The necessity for this proceeding is due to BC Hydro's overall approach to the SMI program – avoiding a commission review prior to initiating the program, providing misleading public information relating the cost of electricity theft, practicing creative accounting techniques in selectively applying the forecast theft reduction benefits of the program without actually forecasting theft reduction energy amounts, and finally delaying the introduction of the opt-out program until the 11th hour. All of this has caused unnecessary acrimony between BC Hydro and a subset of its customers who, for various reasons, don't wish to participate in the SMI program.

BC Hydro Overstates Cost of Electricity Theft

BC Hydro has overstated, and continues to overstate, the cost of electricity theft. This is presumably to make the SMI program appear more beneficial than it actually is. In the Business Case, BC Hydro states that "Estimated consuption [sic] by marijuana growing operations is 1,300 GWh/yr through F2033 (paid and theft), of which theft increases from 500 GWh/yr in F2007 to 850 GWh/yr in F2012."[1] BC Hydro also quantifies the value of energy as "the BC Hydro reference energy price based on the 2009 Clean Call for Power. This price is $124 per MWh for F2010 and adjusted for inflation annually."[2] Both of these statements may be true, but then they are implicitly linked to estimate the current cost of electricity theft: "Electricity theft costs BC Hydro customers more than $100 million each year."[3] Note that 850 GWh/yr times 124 $/MWh yields $105 million.

The calculation of the cost of theft is fundamentally incorrect. The reference prices is related to the cost of IPP contract energy, but IPP contracts are a sunk cost – no change in the amount of theft will change the amount of the contracts already signed, since the contracts are fixed price and fixed term. Correct accounting would base calculation on the expected revenue if the theft were eliminated. Since the theft is primarily related to illegal growing operations, this will initially be a complete load loss when the premises are disconnected. Later, some fraction may be restored to supply the legitimate requirements of the premises. A reasonable assumption might be that the legitimate load is 50% of the diversion load. Any additional energy will either be sold to market (when BC Hydro has an energy surplus) or reduce the amount purchased from the market (when BC Hydro has an energy deficit). So the effective price associated with electricity theft is 50% times the tariff plus 50% times the market price.

In F2012, the residential tariff was a 0.067 $/kWh for step 1 and 0.096 $/kWh for step 2. Assuming a 75:25 split between the two steps, a reasonable estimate of the tariff rate is 75 $/MWh. The market price of electricity in F2012 was approximately 30 $/MWh (estimated from Amended Figure 4-1 of the F12-F14 Amended RRA).[4] A 50:50 combination of the tariff and market prices results in an effective price of just over 50 $/MWh, less than one half of the BC Hydro reference price. This means that BC Hydro has been relying on an estimate of the costs of theft that is more than twice what it should be.

[1] Smart Metering and Infrastructure Business Case, "Appendix 4: Quantified Benefits and Key Assumptions", p. 27
[2] Smart Metering and Infrastructure Business Case, "Appendix 6: Business Case Analysis", p. 31
[3] http://www.bchydro.com/news/conservation/2011/smart_meter_facts.html
[4] http://www.bcuc.com/Documents/Proceedings/2011/DOC_29146_B-1-3_BCH-Amended-F12_F14-RRA.pdf, Amended Figure 4-1, page 4-15

In addition to appearing on BC Hydro's web site as a "fact", this over-estimate has been repeated by BC Hydro executives in public interviews and presentations, a few examples of which are provided from the last 3-1/2 years:

- Cindy Verschoor, October 2010: "BC Hydro says the theft of electricity — mostly from marijuana grow operations — now costs $100 million every year."[5]
- Gary Murphy, June 2012: "energy theft from marijuana grow operations, which account for at least $100 million in lost revenue each year."[6]
- Patrick Hogan, April 2013: "… electricity theft, which has grown … to an estimate of at least 850 GWh today … and amounts to approximately $100 million a year in energy cost."[7]

BC Hydro Overstates Benefit of Theft Reduction

In the BC Hydro Business Case, theft detection is the largest single forecast benefit, at $732 million NPV.[8] Assuming that the same faulty logic was used to calculate this benefit, the Business Case overestimates the benefit by about $400 million, and the NPV of the program drops from $520[9] to $120 million.

BC Hydro continued its creative accounting approach by including in the F12-F14 Amended RRA a line item for benefits from the SMI program. "The net revenue requirement impact for the three year period totals $73.4 million (line 19 in schedule 17 of the F12-F14 ARRA) and reflects reductions in rates attributable to SMI that were passed onto all customers."[10] These benefits are labeled as "Reduced Diversion", but do not relate to any corresponding forecast reduction in theft. This is evident in Schedule 4.0 of the Amended F12-F14 RRA. Actual losses (line loss and system use, which must include theft because there is no separate line item for it) were 9.08% in F2011. In spite of costly BC Hydro programs to reduce its own use by redeveloping its office spaces, and in spite of forecast over $30 million in reduced diversion, the forecast losses for F14 are the same 9.08%.[11] Wong IR 2.6.1 specifically asked for the associated energy amounts related to theft detection, but BC Hydro quietly omitted this information in its response.

In summary, an overestimated benefit of theft reduction based on the wrong electricity price is used to provide a fictitious benefit with no associated real reduction in theft to avoid a short term rate increase. Unfortunately, because the SMI program was exempted from BCUC oversight, there was no opportunity to test this accounting treatment.

Accounting Treatment Transfers Costs between Ratepayer Groups

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[5] http://www.cbc.ca/news/canada/british-columbia/electricity-theft-by-b-c-grow-ops-costs-100m-a-year-1.969837
[6] http://www.comoxvalleyrecord.com/news/159134315.html
[7] http://www.forbes.com/sites/peterdetwiler/2013/04/23/electricity-theft-a-bigger-issue-than-you-think
[8] Smart Metering and Infrastructure Business Case, "Financial Analysis", p. 9
[9] Ibid, "Executive Summary", p. 2
[10] BC Hydro response to Wong IR 2.6.1.
[11] Amended F12-F14 RRA – Amended Appendix A, Schedule 4.0, line 33 divided by line 32 (see attached)

The result of this creative accounting is that BC Hydro has transferred costs from one customer group (current rate payers) to another (future rate payers). By doing so, BC Hydro has set a precedent in the differential treatment of overlapping but not identical sets of ratepayers by forecasting costs and revenues in a way that differs from the way in which those costs and revenues would be expected to actually occur.

In this proceeding, there are also two overlapping but not identical sets of ratepayers – those who currently have elected to participate in the Meter Choices Program and those who haven't done so. The sets overlap because some of those in the Meter Choices Program will eventually elect to leave (and some of the non-participants would like to participate but are prevented from doing so by direction from the government[12]), and because those costs not specifically allocated to the Meter Choices Program will be borne by all customers, including those in the Meter Choices Program[13].

Scope of the Commission Review of Costs for Meter Choices Program Customers

Direction No. 4 states that the "commission must ensure that the rates allow the authority to collect sufficient revenue in each fiscal year to enable it to recover the following costs from the following customers: (a) program costs, investigation costs, and infrastructure costs from (i) applicable customers at applicable premises where a legacy meter or radio-off meter is installed, to the extent that the authority requests recovery of any of those costs from these customers."[14] The key phrase relating to the division of costs between Meter Choices Program customers and all customers is "to the extent". Clearly this does not mean that the commission must approve BC Hydro's application without the possibility of amendment, because it this were the case there would be no reason for this proceeding. Rather, the phrase "to the extent" defines the scope of the request. BC Hydro has narrowed this scope to the capital and operating cost items outlined in section 3.4 of the application, and thus eliminated the possibility that other costs (both positive and negative), such as those potentially related to delays in the overall SMI program, are included.

Although the scope of the review is limited by BC Hydro's application for recovery of only capital and operating costs, the amounts of those costs and the estimated number of subscribers between which to divide the costs is within the purview of the commission.

BC Hydro Is Incurring Higher than Necessary Costs for the Meter Choices Program

In its business case, BC Hydro states that "by adopting smart meters after learning from the experience of other utilities, BC Hydro has the advantage of knowing what factors contribute to successful implementation"[15]. "For the past four years, BC Hydro has been defining the scope and approach for the Smart Metering Program. Key activities include … monitoring the progress and results from utilities who were early implementers of smart metering projects — including Pacific Gas & Electric, Southern California Edison, San Diego Gas & Electric, Duke Power, ENEL (Italy), and in Ontario—Hydro One,

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[12] Direction No. 4 To the British Columbia Utilities Commission, Section 4.2.2
[13] Ibid., Section 3.1(a)
[14] Ibid., Section 3.1(a)(i)
[15] Smart Metering and Infrastructure Business Case, "Lessons Learned from Other Jurisdictions", p. 11

Toronto Hydro—and incorporating their "lessons learned" into BC Hydro's project planning"[16]. BC Hydro acknowledged that "customer resistance to the installation of smart meters was one of the factors that some other utilities experienced".[17]

According to BC Hydro's response to BCUC IR 1.5.2, which provided a table showing a limited set of comparable opt-out programs, the earliest program began in 2011 (Central Maine Power and Portland General Electric), around the time that BC Hydro began to roll-out its SMI program customer installations. This would have been the appropriate time for BC Hydro to take advantage of the experience of other utilities, be pro-active instead of reactive, and offer its own opt-out program. Instead, BC Hydro continued blindly for another two years, developing the software and installing the hardware, while customer opposition continued to increase, before belatedly offering a program, to only hold-out customers, at a higher cost than it could have been because of the delay.

BC Hydro did not disagree with the assertion that "In general, the later in a capital project that changes are introduced, the higher the cost of those changes. Please confirm that if the "Meter Choices Program" had been included in the original capital project, the incremental costs associated with this program would be lower.", but instead responded that "It is not possible to determine what the costs might have been under this hypothetical scenario."[18]

While many of the capital costs may not be lower had they had been identified earlier, the costs related to changing the software certainly would have been. In the follow-up IR, Wong provided a reference to the paper "Measuring the Impact of Changing Requirements on Software Project cost: An Empirical Investigation"[19] BC Hydro responded three questions related to the project software costs and the conclusions of this technical paper, prepared by IT experts, based on empirical data, with the response "BC Hydro is not familiar with the cited paper, and declines to comment on any inferences drawn between the findings of the paper and the Information Technology estimates provided in the Application."[20] The findings of the authors of the paper suggest that the software capital costs would be 1/35, or less than 3%, of those proposed in the application had BC Hydro considered an opt-out program prior to designing and implementing the software[21]. BC Hydro had the opportunity to refute this claim, and elected not to do so.

Recommended Commission Decision

The following are the recommended commission decisions:

1. Include the cost reductions acknowledged by BC Hydro in its Final Submission in item numbers 36 (Reduced Number of Transformers Needed for Range Extenders) and 47 (Deferred Capital Cost Savings Related to Retention of Legacy Meters).

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[16] Ibid, p. 18
[17] BC Hydro response to Wong IR 1.1.2
[18] BC Hydro response to Wong IR 1.1.3
[19] www.ijcsi.org/papers/IJCSI-9-3-1-170-174.pdf (see attached)
[20] BC Hydro responses to Wong IRs 2.3.2, 2.3.3, and 2.3.4
[21] Wong IR 2.3.3

2. Reduce the Information Technology Capital Cost from $1, 238, 577 to 1/35 of its value, or $35, 388, based on the argument that the IT costs are higher than necessary because of the delay in introducing an opt-out program as noted above. The delay in the introduction of this program is not the responsibility of the customers who desired to opt-out – on the contrary, those customers would undoubtedly have preferred to have had the opt-out option sooner rather than later.
3. Based on the precedent set in BC Hydro's accounting treatment of SMI benefits in the F12-F14 Amended RRA, choose the customer base denominator for calculating the cost per customer to be those customers who initially refused smart meters (60, 000 customers[22]) plus an estimated number of customers who would have liked to have joined an opt-out program, but were not given the option at the time a smart meter was installed at their premises, succumbing to BC Hydro's demand that they accept a smart meter. Some IRs queried this topic, but BC Hydro refused to provide any evidence on the number of such customers. In the absence of evidence, assume a further 60, 000 customers, for a total of 120, 000. Again, the logic here is that had the program been offered from the start of the smart meter installation process, enrolment would be much higher and the unit cost therefore much lower. The higher unit cost due to the late introduction of the Meter Choices Program should not fall exclusively on the customers electing to take up the program.

Final Comments

By government direction to the commission, only customers who acted on some level of "civil disobedience" by refusing BC Hydro's demand that they accept a smart meter are able to participate in the Meter Choices Program. The fact that only customers who stood up to BC Hydro benefit from doing so may come back to haunt BC Hydro. It rewards these customers for their actions and thereby encourages further civil disobedience on their part, and on the part of others, in future dealings with BC Hydro.

BC Hydro's proposed program costs lie above the price-demand curve of the six other utility programs provided by BC Hydro for comparison purposes. BC Hydro acknowledges that "standard charges for the Meter Choices Program would factor into a customer's decision to participate in the program."[23] If the commission approves this program as requested by BC Hydro, with total costs of $1300 + GST over a 5 year horizon for radio-off meter customers and $2100 + GST for legacy meter customers, customers will be incented to seek cheaper alternatives, such as Faraday cages. This may result in additional conflict between BC Hydro and its customers, since BC Hydro acknowledges in its response to Wong IR 2.5.1 "that remedies exist within the BC Hydro Electric Tariff to deal with such a scenario, including requiring the customer to remove such a cage."

It would behoove the commission to also take consideration of the two above-mentioned potential impacts into account, insofar as it is legally able, in rendering its decision.

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[22] Application for Approval of Charges Related to Meter Choices Program, page 1-1
[23] BC Hydro response to Wong IR 1.3.3

Cost of Energy (COE)
($ million)

Line		Reference	F2008 Actual	F2009 Actual	F2010 Actual	F2011 NSA-9	F2011 Actual	F2011 Diff	F2011 % Diff	F2011 NSA-12	F2012 Update	F2013 Update	F2014 Update
	Column		1	2	3	4	5	6 = 5 - 4	7 = 6 / 4	8	9	10	11
	Cost of Energy ($ million)												
	Heritage Energy												
1	Hydroelectric (water rentals)		315.0	309.7	311.1	323.5	**314.0**	(9.4)	-2.9%	323.5	356.1	361.2	378.0
2	Market electricity purchases		153.3	272.6	80.5	148.3	**128.4**	(19.9)	-13.4%	148.3	37.2	45.7	23.9
3	Market Purchases to Non-Heritage		(143.5)	(22.8)	0.0	0.0	**0.0**	0.0	N/A	0.0	0.0	0.0	0.0
4	Natural gas for thermal generation		49.1	47.3	38.9	37.3	**31.2**	(6.1)	-16.3%	37.3	29.3	41.0	50.4
5	Domestic transmission		15.7	15.8	15.9	15.7	**15.7**	(0.1)	-0.4%	15.7	15.3	15.3	15.4
6	Surplus Sales		(31.9)	(9.7)	0.0	0.0	**(0.1)**	(0.1)	N/A	0.0	(3.7)	(34.8)	(65.8)
7	Other		6.0	2.4	8.4	(25.1)	**(22.6)**	2.5	-10.0%	(25.1)	(32.0)	(34.7)	(30.8)
8	Total		363.7	615.3	454.8	499.7	466.7	(33.0)	-6.6%	499.7	402.2	393.8	371.2
	Non-Heritage Energy												
9	Mkt Purchases From Heritage	Line 3	143.5	22.8	0.0	0.0	0.0	0.0	N/A	0.0	0.0	0.0	0.0
10	Waneta (water rentals)		0.0	0.0	0.5	7.0	**6.9**	(0.1)	-1.6%	7.0	8.1	8.3	8.4
11	IPPs and Long-Term Commitments		480.0	543.0	567.4	710.4	**675.1**	(35.3)	-5.0%	710.4	793.2	888.9	1,058.9
12	New Capital Leases Under IFRS	18.0 L1	0.0	0.0	0.0	0.0	0.0	0.0	N/A	0.0	0.0	8.1	9.7
13	Non-Integrated Area		21.7	24.0	20.7	23.6	**23.2**	(0.4)	-1.5%	23.6	27.5	31.4	35.4
14	Gas & Other Transportation		11.5	11.5	11.4	13.3	**13.9**	0.5	3.9%	13.3	14.4	13.2	12.2
15	Domestic Transmission		75.7	92.0	87.9	92.4	**85.8**	(6.6)	-7.2%	23.1	0.0	0.0	0.0
16	Net Purchases (Sales) from Powerex		(125.6)	(25.8)	67.2	46.8	**37.6**	(9.3)	-19.8%	46.8	(42.3)	4.7	(26.3)
17	Total		606.7	667.5	755.1	893.6	842.4	(51.2)	-5.7%	824.3	801.0	954.5	1,098.4
18	**Total Gross COE**	Lines 8+17	970.4	1,282.8	1,209.9	1,393.3	1,309.1	(84.2)	-6.0%	1,324.0	1,203.2	1,348.3	1,469.5
	Sources of Supply (GWh)												
	Heritage Energy												
19	Hydroelectric (water rentals)		52,140	43,812	43,137	40,669	**38,295**	(2,374)	-5.8%	40,669	45,252	45,167	46,514
20	Net Purchases (Sales) from Powerex		(2,412)	(65)	1,525	847	**1,077**	230	27.2%	847	(1,304)	(210)	(691)
21	Market electricity purchases		2,258	5,020	2,161	3,553	**3,791**	238	6.7%	3,553	1,610	1,419	660
22	Market Purchases to Non-Heritage		(2,113)	(419)	0	0	**0**	0	N/A	0	0	0	0
23	Natural gas for thermal generation		423	312	400	329	**251**	(79)	-23.9%	329	334	517	627
24	Surplus Sales		(811)	(196)	0	0	**(53)**	(53)	N/A	0	(109)	(874)	(1,496)
25	Exchange net		(485)	536	(1,092)	177	**372**	195	110.2%	177	(211)	(447)	(572)
26	Total		49,000	49,000	46,131	45,575	43,733	(1,842)	-4.0%	45,575	45,573	45,572	45,041
	Non-Heritage Energy												
27	Waneta (water rentals)		0	0	71	1,008	**1,008**	(0)	0.0%	1,008	**1,008**	**1,008**	**1,003**
28	IPPs and Long-Term Commitments		7,765	8,374	8,893	10,504	**10,805**	301	2.9%	10,504	11,618	12,367	13,606
29	Mkt Purchases From Heritage	Line 22	2,113	419	0	0	0	0	N/A	0	0	0	0
30	Non-Integrated Area		115	116	113	116	**114**	(2)	-1.8%	116	**120**	**126**	**132**
31	Total		9,993	8,909	9,077	11,628	11,927	299	2.6%	11,628	12,745	13,500	14,741
32	**Total Sources of Supply**	Lines 26+31	58,993	57,909	55,208	57,204	55,660	(1,544)	-2.7%	57,204	58,318	59,072	59,783
33	**Less Line Loss and System Use**		(5,694)	(5,593)	(4,975)	(5,409)	**(5,053)**	356	-6.6%	(5,409)	(5,399)	(5,544)	(5,427)
34	**Total Domestic Sales**	14.0 L9	53,299	52,316	50,233	51,794	50,607	(1,187)	-2.3%	51,794	52,919	53,527	54,356
	Losses as Percent of Supply (line 33 ÷ line 32)						9.08%			9.46%	9.26%	9.39%	9.08%

Measuring the Impact of Changing Requirements on Software Project Cost: An Empirical Investigation

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Abstract

It is generally accredited that software development is a dynamic process so during the development of a software project many requirement changes are proposed. Literature shows that these proposed changes have the potential to affect the software development in different dimensions. Among these dimensions, cost is major.

This paper demonstrates the impact of a requirement change on the cost of a software project in terms of development effort, i.e. total working hours to implement that change. In our study, a new approach is suggested to compute the effort with the help of Regression Equation. This equation is derived by performing Correlation and Regression analysis on the change request data. The data is collected from nine different software projects of Pakistan's software Industry. Proposed approach is based on a conceptual model for cost estimation presented in this paper. In this empirical study, a systematic impact analysis approach is also discussed to analyze how the impact of a change in requirement propagates from one phase of Software Development Life Cycle (SDLC) to other phases.

Keywords: *Requirement Change, Effort, Requirement Change Attributes*

1. Introduction

Requirement's evolution is mandatory for any software project. Users can propose requirements change at any stage of SDLC. Although change in requirements may affect Cost, Schedule and Quality of a software project [3] but change should be allowable when it is inevitable to meet the customer expectations. Change can be one of the difficulties in software-development [2].

When a change is occurred during the implementation of existing requirements, its impact is not only limited to that particular phase where change was proposed but also propagates to other subsequent phases of SDLC [1]. Because of this propagation effect Cost in terms of development effort is directly affected [6]. Frequent changes in project requirements interrupt the project and contribute to a greater effort each time work is resumed.

This paper demonstrates our findings based on empirical investigation of requirement changes and its impact on Software Project Cost in terms of development effort that is the total working hours of a resource to implement a change. This research study also identifies those requirement change attributes which are the potential factors for the estimation of the effort associated with change by suggesting a conceptual frame work for cost estimation. This paper furthermore discusses a systematic way to analyze the impact of change with respect to a particular phase of SDLC and a generic equation based upon Correlation and Regression Analysis is also derived for cost estimation.

This paper provides information on the related work that has been done in this area (section 2) and then describes the research methodology that has been used to derive the equation for the computation of cost associated with change and the detail description of each step (Section 3). On the basis of the lessons learned from this empirical study conclusion is drawn (Section 4).

2. Literature Review

Bhatti et al [1] analyzed the impact of requirement change with respect to the development phase and reported that more changes are proposed during maintenance phase. Also concluded that changes proposed in requirement phase and changes proposed in design phase have significant relationship and this significant relation indicates that by increase in change requests during requirement analysis phase the requests would also increase in Design phase. Changes proposed in design phase and changes requested in testing phase also have significant relationship and this significant relation depicts that if more changes are requested in design phase then the changes in testing phase would be decreased.

Zowghi et al [9] defined two types of Requirement Volatility. Pre-SRS i.e. requirement volatility in early phases. Post-SRS, i.e. requirement volatility in later phases of software development life cycle.

Barry et al [7] analyzed the relationship between project duration and project effort by developing and evaluating a two-stage model.

To determine the impact of a requirement change on software development Neal et al [4] presented impact analysis method based on requirement traceability. They created classes of requirement changes by identifying attributes of different work products and traces. Then they prioritized those requirement classes according to their potential impact.

Damian et al [10] reported that there is a positive relationship between improved requirement engineering process and software productivity. According to them a mature requirement engineering process improves overall software development.

To demonstrate the impact of requirement instability on project performance Pfahl et al [11] used the simulation models.

To analyze the impact of requirement volatility on Software Project Performance Nurmuliani et al [6] presented a conceptual Model. In this model they analyzed the direct relationship between Requirement Volatility and Project performance and the impact of other factors. They finally reported that project performance is being measured as the project that is being developed within budget and within schedule and requirement volatility can affect the project performance, and this impact of RV on project performance can be affected by other factors such as organization size and project size.

They also investigated the impact of Requirement Volatility on development effort that is total working hours to implement a change [5]. Their findings reported that if new requirements are added in the later phases during software development it would be a high risk because it will cost the organization in the form of schedule delays or budget overruns. And identified different requirement change attributes that can be used to estimate effort e.g. number of document affected, Source of change and type of change.

3. Research Approach

Fig. 1 describes a novel approach which is used to derive generic regression equations for the computation of the effort as a result of a proposed change.

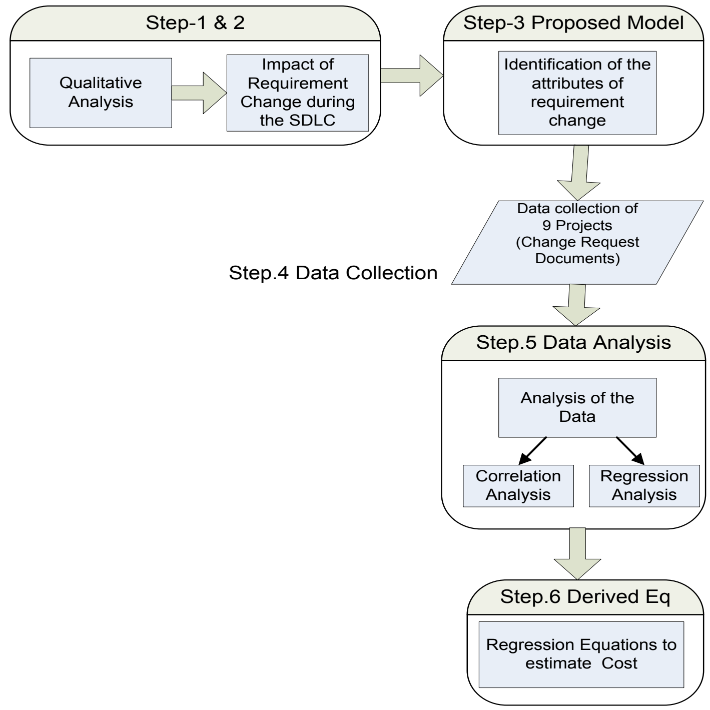

Fig. 1 Research Methodology

3.1 Qualitative Analysis-Research Questions

Qualitative Analysis is the most important phase of proposed approach because it is used to identify the potential requirement change attributes which can contribute to the estimation of the associated cost of change. To achieve this, different questions were asked from the experts of Pakistan’s Software Industry. These following research questions guided the research study.

Q1. How changing requirements affect the cost and schedule of software?

Q2. How impact analysis of a change request is performed?

Q3. Which type of requirement change requires extensive rework? (E.g. GUI change, Workflow change, DB change, Process change, Functionality change)

Q4. When change request arises in any phase of SDLC, which work products are affected from it?

Q5. How the effort is measured to implement a proposed change in different phases of SDLC?

3.2 Conceptual framework for analyzing the impact of change through relationship among artifacts.

The conceptual framework describes the different artifacts which are developed in each phase of SDLC and address the second and fourth research questions (Qualitative Analysis). Impact of a change is calculated using horizontal traceability. Fig.2 depicts that to perform the impact analysis of a requirement change, first the SDLC Phase in which change is requested is spotted. Impact of the change is measured on the basis of No. of artifacts to be changed, which depends on the SDLC phase in which change is requested. For earlier phase no. of affected artifacts will be low, while in later phase the no. of artifacts will be greater since more no. of artifacts are produced till later phases of SDLC.

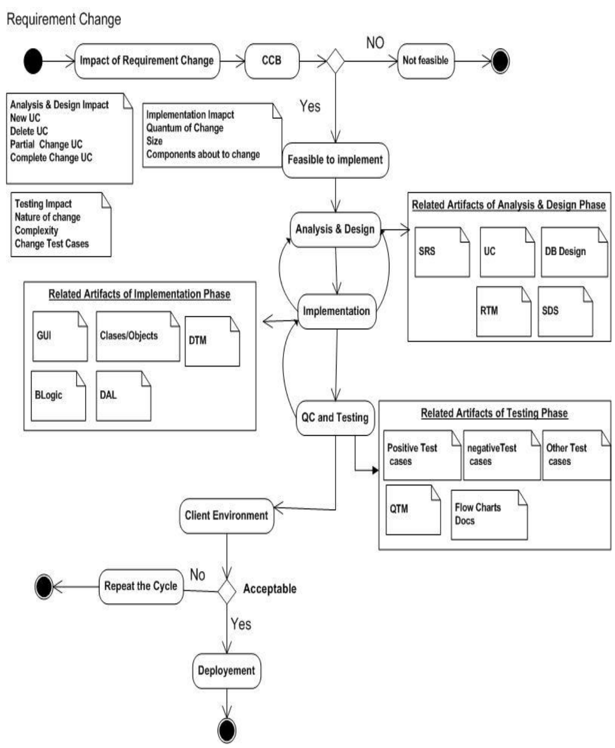

Fig. 2 Conceptual Framework

Frame work also depicts that a change requested during Requirement analysis phase has no chain effect. So only Analysis and Design phase related artifacts which are (SRS (Software Requirement Specification), Use Case Document(UC),RTM (Requirement traceability matrix), SDS (Software Design Specification) , DB Design) would require modification which need less working hours and few number of resources, so computed effort would be low to implement change at this stage. In Implementation phase artifacts related to this phase i.e. (Development traceability matrix (DTM)) and artifacts related to earlier phases i.e. (RTM, DB/Design, SDS, SRS) would need modification so more effort would be required as number of artifacts has increased. In Testing phase artifacts related to this phase i.e. (Quality Traceability matrix (QTM), test cases and artifacts of earlier phases i.e. (RTM, DB/Design interaction (matrix), DTM) would need updation. Traceability Matrices are used to find out size of work (effort) required against a change. This matrix links a requirement to a UC document and UC document to Graphical User Interface and GUI to different classes and objects and links UC document to Test cases. In Maintenance phase the artifacts like RTM, DB/Design interaction (matrix), DTM and QTM are used to find out size of work (effort) required against a change.

3.3 Change request attributes

In this phase, we identified significant attributes of requirement change from change request forms that can be useful in the estimation of effort associated with change. Following are the required attributes

i. Type of requirement change (i.e. GUI, Functionality, Process, Work flow, DB Design)
ii. Software development life cycle phase (Analysis, Design, Implementation, Testing, Maintenance/ Support)
iii. Change Priority (Low, Medium, High)
iv. Number of working hours
v. Number of resources

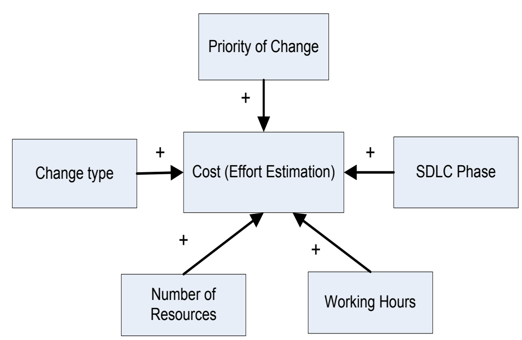

Fig. 3 Conceptual Frame work for Cost Estimation

3.4 Data collection

At this step various change request forms were collected from nine different projects of different organizations. Almost one hundred Change IDS were analyzed against different change request types.

3.5 Analysis of data and Results

Data extracted during qualitative analysis and from change request forms was collectively analyzed using SPSS software to perform correlation and regression analysis to derive an equation for the computation of the cost i.e. development effort required to implement the change.

3.5.1 Correlation Analysis Results

This statistical analysis shows that the selected change attributes are significant factors for the cost estimation model.

Table 1: Correlation Matrix - Significant factors for the cost estimation model

	Request Type	SDLC Phase	Priority	Man Days Cost
Request Type				
SDLC Phase	-.048			
Priority	.105	.388**		
Man Days Cost	.121	.604**	.620**	

**. Correlation is significant at the 0.01 level (1-tailed).

The statistics of table 1 shows that coefficient of correlation between SDLC Phase and Cost is .604 and this correlation is significant at 0.01 level (1-tailed). This positive relation indicates that if more changes are requested in the later phases of software development life cycle then more effort would be required to implement that change (Fig. 4).

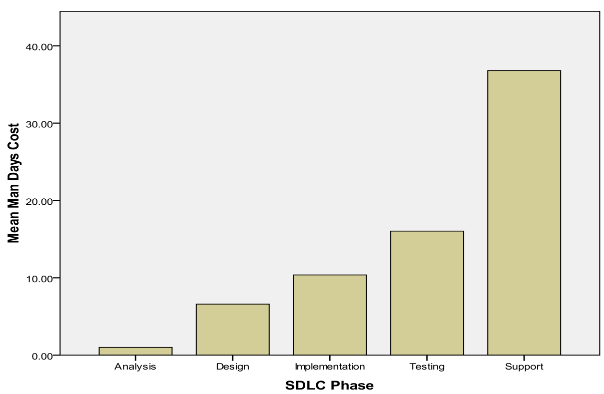

Fig.4 SDLC Phase and Cost of associated change.

This is because if change is proposed in later phase e.g. in Maintenance phase its effect would be propagate to the earlier phases which are, Analysis, Design, Implementation and Testing. As more rework would be required so it would have great impact on the cost associated with change.

The coefficient of correlation between Priority and Cost is .620.This correlation is significant at 0.01 (1-tailed).These results indicate that there is positive relation between Cost and priority of change i.e. a high priority change in requirement results as intensive rework as compare to the low priority change (Fig.5).

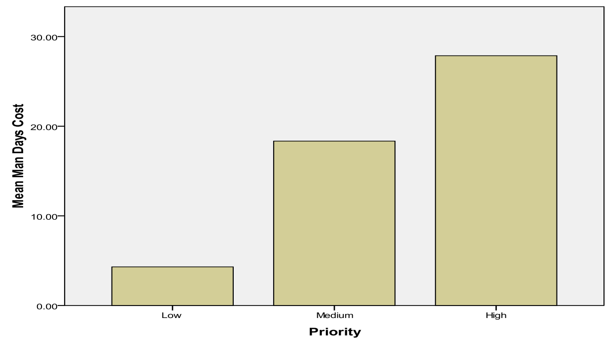

Fig. 5 Priority of Change and Cost of associated Change

The coefficient of correlation between change request type and cost is 0.121.This weak positive correlation shows that up to some extent change type would affect the effort required to implement the change (figure 6).

This is because it depends during which phase Of SDLC change was proposed. If GUI related change occurs in Design phase few rework would be required to make modifications in the related artifacts of analysis and design phase. If same change occurs at testing phase more effort would be required because artifacts related to Testing phase plus artifacts of the prior phases would need modification.

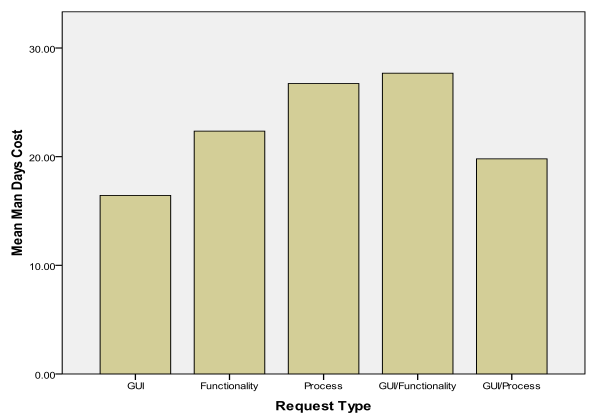

Fig. 6 Request Type of Change and Cost of associated Change

3.5.2 Regression Analysis Results

This statistical analysis shows that Adjusted R-Square is 0.534 and Sig F. change is .000.Which indicates that relationship of Cost in terms of development effort is significant with independent variables Change Priority, SDLC Phase and Change Type at 99.99 confidence interval. This indicates that 53.4 % variance in project cost is because of these three independent variables (Change Priority, SDLC phase and Change Type).

3.5.3 Regression Equation

Following regression equation is derived by performing regression analysis on the collected data set. This equation is based on the model depicted in Fig.3.

$$\mathbf{Cost = -45.967 + 8.605\ SDLC\ Phase + 9.784\ Priority + 1.844\ Request\ Type} \quad \mathbf{(1)}$$

Where Cost is the dependent variable and would be computed in terms of development effort i.e.

$$\mathbf{Effort = Number\ of\ Resources * Number\ of\ working\ hours} \quad \mathbf{(2)}$$

SDLC Phase is the independent variable and it represents the software-development phase during which change was requested. Coefficient of this variable is 8.60.5

Priority is independent variable and it represents the priority of the requested change. Coefficient of this variable is 9.784

Request type is another independent variable. It represents the type of the requested change. Coefficient of this variable is 1.844

With the help of this generic regression equation (Eq.1) the value of dependent variable that is cost can be predicted against a particular change.

4. Conclusion

In this paper, we have empirically investigated the impact of changing requirements on the estimated cost of the anticipated project. The results drawn during this empirical investigation help to understand how the impact of a particular change in requirements propagates from one phase of the software- development life cycle to another phase. This study has also identified major change attributes, which significantly contribute in estimation of cost associated with change. The momentous relation of change Priority and Cost shows that because of high priority of change, more effort, i.e. more working hours are required to implement that change. The significant relationship of SDLC phase and Cost indicates that if changes are proposed in later phases of SDLC, then more rework is required to implement that change. Our Research also suggests a cost estimation model and a generic regression equation to compute the associated cost of a change.

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