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EXPLORING CAUSES OF REQUIREMENT CHANGE

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ABSTRACT. *Software development process is dynamic in nature and it has contrasting impact on software development based on Return on Investment (ROI). It plays an important role in successful software development and can also create difficulties during the software construction in terms of increasing effort, schedule and cost. Factors of changing requirements, prediction of requirement change and the strategies to deal with them are needed to be analyzed for better management of requirement change. Regardless of all research efforts based on requirement change, there is still a need to analyze the factors of requirement change from industrial evidences to minimize its negative impact on software development. The aim of study is to highlight main and sub causes of requirement change that can disrupt software development process.*

Keywords*:* Requirements Change, Requirement Uncertainty, Organizational Considerations, Customer Needs, Technology Change

1. **Introduction.** In 21st century software engineers faced many challenges during software development that are; change, uncertainty, emergence, dependability, interdependence [15], among these causes changeability is growing day by day due to the changing environment of business and technology. Impact of change can be minimized by research for development of paradigm to support software change and real world case studies for validation of software change causes [14].

Several aspects of requirement change and its associated terms have been studied by the researchers but relatively small numbers of empirical studies are present in literature that specifically consider the requirement change and its associated terms. The studies found relevant to this type of research are integrated with other software development factors rather than requirement change itself. Multiple causes of requirement change have been identified from the literature but this does not deny the fact that there are other causes of requirements change. During this research identification of causes for requirement change from literature will be focused.

2. Related Work. Causes of requirements change are discussed in literature by various aspects. Some of these studies are highlighted in text for exploring factors of change. A study evaluates the change requests over maintenance [16]. Another study explores one major cause of change and considers requirement uncertainty as a major cause [2]. A research study identifies the causes of requirements change based on casual analysis method during a software development life cycle [4]. One more Study finding is based on a single project and its purpose is to explore the impact of requirement change on change effort [3]. An Avionics Safety-Critical Case Study by [6] analyse the requirements change process by metrics. An author explores the causes from GSD perspective [7]. The case study [1] highlights those factors which affect the RE process quality. To explore how some projects better deal with changing requirements. A study gives an idea to map the perception and theory [8]. In a study by [11] change management framework is designed using the literature study and framework is validated and modified using 106 data set of Change Request Forms (CRF) from a change management history.

Several causes (more than 60) are identified from the literature study to form requirement change source taxonomy [5] but no empirical evidence is provided for these causes. A non-empirical [17] study lists 8 situation related to the kinds of requirements change. According to the results of the study, critical need changes should be more focused than the requirements change. So, need change is the major cause/ driver of requirement change.

According to the Systematic Literature Review (SLR) [18], there are only five studies that provide the causes of requirement change from the industry. After reviewing all these studies it is found that no empirical evidence from the industry is provided to explore the causes of requirement change specifically rather the Requirement Change is discussed through integration with other software development factors.

3. Main Causes of Requirements Change (Essential / Accidental). Classical paper "No Silver Bullet" by F. P. Brooks[19] categorized software difficulties in two major categories, that are defined as essential and accidental difficulties faced by software practitioners Ikram et.al. [18] in his work considers these categories as two dimensions of requirements change, further explored and categorized these causes in three sub dimensions referred as business, organizational and project. Figure 1 shows main causes of requirement change proposed by Ikram et.al[18].

3.1. Business Essential. Business essentials are high level functional requirements that are mandatory to run day to day business. Change in these types of requirements cause major adjustments in software development process.

3.1.1. Customer Needs/ Market Demands. Business requirement are normally customer focused and based on market demand, both plays major role in core business functionality. Change in software requirements depends on minor/major change in customer trend and market demand or supply. These factors are further subcategorized in functionality enhancement's requests, change in business processes, external and competitor's pressure as shown in figure 2.

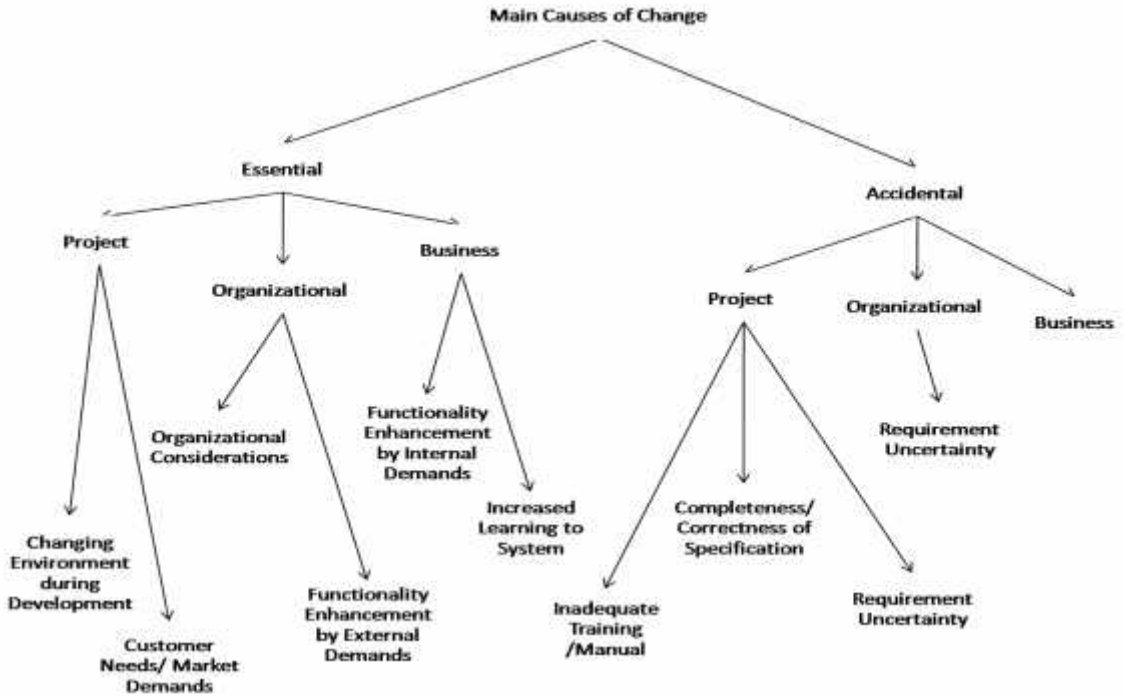

Figure 1 Main Causes of Requirement Change

3.1.1.1. Functionality enhancement due to market demand. Software functionality enhanced due to varying demand of different interfaces (i.e. web, desktop, mobile etc.), development techniques and technologies by consumer and also derived from changing market trends [5] [7] [11].

3.1.1.2. Change in business processes of enterprises. Requirements change due to change in business processes is an important factor. Change in business environment is inevitable so requirements of software related to businesses are mostly changed. In context of Globalization this factors contributes as trigger to change [5] [7].

3.1.1.3. Competitors pressure from competitors. Requirement change incurred due to competition of proprietary solutions of different vendors. Competitor's pressure having high impact on change in today's global environment [4] [7].

3.1.1.4. Change in external factors. External factors include all other factors excluding market demands, competitor's pressure, business processes. Government regulation is an example of external factor [5] [7].

3.1.2. Changing Environment during Development. Factors of change in software requirements occurred due to change in technology, environment and 3rd party hardware or software change during software development process[4][5][6][7]. Figure 2 shows sub causes of changing environment during developing stage.

3.1.2.1. Technology change during development. One of environmental factor that can cause requirements to be changed is change of any technology during development. It could be development technology or any other technology that is directly related to system which is being developed [4] [5] [7].

3.1.2.2. Change in developing environment during development. Factor of technology change also cascades with this category in taxonomy of change. Development environment may be a kind of language change, framework change and change in software development approaches [4].

3.1.2.3. Change in hardware and software due to change in 3rd party software Factors of non compliance, partial compliance and hardware modifications determined a cause of change. These factors fall in the category of hardware/software change in 3rd party software [6].

3.2. Organizational Essential. Organizations essentials such as policies, by laws, strategies, goals and external demands by consumers either error corrections or change in test scenarios is a major cause of requirement change as shown in figure 1.

3.2.1. Organizational Consideration Organizational consideration is comprehensively focused on customer satisfaction and product quality and plays a major role in requirement change. Organizational consideration are subdivided in two major sub causes i) Change in goals and policy about enhancement and release ii) Change in product strategy by market groups as shown in figure 2.

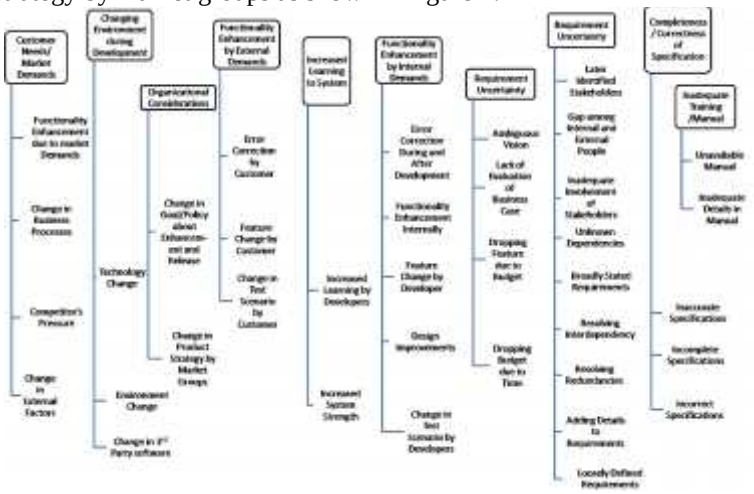

Figure 1 Sub Causes of Requirement Change

3.2.1.1. Change in goals and policy about enhancement and release. Organizations have their own goals and policies about functionality enhancement and release of their products. Any change in goals and policies of an organization may affect continuing software development projects, which automatically results in requirement change [1].

3.2.1.2. Change in product strategy by market groups. Change in requirements through market[4] pressure is usually determined by market groups of an organization. Product strategy can be changed based on recommendations of these market groups [3] [5].

3.2.2. Functionality Enhancement Due to External Demands. Functionality enhancement requests usually initiated by customer, in a variety of changing test scenarios, error correction and feature change request during software development shown in figure 2.

3.2.2.1. Error correction by customer. Any kind of error which is detected by customer due to specification error is a cause of change. Loosely defined initial requirements and stated goals could be reached with fewer goals also fall in category of error correction by customer [3] [9] [11] [12].

3.2.2.2. Feature change instigated by customers. Customer demands are outlined by market demands. Customer can claim any type of feature change which results in requirement change. Changing legislation during projects is a category of feature change by customer [1] [9] [12].

3.2.2.3. Change in test scenarios by customers. Customer needs and organizational policies results in changing the feature of software which further impacts on test scenario. Customer can also demand change in test scenarios, starting from Graphical User Interfaces to the flow of navigation. Change in test scenarios may highlight errors that were not identified yet [4] [11].

3.3. Project Essential. Causes of requirements change originated from developer side are known as project causes. Causes of requirements change of project essential are; increased learning to the system and internal demands of functionality up gradation by software developing teams as show in figure 1.

3.3.1. Increased Learning to the System. Learning to the system is greater than beginning as development practice proceeds because perceptive of developer to the functionality of system increases and system strength or independency also improves [7] [13]. These sub causes of requirements change shown in figure 2

3.3.1.1. Learning to the system increased by the developers. During development process developer's knowledge to the system increases gradually. This increase in knowledge is an essential factor of requirement change [7].

3.3.1.2. Effort to increased system's strength and independency. Some obstacles for handling failures and anomalies are; Inconsistent requirements**,** poorly understood requirements and handling inconsistency. These lead to a main cause of change that is effort to increase system's strength and independency [13].

3.3.2. Functionality Enhancement Due to Internal Demands. Functionality enhancement requests initiated by developer/ developer organization are documented as internal demands. Internal demands originated by developer are error correction, change in test scenarios, design improvements, feature change and functionality enhancement shown in figure 2.

3.3.2.1. Error correction during and after phase of development. Defect fix during development may be a result of error correction in requirement specification. After development usually errors are corrected at initial stage of review and testing by developers as mapping with requirements specification. Both type of error correction may change the requirements of software [3] [11] [12].

3.3.2.2. Functionality enhancement of product originated internally. Functionality enhancement of a product by internal demands or by developer's team is another cause of change. Increased understanding to the system may be one form of this change; mostly customers are unaware of specifications so change is

demanded from developer side to increase the functionality of system [5].

3.3.2.3. Feature change instigated by developer. Feature change instigated by developers occur mostly due to shrinking budgets, running out of schedules, missing requirements and due to the fact that stated goals could be reached with fewer requirements [4] [9] [12].

3.3.2.4. Design improvements. Any kind of design improvements of a system may possibly lead to change in requirements [4] [5].

3.3.2.5. Changes in test scenarios by developers. Change in test scenario by developers mostly occurs due to unexpected errors. Adaptive, corrective, perfective and preventive approaches of test scenarios can be factors of change [4] [11].

3.4. Business Accidental. No sub causes is listed in literature as business accidental. Business accidental causes may vary from project to project. All causes found in literature related to business are essential in nature.

3.5. Organizational Accidental. Organizational or customer side factors of requirements change taken place by mistakes of developers are listed under requirement uncertainty, considered as main cause of change shown in figure 1.

3.5.1. Requirement Uncertainty. Uncertainty in requirements is considered as an important factor of requirements change. Causes of requirements uncertainty are ambiguous vision, partially evaluated business case and dropping feature due to budget or time deficiency, shown in figure 2.

3.5.1.1. Ambiguous product vision. Requirement uncertainty is a major cause of change. This major cause has a mixture of drivers and root causes for requirement uncertainty [2].

3.5.1.2. Lack of thorough evaluation of business cases. Some of requirement's uncertainty factors are; business case not thoroughly evaluated, requirement not sufficiently specified and analyzed, vague product vision, Key stakeholders not involved, Unknown project dependencies [2].

3.5.1.3. Dropping a feature due to budget shortages. Budget shortage usually results in reduced requirements set which may force on requirements to be changed [4] [8] [9].

3.5.1.4. Dropping a feature due to time deficiency. Running out of schedule is an important factor of change. Mostly projects failure cases are reported with slippage of time schedules. Project team and project management play an important role for occurrence of this cause [4] [8] [9].

3.6. Project Accidental. Factors of requirements change related to project (developer side) can occurred mistakenly. These mistakes of developers come into view as issues of requirement uncertainty, incomplete/incorrect requirement specification and inadequate training or manual provided with the system to guide users shown in figure 1.

3.6.1. Requirement Uncertainty. Ambiguity in requirements is a crucial issue that may impact the software very deficiently. Requirement uncertainty caused by developer's organizations include factors related to stakeholder identification and involvement, communication issues, redundancies, dependencies, conflicting requirements and detailing the requirements, shown in figure 2.

3.6.1.1. Later identification of stakeholders. Later identification of stakeholder and overlooked to stakeholders is a major cause of requirement uncertainty [2] [5] [9].

3.6.1.2. Inadequate involvement of stakeholders. Insufficient key stakeholder's involvement during requirement engineering process causes requirements to be changed [1] [2] [5] [9].

3.6.1.3. Communication gap among external and internal people. Communication gap among customers and developer team may results in requirements change. This factor is mostly highlights in global software development context. Projects having strong communication between internal and external people usually are better dealt with requirement specification and changing requirements [7] [8].

3.6.1.4. Unknown dependencies on other projects. Unknown project dependency in context of traceability and compliance factors is somewhat related to requirement uncertainty also cause requirements change [2] [5] [6].

3.6.1.5. Initially broadly stated requirements. Requirements are usually broadly stated by customers. Later on, during specification and development process these requirements may shrink down and may cause in requirement change [4].

3.6.1.6. Resolving interdependencies among requirements. At initial phases requirements are dependent on other requirements due to ambiguity. This dependency is resolved during specification process. Resolving interdependencies among requirements usually results in diverse requirement set as compared to defined earlier [4] [5].

3.6.1.7. Resolving redundancies among requirements. This factor of change is also associated with resolving ambiguities of requirements [4].

3.6.1.8. Adding details to initial defined requirements. Adding details to initial defined requirements is a factor of requirements uncertainty and initial set of requirements are more specified after adding necessary details [4] [2].

3.6.1.9. Initial requirements were loosely defined. A loosely defined initial requirement is a sub factor of requirement uncertainty and ambiguous requirements which generally results in requirements change at later stages [2].

3.6.2. Completeness and Correctness of Requirement Specification. High quality requirements specification leads to high quality system at the end of development. Correctness, accuracy and completeness of requirements specification are listed under this category of requirements change, shown in figure 2.

3.6.2.1. Inaccurate system requirement specification. Requirement not sufficiently specified and analyzed cause requirement specification to be incorrect, inaccurate and ambiguous as factors of requirement uncertainty [2].

3.6.2.2. Incomplete system requirement specification. Business case not thoroughly evaluated and vague product vision are important factors that cause requirements to be uncertain. Incomplete requirement specification is an attributed factor associated with above uncertainty factors [2] [3].

3.6.2.3. Incorrect system requirement specifications. Requirement not sufficiently specified and analyzed cause requirement specification to be incorrect, inaccurate and ambiguous as factors of requirement change [2].

3.6.3. Inadequate Training or Manual. Manual is prepared with the development of software for ease of users and afterward to incur changes in software. Correspondingly training is arranged for understanding of system in case system is complex to understand solely by a manual. Omitted or partial training/manual is a cause of change instigated by developer side, shown in figure 2.

3.6.3.1. Unavailability of user manual. Factors which affect the RE process quality are Requirement change, Missing requirements an incorrect requirements. These main causes may occur due to customer unawareness of requirements change and change without formal approval. Customer will remain unaware of requirements in absence of user manual. This will cause change request from customer/ user, even though requested functionality already exist in the system [1].

3.6.3.2. Inadequate details of user manual. RE process quality factors are also occurred due to insufficient user manual details. As user manual unavailability will cause requirements change. Similarly continuous update to user manual is very crucial to Requirement engineering process [1].

4. Discussion. Classical factors of software development difficulties presented by F.P Brooks are accidental or essential that are further reflected as a dimension of change along with another dimension of originated source as project, business and organizational factors by N. Ikram, et.al 2010 and also listed 10 major causes of requirements change as a result of systematic literature survey. We have explored 37 sub causes alongside these 10 major causes from literature while adjusting and updating 10 major causes identified in literature. After adjustment requirement uncertainty appears an important causes both in project and organizational type of change factors.

5. Conclusion and Future Work. In this research article, we present all possible causes and sub causes that can happen within requirement specification, development, design and testing phase of software process. These causes can disrupt the software development process and consequentially enhance software development cost and never ending development results in project failure. So there should has some proactive strategies and policies exist to overcome continuous requirement change during software development process. Suggested causes and sub causes of requirement change guide software practitioners to identify and solve these type of problems during requirement specification and project execution phase. As a future work these causes will be validated and verified from industry survey, expert opinion and consumer feedback. A comprehensive requirement change framework can also be developed based on these causes.

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