP model for better effort estimation value. We will discuss those factors in detail. 7 industry experts (3 project managers and 4 IT architects) accepted our extension to the UCP model without any changes.

The additional human factors that 2 industry experts have suggested are social, cultural, and economic factors. According to industry experts, these human factors greatly influence software projects' efforts. Social factors are those factors that affect people's lifestyle and behavior. Those factors include education, housing, employment, religion, and others. Cul-

tural factors are those factors that define a set of traditions, values, languages, and laws that are common to a group of people. Economic Factors have a great impact on the economy as well as a person's economy. These factors include tax rate, inflation rate, labor rate, wages, and government policies. The suggested human factors, their types, and their impact on the UCP model can be represented in TABLE 16.

We can improve the effort estimation value in multiple ways. Observing historical data from the same type of project can also improve the effort estimation value. Expert judgment is also useful to improve effort estimation value. The involvement of stakeholders in the overall effort estimation process may also improve the effort estimation process. Expert opinion contains different potential biases that can affect the reliability of experts. Those potential biases are given in TABLE 17 below.

These biases can be reduced by taking anonymous experts and ensuring that the experts' selection process is transparent. The potential biases can be reduced by making a diverse expert panel. We can reduce biases by taking experts from different backgrounds and disciplines. The evaluation criteria should be clear to all experts to mitigate the expert's biases. Training regarding bias awareness can also be provided to deal with it. One of the best ways to mitigate the potential biases is to take iterative feedback from the experts to reevaluate their evaluations. Documentation of all evaluation processes is necessary for transparency and mitigating biases. The review of evaluation procedures regularly is also an effective way to reduce potential biases.

Incorporating the latest tools and technologies is also useful in terms of effort estimation. Many new technologies can improve the estimation process of effort. Machine learning and deep learning techniques are very useful in project management. Through machine learning predictive models, we can predict the effort of any software project by analyzing the historical data. Feature engineering can select features from datasets that can influence the effort estimation process. Deep learning models, especially neural networks, are useful

for finding accurate effort for any software project. Through transfer learning, we can train the model for a specific domain and apply that model in that domain. In the future, we will also consider these values to estimate the effort required for a software project accurately. Our proposed framework of the UCP extension model gives better results than the existing literature.

#### A. DISCUSSION AND COMPARATIVE ANALYSIS

In our proposed study, we have shown a new direction of the UCP model. Our study focused on the estimation of effort for software projects by using multiple views of the UCP model. Traditionally, researchers used the UCP model for effort estimation of software projects by using functional requirements only. However, our study focused on quality as well as the emotional requirements of the system. Our proposed extension to the UCP model framework gave UCP a new direction. The main reason for selecting a healthcare system is its complex and diverse nature. Healthcare systems have a significant number of quality attributes. After COVID-19, most researchers have changed their focus on the healthcare system. Emotional requirements can easily be extracted from the healthcare system. Through our framework, we elicited all types of requirements (functional, quality, and emotional) from the user. After taking the requirements, we analyzed those requirements through a feasibility study. We have selected the requirements that are relevant to the system. After that, we developed a functional, quality, and emotional model of the system. The functional model can be expressed by a use-case diagram. A functional model is necessary to find the values of UUCW, UAW, and UUCP. These three values gave us the impact of functional requirements on the system. We have developed a quality model and checked the quality parameters necessary for our system. We connected those quality parameters with the technical factors of the UCP model. Weights have been calculated by the requirement's complexity and assigned to the factors according to the number of quality requirements. By developing the quality model, we found the technical complexity factor value. We have developed an emotional model to tackle the emotional requirements of the system. We found a connection between emotional requirements and environmental factors of the UCP model. Weights have been assigned to the factors according to the number of emotional requirements. This model gave us the value of environmental factors. UUCP, TCF, and EF values are useful for finding UCP values. Through UCP value, we can find estimated effort and MRE. MRE has been calculated using the estimated effort value and actual value of the system. We observed the MRE value of 0.086, which supports our accuracy. We have the expert opinion of industry experts regarding our study. Industry experts accept our system with little changes. Expert information can be found at the end of the paper in TABLE 19 as Appendix A.

Our proposed extended UCP model provides valuable insights when applied to a real-time emotion-based healthcare system. Our proposed model is useful for risk manage-

ment and resource allocation. Through the proposed UCP model, we can utilize all resources efficiently. Our proposed extension to UCP model gave us better results as compared to other methods like COCOM 2 and function point model. The proposed methodology focuses on technical as well as emotional aspects of software requirements that were not existed in previous models. Our extended UCP framework efficiently manages the project scope. It will also help the project managers by giving time management. UCP model works efficiently for all types of requirements. Human factors are important aspects of the estimation of any software project's effort. Human values play an important role in software projects' cost, time, and budget. According to experts, numerous human factors influence the value of UCP. Social, cultural, and economic are major human factors that influence UCP value. Estimation of emotional requirements in software systems is a difficult task. We have tried an extension of UCP to focus on the emotional aspects of software systems in our study. We can extend the UCP model in multiple ways. One way is to make an emotion-oriented use case specifying the emotional response to software tasks. We can extend the UCP model by assigning the weights to different categories of emotions like joy, sadness, happiness, or frustration and build a metric. We can also assign weights to emotional responses according to customer feedback. We can also extend the UCP model by incorporating different emotional design models into the UPC model. Effort estimation of emotional requirements is an uncertain process. A proper guideline and procedure should be used to estimate the emotional aspects of the software system. We have extended the UCP model by connecting emotional and quality aspects with existing environmental and technical factors of the UCP model. Incorporating quality and emotional aspects in the UCP model will give developers a broader view of the UCP model and meet its expectations regarding the software system. For the quality and emotional model of our system, we have identified users' quality attributes and emotional responses regarding our system. We can check our quality model with an existing quality outcome to assess quality attributes. To validate emotional requirements, we can take surveys or feedback from users to check whether the system meets its emotional response. We have compared our proposed study with existing literature on effort estimation through the UCP model and found numerous benefits of our study. The comparative analysis is given in TABLE 18.

#### B. LIMITATIONS

Implementing our proposed extension framework to other domains presents numerous limitations. Every domain has its variables that may produce a significant effect on the generalizability of the proposed framework. The stakeholders in domains other than healthcare may not be aware of emotional theories and values and prefer traditional methods that focus on the system's functional requirements. Domains like finance and manufacturing may not have enough tools and techniques to capture emotional requirements. Integration of

**TABLE 18. Comparative analysis of proposed methodology with existing literature.**

No.	Characteristics	Existing Literature [8], [19], [45], [71], [72], [73], [74], [75], [75], [76], [71]	Proposed Framework
1	Main Methodology	<p>The study [8] addressed effort estimation through the COCOMO 2 model.</p> <p>The study [19] only discussed effort estimation through generic UCP with a scrum framework.</p> <p>The study [71] discussed effort estimation of only those projects that use reusable artifacts that have previously been developed.</p> <p>The study [45] discussed enhanced UCP technique for effort estimation.</p> <p>The study [72] used non-linear regression analysis with a use-case diagram for effort estimation.</p> <p>The study [73] used a linear regression model with a UCP model for effort estimation.</p> <p>The study [74] proposed a multi-tasking framework that used commonsense knowledge and knowledge of the dataset to learn the model for both tasks at the same time.</p> <p>The study [75] proposed a methodology to guide the design and evaluation of healthcare IT systems.</p> <p>The study [76] proposed a methodology for personality subtyping from the suicide notes dataset.</p> <p>The study [77] proposed a methodology for emotions and depression detection from different user descriptions.</p>	Our proposed framework addressed effort estimation by using an extension to the use-case point model. UCP extension model can view the system in multiple directions.
2	Type of Project	<p>The study [8] addressed the effort estimation of aeronautical industry projects.</p> <p>The study [19] only focused on web-based projects and user stories.</p> <p>The study [71] focused only on those technical aspects of UCP that are relevant to the system.</p> <p>The study [45] only focused on the functional requirements of the web and online shopping projects.</p> <p>The study [72] focused on three non-linear regression analysis equations to compute the effort for the two public data sets.</p> <p>The focus of the study [73] was to handle the weighting issues of projects.</p> <p>The focus of the study [74] was to detect the emotion causes extraction of relevant emotions for a healthcare system.</p> <p>The focus of the study [75] was to provide guidelines from the literature review to design a healthcare system.</p> <p>The study [76] focused on the suicide notes dataset for feature extraction.</p> <p>The study [77] focused on the emotions and depression detection from Twitter's dataset.</p>	Our proposed study addressed the effort estimation of one of the most used safety-critical systems, an emotion-based healthcare system.
3	UCP Factors	<p>The study [8] focused only on the functional requirements of aeronautical projects.</p> <p>The study [19] addressed only functionalities and transaction attributes of web projects.</p> <p>The study [71] focused only on those environmental factors of UCP that are relevant to the system.</p> <p>The study [45] focused on changing the weights of actors and use cases and seeing the results.</p> <p>The study [72] addressed only functional requirements to estimate the project's effort.</p> <p>The study [73] only resolved weighting issues related to functional requirements.</p> <p>The study [74] only focused on emotion causes extraction tasks.</p> <p>The study [75] only focused on the guidelines from 14 literature reviews to build a healthcare system.</p>	Our study focused on functional as well as non-functional and emotional requirements of the emotion-based healthcare system.
4	Expert Opinion	<p>No expert opinion is used in the study [8].</p> <p>The study [19] did not conduct expert judgment to assess methodology.</p> <p>The study [71] conducted expert opinions from postgraduate students and industry expert teams.</p> <p>The study [45] only used some parameters for assessing the methodology.</p> <p>The study [72] used some parameters for assessing the methodology.</p> <p>The study [73] used weight parameters for assessing the methodology.</p> <p>No expert opinion is used in the study [74].</p> <p>The study [75] used expert opinion and survey to evaluate the healthcare system.</p>	Our study used 10 industry experts to assess the framework. The majority of industry experts support our study. They have also introduced some new influential factors that will be addressed in the future.

emotional models with traditional approaches is also a challenging task. Emotional requirements vary across different cultures and can confound the usage of a single model across numerous domains. Scaling the proposed extension for large projects may produce a problem because of low resources. Some organizations are not allowed to gather emotional data because of their regulatory or ethical requirements. It may also produce a limitation to applying the proposed extension framework in other domains. In the future, we can also deploy our proposed extension model on non-emotion systems. We can identify sustainable requirements in the system and connect those requirements with the environmental factors of the proposed model. This connection may be effective in producing sustainable software systems.

## VI. THREATS TO VALIDITY

Many threats to validity exist in this study. Those threats are given below:

### A. CONCEPTUAL THREAT

We have made some assumptions in our study. We have made assumptions explicit. We have assumed that a person-month equals 40 hours/week and 160 hours/month. Some assumptions require more support and arguments. However, these assumptions will not negate our proposed framework.

### B. INTERNAL THREAT

It defines the characteristics that cause those experimental errors that can impact the results. Though we have scrutinized our mathematical calculations, any unobserved chance of error may exist.

### C. EXTERNAL THREAT

The external validity defines whether our proposed framework is generic or not. We have selected an emotion-based healthcare system to support our framework. The proposed approach is evaluated based on UCP and MRE values. The results show the accuracy of our framework. However, we cannot generalize this framework to other systems because the framework is valid only for emotion-based systems. We can generalize this framework by applying it to other emotionless systems.

### D. EXPERT OPINION BIASNESS THREAT

The proposed framework has been assessed by 10 industry experts. Industry experts also gave their opinions regarding changes in the proposed framework. There is a chance of bias towards accepting or rejecting the proposed framework. However, we can minimize this threat by obtaining the opinions of the majority of experts from different organizations or countries. While most experts belong to the same country, there is a high chance of ambiguity and inconsistency in the software project's requirements. Multiple threats and challenges occur when experts translate software requirements from another country. Those threats are given below:

### 1) CULTURAL DIFFERENCE THREAT

Cultural differences can greatly impact the understanding of the software requirements. Communication way and user interface design are different in different cultures. This can be minimized by training developers to understand the culture and terms of the designated organization.

### 2) LEGAL AND REGULATORY THREAT

Different countries have different legal and regulatory requirements, which can have an impact on software projects. For example, Europe has data handling laws and regulatory requirements related to healthcare systems. This threat can be minimized by understanding the legal aspects of the target country.

### 3) TECHNICAL ENVIRONMENT DIFFERENCE THREAT

Technical and environmental differences also have a great influence on software projects. Different countries have different internet speeds and system specifications. Old systems and slow internet can produce software risks that can influence the value of effort. This threat can be minimized by upgrading the technical and environmental setup of the software-developing organization.

### 4) LANGUAGES AND TIME ZONE DIFFERENCES THREAT

Different countries have different languages and time zones. Inaccurate translation of software requirements can negatively affect the software effort value. Different time zones make the coordination between different team members difficult. These threats can be minimized by consulting with translation services and adapting flexible software management strategies.

### 5) DATASET LIMITATION THREAT

We have used a dataset of 70 healthcare requirements. The small dataset gave us good results. Our proposed methodology may be compromised on large datasets. This threat can be reduced by taking large healthcare requirements dataset and train the proposed model on it.

## VII. CONCLUSION

This paper proposed a new framework for effort estimation of emotion-based software systems. Our proposed UCP model is an extension of the existing UCP model with elements that describe a software system's emotional and quality aspects. This study helps emphasize the importance of the UCP extension model in estimating the effort for emotion-based systems. Predicting software efforts using the UCP model has gained much interest among researchers in the last decade. However, there is minimal focus on software systems' emotional and quality aspects and their impact on software estimation value. We have developed a new framework for the UCP model that shows a new direction and view of UCP. Our proposed framework extracts hidden emotional and quality characteristics from the user and

TABLE 19. Industry experts' information.

No.	Industry Experts Role	Years of Experience	Certification	Years of Experience with the UCP Model	Organization
1	Project Manager	6	PMP Certified	4	TeleMutants Islamabad, Pakistan
2	Project Manager	6	PMP Certified	3	VitaLink Bahawalpur, Pakistan
3	Project Manager	7	PMP, RMP Certified	5	Tajer Software Solutions, Doha, Qatar
4	Project Manager	5	Scrum Master Certified	2	Noor IT Solutions, Bahawalpur, Pakistan
5	Project Manager	8	PMP, SP Certified	4	Tabaaq Solution, Lahore, Pakistan
6	IT Architect	5	IBM Certified	3	IBMS Solutions, Lahore, Pakistan
7	IT Architect	5	Scrum Master Certified	3	All Zone Technologies, Lahore, Pakistan
8	IT Architect	6	AWS Certified Architect	2	Sequel Systems, Islamabad, Pakistan
9	IT Architect	8	IBM Certified	4	Red Technologies, Lahore, Pakistan
10	IT Architect	7	Red Hat Certified Architect	5	Arbi Soft Solutions, Lahore, Pakistan

integrates these characteristics into the effort estimation UCP model. Our UCP extension model has changed the dependency from functional to emotional and quality requirements. Our study results show an improvement in effort estimation results compared to existing literature regarding UCP model estimation. Our framework gives an error of 0.086, which presents our accuracy. Our study has main 4 research questions RQ1, RQ2, RQ3, and RQ4. To answer RQ1, we have developed an extension to the UCP framework that listens to the emotional requirements of the user. We have elicited emotions, emotion theories, and emotional requirements from the user. After analyzing the feasibility study of requirements, we have selected those emotional requirements relevant to our system. To answer RQ2, we have developed a quality model that will analyze the quality parameters of the system and their impact on the system. To answer RQ3, we have applied our extended UCP framework to a real-time emotion-based healthcare system. We have gathered all types of requirements of the healthcare system. We have connected the functional model of the system with UUCW, UAW, and UUCP values. The quality model is connected with 13 technical factors of the UCP model according to their impact and weights to get the value of TCF. We have connected the emotional model of the healthcare system with 8 environmental factors of the UCP model to get the value of EF. All these values will be helpful to find the final value of the UCP extended model. To answer RQ4, we assessed our study with 10 industry experts. Most industry experts have accepted our study by giving us feedback regarding other factors that should be included to estimate the effort for software systems. Those factors are social, cultural, and economic factors. Our proposed model is also useful for e-commerce systems. By analyzing historical data of previous e-commerce systems, we can refine our estimation values. Special requirements can also be added in our system to make it adaptable for all types of information systems.

In the future, these three factors can also be included for effort estimation. We will consider these factors in effort estimation and analyze their impact on the functional, technical, and environmental factors of UCP. Our study can be extended by applying this framework to big and other domain

projects like education and business. All safety-critical projects have the same emotional influence. This methodology can easily be adapted to other safety-critical software systems. Lastly, we expect that the results of this study can inspire the researchers and scientific community to close the holes mentioned above. This work can be a first step toward the different extensions of the UCP model for effort estimation.

#### AUTHOR CONTRIBUTIONS

The authors confirm their contributions to the article as follows: Shoaib Hassan: Conceptualization, Methodology, Writing Original Draft Preparation; Qianmu Li: Supervision, Project Administration; Ayed Alwadain: Writing–Reviewing and Editing, Data Visualization, Funding Acquisition; Affan Yasin: Formal Analysis, Writing–Reviewing and Editing; Javed Ali Khan: Writing–Reviewing and Editing, Formal Analysis.

#### DATA AVAILABILITY STATEMENT

No data was created in this study.

#### CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

#### APPENDIX A

See Table 19.

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