Development of Multi-Dimensional Control Tool for Controlling Construction Project's Performance

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Abstract

The reputation of construction industry is not so good in completing projects on planned time and budget. Irrespective of academic attention and years of practice in the field of project management, project's performance remains challenging. Construction projects involve complex processes as they continue to develop. Complication and uncertainty in construction projects validate the requirement of exploring further tools and techniques for project's performance and development. The issue of delay in project's completion and increased cost may result in formation of some other problems. There is a dire need of utilization of analytical tools for controlling projects that enables the project manager to play their role effectively and also provide simulations so that corrective actions can be taken at right time. The aim of the research is to develop innovative and sensitive indicators in five dimensions (5D, time, cost, safety, quality, disputes & claims) for project performance measurement, monitoring and control by modifying EVMS and to develop control tool on spreadsheet to cater identified indicators for better project performance measurement, monitoring and control (5D) by test run of 3 real time projects & making analysis of performance. To control time, cost, quality, safety, disputes and claims, a project control tool has been developed by incorporating different performance control indicators and have been implemented on Mega Constructions Projects. This research develops control tool in order to put forward a project monitoring and control system that works in such a way to indicate the variations and report's project status and gives warnings for corrective actions. This control tool can be further utilized by project managers to timely evaluate their projects for better performance.

Keywords: performance measurement, control tool, indicator

1. Introduction

Construction industry plays an important role in the development and growth of a country. The index of successful project delivery is that the project is timely completed within anticipated cost and also meets the quality standards [1]. Conventional methods are still part of construction industry due to which there are few shortcomings among which delays, cost overrun, poor quality, poor safety, legal disputes and claims are on hit list. Mega projects in Pakistan are more subjected to these problems as they are complex in nature. There are very harmful effects of these attributes such as loss of revenue and productivity, termination of contract and litigations between contractor and client. Different project controlling techniques and software are available but still objectives of cost, time, quality, safety and claims are not achieved by many construction projects. It becomes difficult for a construction project to be completed within planned budget and schedule when time and cost performance is poor. This problem is increasing with passing time and is a worldwide issue. Different project management software like Primavera P6 and Microsoft project represent the data in different formats but don't provide alerts for corrective actions and deal only with time & cost but not with other factors of safety, quality, disputes & claims that indirectly effect project's budget and schedule. It is vital to develop a technique that is reliable for controlling performance of construction projects and provides alerts for tackling the project on time. The project control software used in construction field so far deal with time and cost together and other metrics of quality, safety, claims and disputes separately. At the moment, diagnostic project control techniques and tools are required that enable the project managers to effectively control time, cost, quality, safety, claims & disputes by undertaking corrective actions at the hour of need. Statistical control techniques can be utilized for this purpose. The aim of the research is to develop innovative and sensitive indicators in five dimensions (5D, time, cost, safety, quality, disputes & claims) for project performance measurement, monitoring and control by modifying EVMS and to develop control tool on spreadsheet to cater identified indicators for better project performance measurement, monitoring and control (5D) by test

run of 3 real time projects & making analysis of performance. To control time, cost, quality, safety, disputes and claims, a project control tool has been developed by incorporating different performance control indicators and have been implemented on Mega Constructions Projects. This research will assess the indicators and devise mechanism to control performance of project in terms of time, cost and other parameters of quality, safety, claims & disputes together by formulizing a control tool and implementing it on mega construction projects.

According to a French saying, everything flourishes when the construction industry grows. There is no doubt that a country's growth is dependent upon advanced construction techniques. The use of different tools and techniques is vital part of project management [2]. Every client is interested to get the projects completed within scope, quality, time and cost. A project is said to be successful if it is safely completed within the planned time, budget, and quality and without any legal disputes or claims. Conventional methods are still part of construction industry due to which there are few shortcomings among which delays, cost overrun, poor quality, poor safety, legal disputes and claims are on hit list. Mega projects in Pakistan are more subjected to these problems as they are complex in nature. There are very harmful effects of these attributes such as loss of revenue and productivity, termination of contract and litigations between contractor and client. Different project controlling techniques and software are available but still objectives of cost, time, quality, safety and claims are not achieved by many construction projects. It becomes difficult for a construction project to be completed within planned budget and schedule when time and cost performance is poor. This problem is increasing with passing time and is a worldwide issue. In case of both government and private sector construction projects, non-existence of common decision techniques and tools for measuring performance indicators is a significant issue. This issue may intensify when time extension along with compensation of cost is demanded by the contractor because of inadequacy of performance contract. The conventional methods are used by the contractor for forecasting money and time required for project's completion. Such traditional forecast methods may lead to conflict between the stakeholders and will ultimately affect the performance of project. Different project management software like Primavera P6 and Microsoft project represent the data in different formats but don't provide alerts for corrective actions and deal only with time and cost but not with other factors of safety, quality, disputes and claims that indirectly effect project's budget and schedule. It is vital to develop a technique that is reliable for controlling performance of construction projects and provides alerts for tackling the project on time. Most of the research done in this field has been restricted to identify and evaluate the factors causing Time and Cost Overruns (TCO). Only a limited research has been done for controlling the projects effectively. The project control software used in construction field so far deal with time and cost together and other metrics of quality, safety, claims and disputes separately. At the moment, diagnostic project control techniques and tools are required that enable the project managers to effectively control time, cost, quality, safety, claims and disputes by undertaking corrective actions at the hour of need. Statistical control techniques can be utilized for this purpose. This research will assess the indicators and devise mechanism to control performance of project in terms of time, cost and other parameters of quality, safety, claims and disputes together by formulizing a control tool and implementing it on mega construction projects.

2. RELATED WORK

There are various articles in which major reasons of schedule delays in construction of projects have been discussed in variety of ways. Many researchers have identified and evaluated delays in different countries and different types of projects. Some researchers have also elaborated use of several techniques for the analysis of delays and also suggested different strategies to overcome them. The issues of time, cost, quality, safety, disputes & claims have been faced by not only developing but also developed countries throughout the world. Thus, not having control on project control metrics is a worldwide problem. These issues have negative effect on economic growth and development. There is need to control the performance of project in terms of time, cost, quality, safety, disputes and claims together by developing different techniques.

The major purpose of controlling a construction project is to make sure that project is completed within budget, time and other predefined objectives. Project managers measure the progress of ongoing projects, evaluate them and take remedial actions where required [3]. A construction project may be successful if its performance in terms of quality, cost and time is measured. Not only cost but time also serves as a warning for accomplishment of project. Poor performance of construction projects in terms of cost, quality and time is major issue not only in developed but also in developing countries including Pakistan, Portugal, Malaysia, UK and USA [4]. Making

different measurements and then comparing them with the expected or desired values as project goes on is project performance monitoring [5]. The point at which the difference between actual and planned is great, a control act is required in order to bring the project's actual performance close to the planned performance. The project manager should monitor the progress of the project and compare that progress to highlight the differences. Restriction to data related to cost limits the measurements in number. Various methods are conventionally utilized in construction for monitoring and reporting the project's progress. Some of the methods are dependent upon work types while other rely on activities related information. Despite the fact that all of the methods are used for performance measurement of project, economically or on aspects, performance interpretation of work vary in each method. Therefore, it is anticipated that some of these methods make measurements which may require control action whereas some other methods may fail in doing so [5]. Formerly, various methods of controlling projects have been developed including Gantt Bar Chart, Critical Path Method (CPM), Program Evaluation and Review Technique (PERT) [3]. Different software tools have been developed that incorporate these methods of controlling projects like Microsoft Project, Primavera, Asta Power Project, etc. [3].

2.1 Techniques for Controlling Projects

Traditionally, project control cycle consists of three steps [5]:

- Measuring the current state of project.
- Making comparison of the measurements with desired or planned values.
- Taking corrective measures in order to bring the project to expected state and to minimize the losses.

To a great extent, performance measurement measure the utilization of resources as per planned. The measurement of performance give prediction where the control action should be taken in a current or future project. It is useless to spend time, money and effort in performance measurements if no corrective action is taken on results. If control action is taken then it is assured that the work is performed as planned by using the optimized resources [6]. There are various techniques for measuring performance. Some of them are given below:

Curve Fitting: This technique is used for planning and controlling project's financial performance. Like Earned Value Management (EVM), it not only provides estimate of project's completion but also predicts that cash inflows and cash outflows throughout the project's entire life. It also gives information about the shortages of cash also about their sizes [7].

Statistical Control Charts: This technique was introduced by Shewhart [8]. It was initially used in manufacturing operations in order to safeguard quality. Now, it is also used to control the performance of projects. Its major purpose is to give promptly warning signs whenever progress of the project is moving towards danger. There are lower and upper control limits and a central line in a control chart. If all the data which plotted remains within control limits and none of it is outside, then the process if said be in controlled state. The patterns of the control charts give information regarding the state in which the process is. When plotted data gets out of the control limits or has a tendency to get out, it is not a process which is under control. This means that there are some variations which should be identified for improvement of efficiency. Distinct control charts have been utilized for monitoring performance variation in order to detect the hostile variations timely. Such control charts not only highlight progress of project in terms of budget and schedule but also determine the requirement of corrective action [9].

Statistical Process Control: Statistics has a branch for controlling and monitoring processes which is names as Statistical Process Control (SPC). Variation in performance through life cycle of project can be detected by applying SPC and also those factors can be identified which have effect on the project's performance There are many tools for controlling project's performance but SPC is considered to be most operational [10].

Leading Parameter: It is a technique which is based on the concept that out of majors work types, one or two types are chosen and they are used for measuring the performance of the entire project. For instance, if a project involves huge part of concrete work, then at any time the quantity of concrete poured is used for measuring the performance of remaining work. The project's total cost as well cost of each leading parameter are compared with their planned values at the same time. This type of technique is used for those projects where there are a number of sections and each section contains different types of work. In such a situation, each section may be treated with a different performance measurement parameter. It is

an effective technique for controlling project's cost but a major issue with it is that there are many important work types in projects and the single parameter which is selected for measuring performance may have a variation with time [5].

Activity Based Ratios: This is a technique which control finances of a project. For measuring performance of project, it makes use of a ration between earnings and expenses of different activities of project. This technique can be utilized for measuring performance of individual activities as well as of the project as a whole. Equations (1-3) are the ratios by which this technique calculated performance:

$$\text{Planned Performance} = \frac{\text{Planned Earning}}{\text{Planned Expenditure}} \quad (1)$$

$$\text{Actual Performance} = \frac{\text{Actual Earning}}{\text{Actual Expenditure}} \quad (2)$$

$$\text{Efficiency} = \frac{\text{Actual Performance}}{\text{Planned Performance}} \quad (3)$$

The calculation of all the three ratios may be done at any stage of the project of which we have an available plan. Same charges for expenditure and same charges for earnings are used for evaluation of the both actual and the planned work. If for instance, the earning rates are taken from initial estimate, then the planned and actual performance calculates the performance for that initial estimate and efficiency calculates the project's performance for the plan. According to theory, all of the calculated valued should be unity as optimistically planning is sensible, however, it is advised to target the efficiency and planned performance of 1.05. These calculations can be done for section of project or whole project and hence can also measure individual subcontractor's contributions in a project [5].

Cost Per Unit Earning: This technique relies on creating a solo performance measure and so called as cost per unit earning, developed by Al-Jibouri [11]. Just like activity based ratio technique, this technique also evaluated the planned and actual situation. In the whole project, each unit of earning is considered and hence the statistical interpretation is way too rigorous as compared to other methods. Moreover, the forecasting practices are used to make prediction of future with much more precision than expected from any other method [6].

Earned Value Management: A project management method known as EVM was introduced in 1966 by United States, Defense Secretary. This method enable the project managers to have control on budget and schedule of project during its execution [12]. Project's success is much dependent upon the cost of project and EVA can serve as an effective control tool for both monitoring and controlling project's cost. The dependability of EVA is on two key zones i.e. project's progress in pragmatic manner and accurate information of cost. Efficiency of these two zones allows the project's progress to be valued. The project's performance is indicated by EVA and hence the requirement of corrective action is considered [13]. According to Subarmani [13], time-phased budgeting can be related to specific contract task with assistance of EVA. EVA is a technique which works by comparing earned value with actual cost and with the planned value. This comparison gives us information about the amount of work performed and the remaining work to be performed for project's completion. Project Management Body of Knowledge (PMBOK) has given much importance to project's monitoring and control by using EVMs [12].

Rozenes et. al. [14] has made a modification in EVA and has also developed multi-dimensional control tool. The goal of his tool was to monitor Work-Breakdown Structure (WBS) of a project at work package level. Decision Support Systems have been formerly developed that combine and analyze data and provide analytical models that play role in selecting alternatives [15].

Data Envelopment Analysis (DEA) has been combined with EVA [16], which is used for efficiency evaluation of Diesel Multiple Units (DMUs) mathematically. Modelling of each project was done as DMU and then for evaluating efficiency, weighted summation of outputs was divided by weighted summation of inputs. It was used for evaluating engineering projects performance.

Many project managers have given importance to graphical visualization of various EVA parameter before they take decisions of project control. In order to describe the variation of planned and actual values and the requirement of corrective measure, graphical tools can serve the purpose. That's why Hazir and Shtub [17] has paid attention to tabular as well as graphical presentation of EVA.

2.2 Construction Projects Performance Indicators

In order to determine construction projects' performance over a number of activities, applicable Key Performance Indicators (KPIs) are mandatory for enabling the stakeholders to monitor the progress of the project towards goals achievement. The identification of KPIs assist the decision makers of making decision according to project's

performance level. At most of the times, cost and schedule variance at a particular point of the projects are determined by comparing current values with the planned values and also forecast the future cost and time. KPIs are benchmark for measuring the services, practices and products continuously. The KPIs adopted for the construction industry for various projects include time, scope, cost, safety and quality. Construction project's KPIs are satisfaction of owner on work's quality (scope), mutual trust b/w stakeholders, cost not more than target of contract, time performance and quantum of conflicts and disputes [18]. A study conducted on Tanzania's road work conclude that KPIs for road construction include time, quality (scope) and cost. For construction project, work packages' progress if measured in term of budget, time and quality and other performance measure depend upon data and inform that whether the activities or project is attaining its target.

It can be concluded from the literature review that there are various issues in construction projects like budget and schedule overruns, safety and quality issues, disputes in claims that have been highlighted by researchers. There are various project management techniques to control the attributes of project's performance. Most of the techniques deal with time and cost but not with other attributes (safety, quality, disputes, and claims) that indirectly effect time and cost of project. EVA deals with budget and schedule and have some deficiencies. Some researchers have done modification in EVA for achieving better results. KPIs for project performance have been developed. Most of the common Project Management software plan and schedule the project but do not provide warnings for corrective actions. So, there is a need to develop a multi-dimensional project performance control tool that controls time and cost by incorporating other dimensions that have effect on time and cost.

3. Methods

The analysis carried out for this research is based upon the development of project performance control tool using combined indicators of time, cost, quality, safety, disputes and claims and then making test run of the control tool on three Mega construction projects. The research methodology shows sequences of different tasks performed in order to achieve the predefined primary and secondary objectives. The research has been divided into different phases. Fig. 1, below shows the graphical methodology of this research.

3.1 Documentation of Indicators

Only two performance measurements of planning and controlling of project, cost and time are taken into consideration in EVA [15]. But there are some performance measures like safety, quality, disputes and claims that may also be critical. In order to extend the EVM's restricted focus, a multi-dimensional control tool was proposed by identifying the indicators for controlling performance of projects on the basis of extensive literature study. Following are the indicators shown in APPENDIX A after comprehensive study.

3.2 Questionnaire for Gap Analysis

Questionnaire is a tool of research that comprises of a number of questions for collection of information from the desired respondents. Questionnaire is a quicker way of collecting data. After the literature review, questionnaire was designed in such a way to assess the current situation of performance of construction projects, the performance indicators commonly used by the project managers, to analyse the gap that why projects are not completing as planned and the need to develop the control tool. The questionnaire comprised of different sections. Section I comprised of respondent's data, section II comprised of statements for collecting data which were further divided into different parts like cost, time, quality, safety, disputes & claims. (APPENDIX B).

From the questionnaire, the gap analysis shows that the majority of the respondents used primavera and Microsoft Projects as control tools and they lack the feature of handling safety, quality, disputes and claims which have strong influence on project's time & cost. The people working in field are not satisfied with their market project control tool as their performance goals were not met in their previous projects. They show low level of satisfaction in their quality and safety management systems. A part of project' budget has been spent on dealing with disputes and claims in their projects. All the issues of safety, quality, disputes and claims have influence on project's budget and time. Hence, it is essential to consider other factors that affect project's planned time & cost while dealing with budget and schedule of project. The professional feel that provision of quality, safety, disputes and claims in control tool is highly important and hence a control tool should be developed by incorporating the five dimensions of time, cost, safety, quality, disputes and claims. (APPENDIX C).

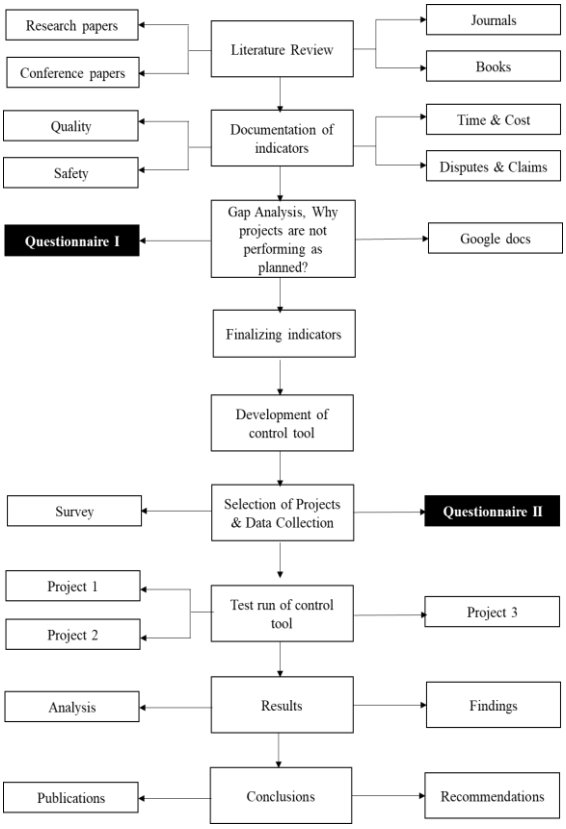

Fig. 1: Research Methodology

3.3 Development of Multi-Dimensional Control Tool

EVM is a methodology to monitor and control projects and is worldwide used technique. As a general theme, this technique is used in control tool but modifications are done in EVM as it only deals with time and cost directly.

The mechanism for multi-dimensional control tool is devised and graphical performance of indicators for time, cost and secondary attributes (quality, safety, disputes and claims) that affect time and cost is developed. Speedometer charts and gauge charts in addition to conditional formatting of excel are mainly used for making graphical indicators in control tool development. This multi-dimensional control tool is mechanized in such a way that a project control system works to give early warnings by indicating the project's status and making a comparison of the status with the planned values and then analyzing variations. The system of the control tool consists of different preliminary warning mechanisms and user-friendly interfaces.

Steps Involved in Development of Control Tool: The control tool is developed on Microsoft Excel 2013. Following are the steps undertaken to develop control tool.

- Details of performance measuring indicators.
- Project Control Panel using EVA and modification in it.
- Development of indicators.
- Scorecard.
- Project Dashboard

Project Control Panel: Project control panel is then created using EVA and more indicators of quality, safety, disputes and claims were added in it. Table1 gives glimpse of project control panel.

Development of Indicators: Separate sheets for individual indicators are created using speedometer/gauge charts, glass charts and conditional formatting. Poor, Average, Good and Great performance results are indicated by the needle on the chart. If the value in the input sheet of EVA is changed the position of the pointer in the chart is also changed. Fig. 2(a-c) give glimpse of the multi-dimensional control tool.

Scorecard: The scorecard was created in which the score of each indicator is calculated based upon its weightage and the value in the control panel. The scorecard is linked with project control panel. The scorecard created in this tool sums up the performance indicated by all the KPIs. All the indicators used in the control tool have been tied to one scorecard which indicates the overall

Table 1: Project Control Panel Using EVA

Reporting Period Date		Budget at Completion	Planned Value (Budgeted Cost of Work Scheduled)		Earned Value (Budgeted Cost of Work Performed)		Actual Cost (Actual Cost of Work Performed)	
Reporting Period No.	Period End Date		Monthly Planned Value	Cumulative Planned Value	Monthly Earned Value	Cumulative Earned Value	Monthly Actual Cost	Cumulative Actual Cost

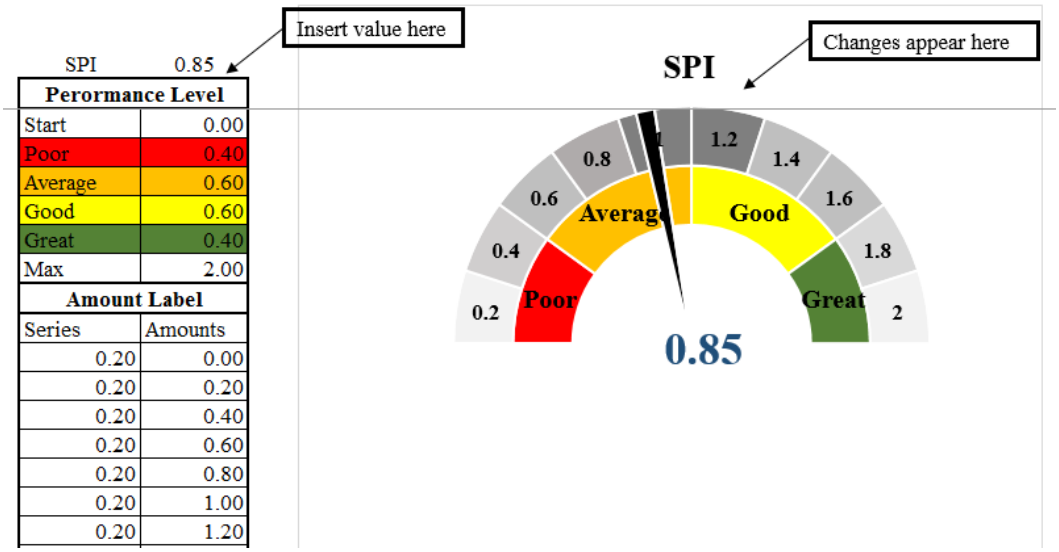

Fig. 2 (a): Spi indicator of control tool

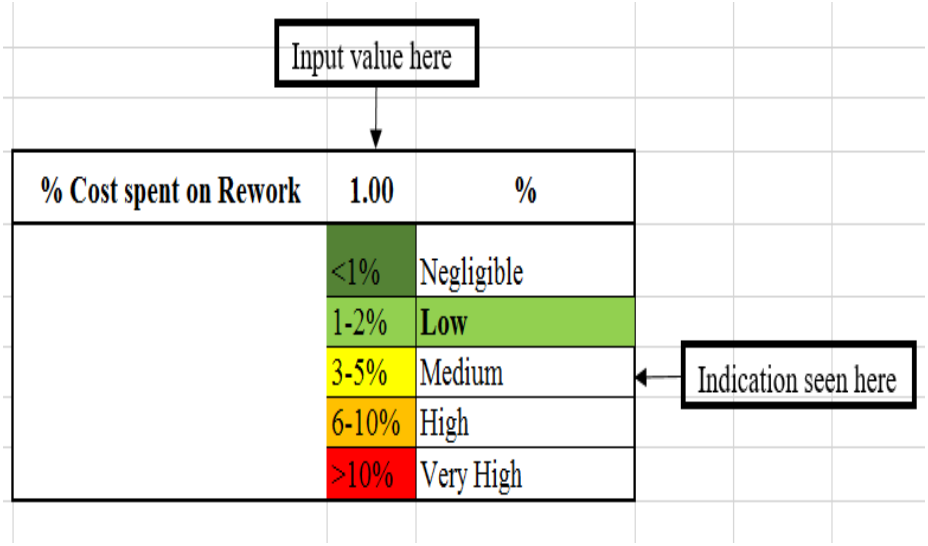

Fig. 2 (b): Rework indicator of control tool

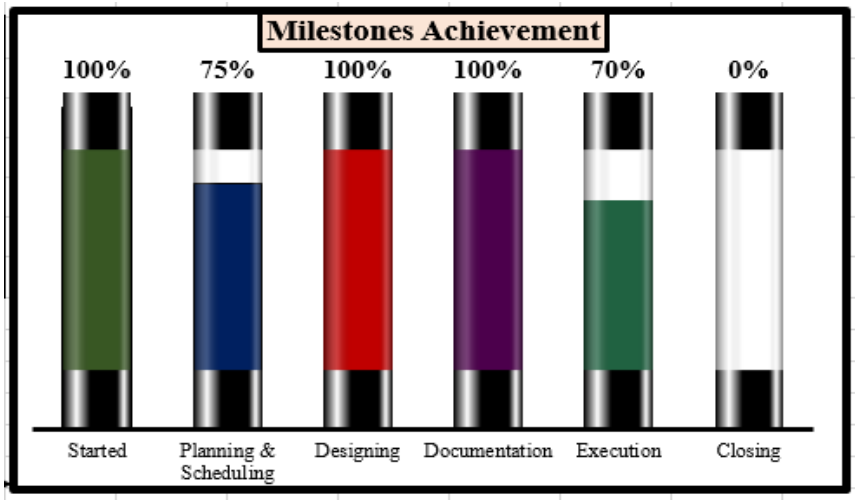

Fig. 2 (c). Milestones Achievement in control tool

performance of the project in terms of a score which is the summation of scores of individual indicators. Table 2 shows a sample scorecard. In the column "Value of Indicator", value comes from the control panel sheet and the score is calculated based upon the weightage in "Score" column.

Table 2: Project Scorecard

No	Indicator	Value from Indicator Sheet		Calculated Score
		Value of Indicator	Total Weight-age	
1	SPI	00.85	10	5
2	SV%	40.00	10	5
3	CPI	00.85	10	5
4	CV%	40.00	10	5
5	Critical Ratio	00.85	5	3
6	Rework Factor	00.50	5	5
7	Percentage of total cost spent on rework	01.00	5	5
8	Percentage Perform-ance to Contract Specifically	50.00	5	3
9	Accident Rate	0.00	5	5
10	Impact of accident on life	01.00	5	5
11	Impact of accident on cost	06.00	5	1
12	Number of lost time incidents	02.00	5	4
13	Number of disputes	03.00	5	4
14	Percentage of total cost spent on disputes	05.00	5	2
15	Number of claims	05.00	5	4
16	Percentage of total cost spent on claims	02.00	5	4
Results			**100**	**65**

From scorecard, indicator for project score has been created to indicate the overall performance of project based upon project's score. Fig. 3 shows the indicator of overall performance of project according to the project score. The value from scorecard becomes input of this indicator and then using if statement performance level appears and output can be seen in the chart.

Project Dashboard: Project dashboard has been created and linked with the input sheets. The output of all the input data appears in this dashboard Fig. 4(a-c).

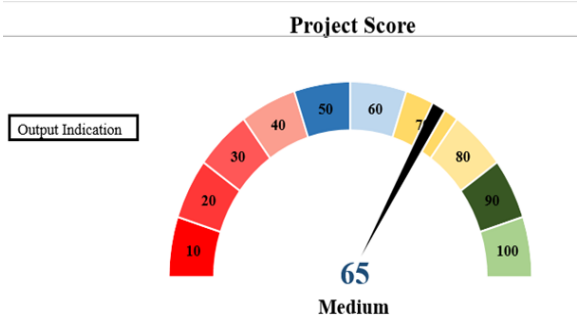

Fig. 3: Project score as indicator in control tool

Data collection for implementation in control tool: Test run of control tool was done by obtaining data of three Mega Construction Projects which include Pakistan Kidney and Liver Institute (PKLI), Punjab Agriculture, Food and Drug Authority (PAFDA) and Orient Square Hotel (OSH). Data was collected through planned and actual schedules of the projects from the companies and Earn Value Analysis was performed on it to obtain value of Indictors of time and cost given in Project Control Panel, glimpse of which is in Table 2.

Remaining data was collected by project managers and planning engineers of the three projects through a test run questionnaire shown in APPENDIX D**.**

Pakistan Kidney and Liver Institute – PKLI

PKLI is project of Public-Private Partnership (PPP) and Punjab Government has given land of 60 acres. The project was planned to be completed 100% till February, 2020 but it is 80% completed till February 2020. The data of the project was obtained from ZKB-RES (JV) and its analysis was done.

Punjab Agriculture, Food & Drug Authority– PAFDA

Punjab government has given land of 64 Kanals for the development of a complex of PAFDA. The project is being executed by IDAP

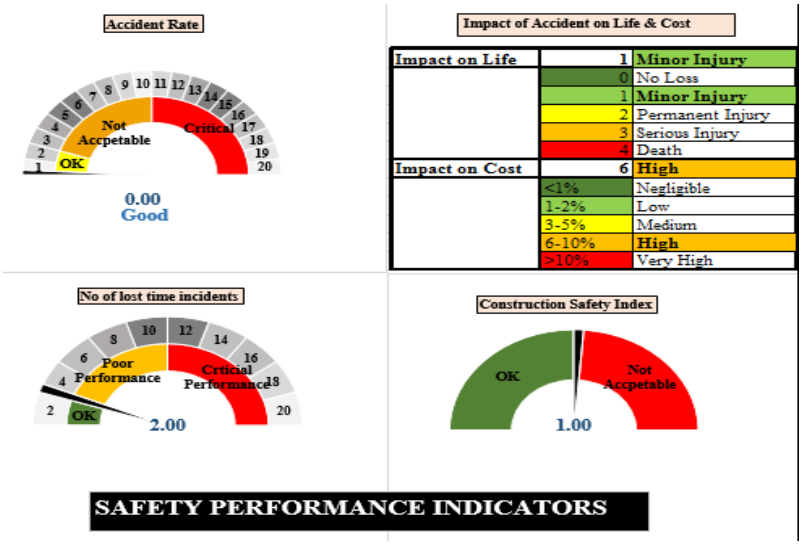

Fig. 4(a): Project Dashboard

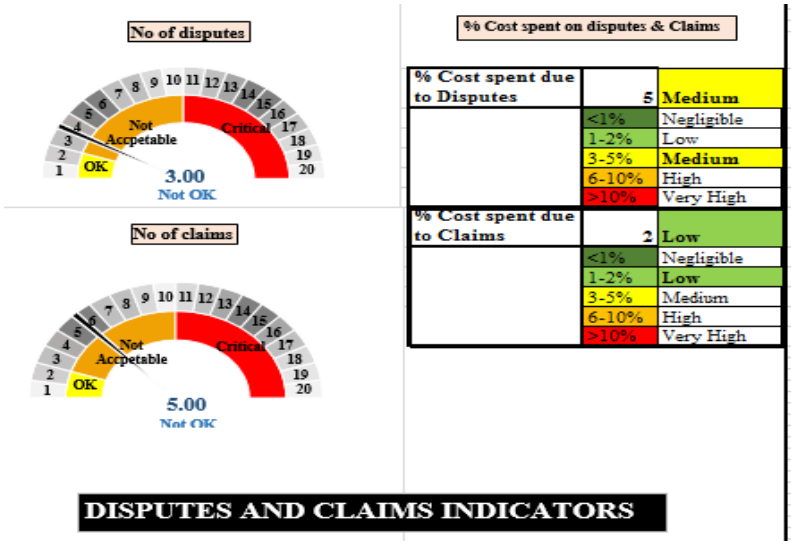

Fig. 4(b): Project dashboard

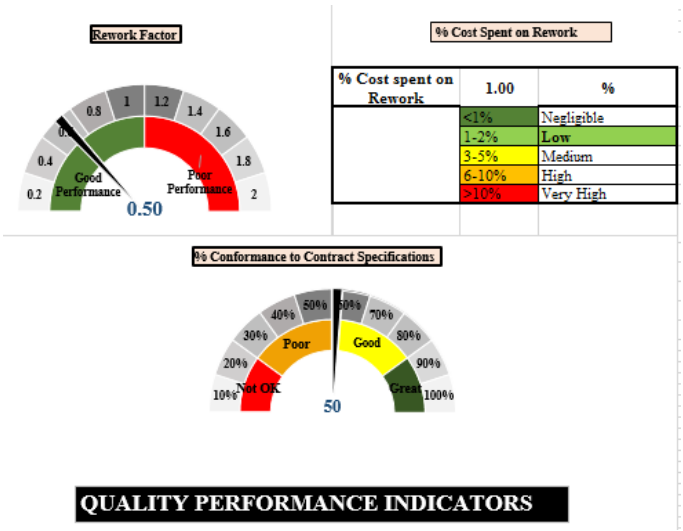

Fig. 4(c): Project dashboard

near Thokar Niaz Baig. The project was started on 5th December, 2017 and it was planned to be completed till 4th March, 2019 but till February, 2020, the project is completed only 38.79% and is expected to completed till 30th June, 2020. There is a delay of 62% in this project.

Orient Square Hotel - OSH

Orient square hotel is a 500 feet high rise building which is being constructed on land of 44 kanals. The project has been started in January, 2020 and is 20% completed till date.

4. Results

Following are the results obtained by implementation of data for three construction projects.

Schedule Performance Index: In PKLI SPI is 0.35 which is below 1 i.e. <1 and project is behind schedule In PAFDA SPI is 0.38 which is relatively poor and depicts that project is behind schedule. In OSH SPI is 0.93 i.e. <1 which is good and nearer to the target.

Schedule Variance: In PKLI SV% is -65% which is not acceptable i.e. behind schedule. In PAFDA SV% is -62% which is really not acceptable, project is behind schedule. In OSH, SV% is -7% which is behind schedule and is acceptable.

Cost Performance Index: In PKLI CPI is 0.56 which is average i.e. <1 and project is over budget. In PAFDA, CPI is 0.67 which is <1 i.e. average depicting that project is over budget. In OSH, CPI is 0.54 i.e. <1 and is average.

Cost Variance: In PKLI CV% is -79% which is not acceptable at all. In PAFDA CV% is -50% which is not good and project is over budgeted. In OSH, CV% is -5% which is average and project is over budgeted.

Difference between Planned and Actual Schedule Percentage: In PKLI the difference between planned schedule % and actual schedule % is 20% which is acceptable, in PAFDA it is 61% which is not acceptable and in OSH it is 7% and is acceptable

Critical Ratio: In PKLI critical ratio of project is 0.03.i.e. <1 and it is poor, in PAFDA it is 0.25 which is poor and in OSH it is 0.88 i.e. close to 1 and is average.

Status: In PKLI status is 0.14 i.e. <<1 and project performance is poor, in PAFDA it is 0.52 i.e. project performance is average and in OSH it is 0.94 i.e. near to 1 and is good.

To Complete Performance Index: In PKLI, TCPI is 0.18 i.e. <<1, in PAFDA it is <1 which means performance can needed to be increase to remain within budget and in OSH it is 1 i.e. =1 which means performance is maintained.

Rework Factor: In PKLI rework factor is 0 i.e. good, in PAFDA it is 1.08 i.e. >1 and is poor and in OSH it is 0 i.e. <1 and is good.

In PKLI % of total cost spent on rework is <1% i.e. negligible, in PAFDA it is >10% i.e. very high and in OSH it is 0 which is <1% i.e. negligible.

Percentage Conformance to Contract Specifications: In PKLI % conformance to contract specifications is 100%i.e. great, in PAFDA it is 50% which is not good and in OSH it is 85 which is great.

Accident Rate: In PKLI accident rate is 0.000000020 i.e. ok, in PAFDA it is 1 i.e. ok and in OSH it is 0.000000021 which is ok.

In PKLI ipact of accident on life is “No loss” i.e. good, in PAFDA it is “minor injury i.e. acceptable and in OSH is 0 i.e. no loss.

Impact of Accident on Cost: In PKLI impact of accident on cost is 1-2% i.e. Low, in PAFDA it is 3-5% i.e. Medium and in OSH it is 1-2% i.e. low.

Number of Lost Time Incidents: In PKLI and PAFDA no. of lost time incidents are 0 i.e. good and in OSH it is 1 i.e. ok.

Number of Disputes: In PKLI, no. of disputes is 5 i.e. not acceptable, in PAFDA and OSH it is 0 i.e. good.

Total Cost Spent on Disputes: In PKLI, % of total cost spent on disputes is <1% i.e. negligible, in PAFDA and OSH it is 0 i.e. good.

Number of Claims: In PKLI, no of claims are 16 i.e. critical, in PAFDA they are 2 i.e. ok. In OSH it is 0 i.e. good.

Cost Spent on Claims: In PKLI, % of total cost spent on claims is <1% i.e. negligible, in PAFDA it is 1-2% i.e. low and in OSH it is 0 i.e. <1% and is negligible.

Milestones Achievement: PKLI has 100% achieved milestones of start, planning and scheduling, designing and documentation, 80% execution and 25% closing. PAFDA has 100% achieved milestones of start, planning and scheduling and designing, documentation is 70%, 39% execution and 0% closing. OSH has 100% achieved milestones of start, planning and scheduling, designing 90%, documentation is 80%, 20% execution and 0% closing.

Percentage Work Done vs. Cost Spent: In PKLI % work done is 80% and % cost spent is 82%. In PAFDA work done is 39% and % cost spent is 46%. In OSH work done is 20% and % cost spent is 23%.

Score: Score of PKLI is 59/100 i.e. Average performance. Score of PAFDA is 56/100 i.e. Average performance. Score of OSH is 94/100 i.e. Excellent performance.

The control tool has clearly indicated performance of projects with the help of gauge charts, conditional formatting and glass charts. The indicators visually described the performance. According to SPI, CPI, SV%, CV%, OSH is better project. According to quality and safety indicators, PAFDA shows poor performance out of all projects. According to disputes and claims indicators, PKLI shows poor performance out of all projects. PKLI is 80% complete and has average performance, PAFDA is 39% complete and has average performance whereas OSH is 20% complete and has excellent performance. It has been forecasted that OSH will perform better in near future until unless not controlled properly.

For effective working of control, the data should be input in control panel of the tool on weekly basis so that a clear picture of the project can be seen timely and corrective actions if required might be taken. The construction companies currently focus on indicators dealing with controlling project's time and cost. They neglect indicators dealing with project's quality, safety, disputes & claims. As construction companies are already using Primavera P6 for scheduling projects time and budget and then performing EVMs on excel sheet, They can utilize this control tool formulated on excel and can effectively manage 5 dimensions of projects i.e. time, cost, quality, safety and disputes timely as this tool gives early indication of performance if updated timely. If data is not updated timely, this tool cannot give indication of the corrective action required earlier than the date of inputting data.

Every construction company is used to of its own system of controlling project's performance. So, people are reluctant to change their methods.

5. Conclusions

(i) The gap analysis from questionnaire I concludes that the majority of the respondents used primavera and Microsoft Projects as control tools and these control tools lack the feature of handling safety, quality, disputes and claims which have strong influence on project's time & cost. The professionals working in field are not satisfied with their market project control tools as their performance goals were not met in their previous projects. They show low level of satisfaction in their quality and safety management systems. A part of project' budget has been spent on dealing with disputes and claims in their projects. The professionals feel that provision of quality, safety, disputes and claims in control tool is highly important and hence a control tool was developed by incorporating the five dimensions of time, cost, safety, quality, disputes and claims. The project control software used in construction field so far deal with time and cost together and other metrics of quality, safety, claims and disputes separately. The project control tools developed by this research enables the project managers to effectively control time, cost, quality, safety, claims & disputes by undertaking corrective actions at the hour of need.

(ii) Innovative and sensitive indicators for project performance measurement and control have been successfully identified and developed. Gauge charts, speedometer charts, glass charts and conditional formatting have been efficiently used in developing innovative and sensitive indicators for project performance measurement and control. Different project management software like Primavera P6 and Microsoft project represent the data in different formats but don't provide alerts for corrective actions. This control tool provides alerts for tackling the project on time.

(iii) A multi-dimensional control tool has been successfully developed for controlling time and budget of MCPs by incorporating the auxiliary factors (safety, quality, disputes and claims) into EVA that indirectly effect project's budget and schedule. Thus, EVA can be made readily functional by making adjustment in it. It is essential that there should be availability of EVM metrics at all levels in the project so that EVM can have strong influence in making project's decisions. The tool has been implemented on three mega projects and hence it can provide real-time project control.

(iv) The scorecard created in this tool sums up the performance indicated by all the KPIs. All the indicators used in the control tool have been tied to one scorecard which indicates the overall performance of the

project in terms of a score which is the summation of scores of individual indicators. All the indicators show score based on the weightage assigned to them and the final score if the sum of those individual scores. According to scorecard, OSH shows excellent performance.

(v) The control tool has been shared with the professionals in the market and it has fulfilled the expectations of project management.

(vi) The control tool has clearly indicated performance of projects with the help of gauge charts, conditional formatting and glass charts. The indicators visually described the performance. According to SPI, CPI, SV%, CV%, OSH is better project. According to quality and safety indicators, PAFDA shows poor performance out of all projects. According to disputes and claims indicators, PKLI shows poor performance out of all projects. PKLI is 80% complete and has average performance, PAFDA is 39% complete and has average performance whereas OSH is 20% complete and has excellent performance. It has been forecasted that OSH will perform better in near future until unless not controlled properly.

6. Recommendations

This research can be further extended for better controlling of construction projects. Following are the recommendations of this research which may enable the researches to take steps for development in the field of project monitoring and control.

(i) The control tool developed in this research is in spreadsheet format, it can be further converted into software and mobile app for the ease of project managers.

(ii) This control tool can be used in complex projects and extended research can be done in order to increase effectiveness of tool

(iii) Indicators of change orders, profitability and uncertainties and risk management may also be further developed to control project change orders, manage company's profit and uncertainties.

(iv) This control tool can be further made add-in of various project management software like primavera P6, Navisworks, Revit and can become part of Building Information Modeling (BIM).

7. Limitation

The control tool can work effectively if the project managers keep on updating the data in control panel periodically after certain time period. This project control tool cannot be effective if data is input after a long gap as then it cannot give clear indication of performance at a certain moment in project and will not warn about immediate corrective actions to be taken at that time.

8. Acknowledgment

Authors acknowledge the Department of Architectural Engineering and Design, University of Engineering and Technology, Lahore, Pakistan.

9. References

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APPENDIX A

PROJECT PERFORMANCE MEASURING INDICATORS				
Sr #	**Indicator**	**Abbreviation**	**Description**	**Formula/Value**
1	**Budget at Completion**	BAC	Baseline cost for 100% of project.	
2	**Planned Value**	PV	The budget for the physical work scheduled to be completed by the end of the time period.	
3	**Earned Value**	EV	Amount of budget earned so far based on physical work accomplished, without reference to actual costs.	
4	**Actual Cost**	AC	Total costs actually incurred so far.	
5	**Cost Variance**	CV	Measure of cost overrun. The difference between the budget for the work actually done so far and the actual costs so far.	Earned Value–Actual Cost EV–AC
6	**Cost Performance Index**	CPI	Cost efficiency ratio. A CPI of 1.0 means that the costs so far are exactly the same as the budget for work actually done so far.	Earned Value/Actual Cost EV/AC
7	**Schedule Variance**	SV	Measure of schedule slippage. The difference between the budget for the work actually done so far and the budgeted cost of work scheduled.	Earned Value–Planned Value EV–PV
8	**Schedule Performance Index**	SPI	The schedule efficiency ratio. An SPI of 1.0 means that the project is exactly on schedule.	Earned Value/Planned Value EV/PV
9	**Estimate to Completion**	ETC	The expected additional cost to complete the project.	Estimate at Completion–Actual Cost EAC–AC
10	**Estimate at Completion**	EAC	Expected total cost based on the current cost efficiency ratio.	Budget at Completion/Cost Performance Index BAC/CPI
11	**Variance at Completion**	VAC	How much over budget will we be at the end of the project?	Budget at Completion-Estimate at Completion BAC-EAC
12	**Critical Ratio**	CR	This indicator combines both the cost performance index (CPI) and schedule performance index (SPI) to represent the project status.	Schedule Performance Index x Cost Performance Index SPI*CPI
13	**Status**		Average of CPI & SPI	(Cost Performance Index + Schedule Performance Index)/2 (CPI+SPI)/2
14	**To Complete Performance Index**	TCPI	It computes the future required cost efficiency needed to achieve a target Estimate at Completion (EAC).	(BAC– EV) / (BAC– AC)
15	**% of funds Utilization**		Actual amount of cost spent	AC/BAC

16	**Rework Factor**	RF	Expenses on field rework	Total direct cost of field rework/Actual Construction Phase Cost
17	**% of total cost spent on rework**		It is % of total cost which is spent on rework.	
18	**% conformance to contract specification**		It is the extent of work conforming to contract specifications.	
19	**Fatal Accidents Frequency Rate**	FAFR	It is a number of fatalities per 100 million man-hours worked	Incidents/1000 employees/year
20	**Safety Performance Index**	SFI	It is a measure of how safe the site activities are carried out without lost time incidents.	Number of Lost Time Incidents to date x 200,000/Total man-hours expended to date LTI*C/M
21	**Impact of accident on cost**			<1% = Negligible, 1-2% = Low, 3-5% = Medium, 6-10% = High, >10% = Very high
22	**Impact of accident on Life**			0 = No Loss, 1 = Minor injury, 2 = Permanent Injury, 3 = Serious Injury, 4 = Death
23	**No of lost time incidents**		It is number of injuries per 100 workers	
24	**No of claims**		Number of claims encountered in project	
25	**No of disputes**		Number of disputes encountered in project	
26	**% Cost spent due to claims**		Amount of budget spent so far on dealing with claims.	<1% = Negligible, 1-2% = Low, 3-5% = Medium, 6-10% = High, >10% = Very high
27	**% Cost spent due to disputes**		Amount of budget spent so far on dealing with disputes.	<1% = Negligible, 1-2% = Low, 3-5% = Medium, 6-10% = High, >10% = Very high
28	**Project Score**		Project score is the sum up of score of all indicators out of 100. Greater this score, better the project is.	Weightage given on basis of expert opinion and literature review and then score calculated accordingly.

APPENDIX B

CONSTRUCTION PROJECT PERFORMANCE CONTROL QUESTIONNAIRE

PURPOSE OF QUESTIONNAIRE: A project is said to be successful if it is safely completed within the planned time, budget and quality without any legal disputes or claims. This research will assess the indicators and devise mechanism to control performance of project in terms of time, cost and other parameters by formulizing a control tool. The purpose of this questionnaire is to find tentative features & characteristics of the control tool to be devised after this questionnaire survey. Your response is highly important and will be kept confidential.

Respondents Data

Name			**Email ID:**	
Company Name			**Cell No: (opt)**	
Designation	**a**. Asst. Engr.	**b**. Asst. Director	**c.** SDO	**d**. Deputy Manager
	e. Deputy Director	**f.** Manager	**g.** XEN	**h.** Director
	i. Construction Manager	**j.** Project Manager	**k.** Chief Engr.	**l.** Contracts Manager
	m. Site incharge	**n**. Superintendent Engr.	**o**. HSE	**p**. Other
Gender	**a.** Male	**b**. Female		
Experience (years)	**a.**1-3	**b**. 3-5	**c.** 5-10	**d.**>10
Size of Projects	**a.** Small	**b**. Medium	**c.** Large	**d.** Mega
Project Management Experience	**a.** Yes	**b.** No		

Note: Please, provide the required data and encircle the correct option to indicate the weightage.

1 Very Low **2** Low **3** Medium **4** High **5** Very High

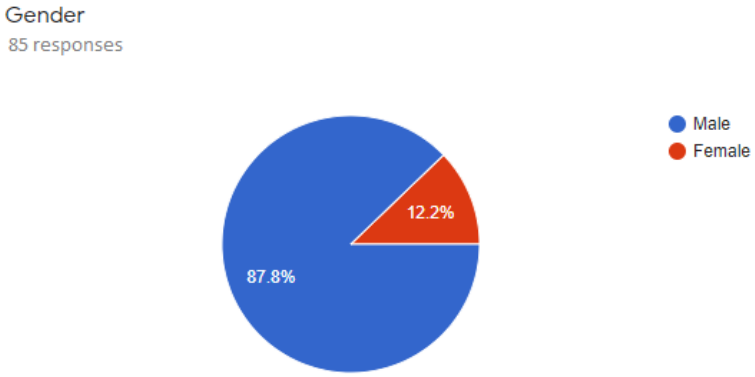
Q#	Questions	Weightage				
Q1-	Which Project Control Tool you used for controlling performance of your previous projects? **a.** Primavera P6 **b.** Microsoft Project **c.** Pertmaster **d.** SAP **e.** Tailor made/Customized tool (MIS) **f.** Other					
Q2-	Effectiveness of your software to meet schedule & cost baseline goals, targets, or expectations in your previous projects.	**1**	**2**	**3**	**4**	**5**
Q3-	Satisfaction of user-friendly behavior of your project control tool/software.	**1**	**2**	**3**	**4**	**5**
Q4-	Which of the following Indicators you used to control project schedule/Cost? **a**. Cost/Schedule Variances **b**. Cost/Schedule performance Indices **c.** Budget at completion **d**. Earned Schedule **e**. Estimate at Completion **f.** Estimate to Complete **g.** Variance at completion **h.**To complete performance Index **i.** Critical Ratio **j.** Rework factor					

Q5-	Satisfaction of using the indicators in controlling project.	**1**	**2**	**3**	**4**	**5**
Q6-	How many of your previous projects were completed on time and within cost? **a.** Nill **b**. 1-2 **c.** 2-5 **d.**>5					
Q7-	Effectiveness of your control tool to meet quality objectives in your previous projects.	**1**	**2**	**3**	**4**	**5**
Q8-	Provision of quality indicators in the project control tool/software is important.	**1**	**2**	**3**	**4**	**5**
Q9-	Variation experienced in quality of work in your previous projects.	**1**	**2**	**3**	**4**	**5**
Q10-	% increase in cost due to rework in your previous projects. **a.** <1% **b.** 1-5% **c.** 5-10% **d.** 10-20% **e.** >20%					
Q11-	How do you monitor quality of your project? **a.** Inspection & testing **b.** Quality control and assessment system **c.** Statistical techniques **d.** Customized software/MIS					
Q12-	Seriousness of your organization on safety and health on project sites.	**1**	**2**	**3**	**4**	**5**
Q13-	Satisfaction of hygienic conditions on site.	**1**	**2**	**3**	**4**	**5**
Q14-	Satisfaction of safety management system of your previous projects.	**1**	**2**	**3**	**4**	**5**
Q15-	No. of accidents reported on your previous projects. **a.** No accident **b.** 1-5 **c.** 5-10 **d.** 10-15 **e.** >15					
Q16-	How much percentage of budget was spent on safety in your previous projects? **a.** <1% **b.** 1-2% **c.** 2-5% **d.** 5-10% **e.** >15%					
Q17-	Provision of safety indicators in the project control tool/software is important.	**1**	**2**	**3**	**4**	**5**
Q18-	How many claims were encountered in your previous projects? **a.** Nill **b.** 1-5 **c.** 5-15 **d.** 15-30 **e.** >30					
Q19-	How many claims were successful in your previous projects? **a.** Nill **b.** 1-5 **c.** 5-15 **d.** 15-30 **e.** >30					
Q20-	How many disputes were encountered in your previous projects? **a.** Nill **b.** 1-5 **c.** 5-15 **d.** 15-30 **e.** >30					
Q21-	How many disputes were resolved in your previous projects? **a.** Nill **b.** 1-5 **c.** 5-15 **d.** 15-30 **e.** >30					
Q22-	Provision of disputes management in the project control tool/software is important.	**1**	**2**	**3**	**4**	**5**
Q23-	Provision of claims management in the project control tool/software is important.	**1**	**2**	**3**	**4**	**5**
Q24-	Majority of performance goals of previous projects met.	**1**	**2**	**3**	**4**	**5**

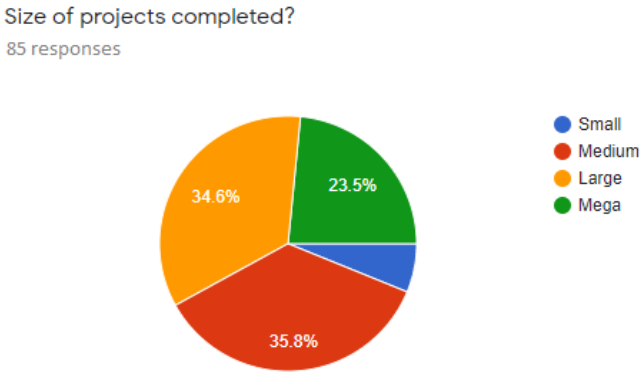
Q25-	Do you think is there any need to develop a customized project control tool/application that incorporates time, cost, quality, safety, claims & disputes? Please share any optimal model in your mind to tackle time, cost, quality, safety, claims & disputes. --- --- --- --- ---

APPENDIX C

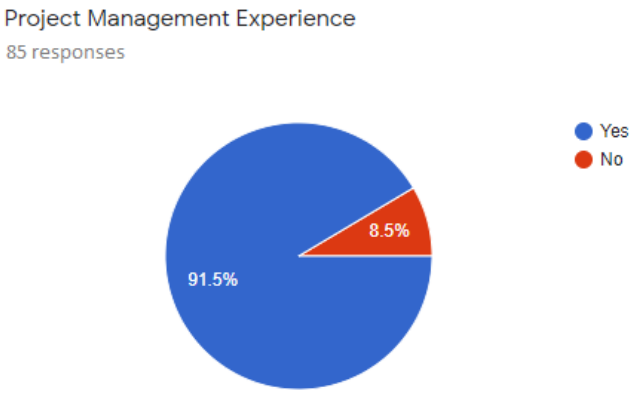
Analysis of questionnaire was done via Google docs.



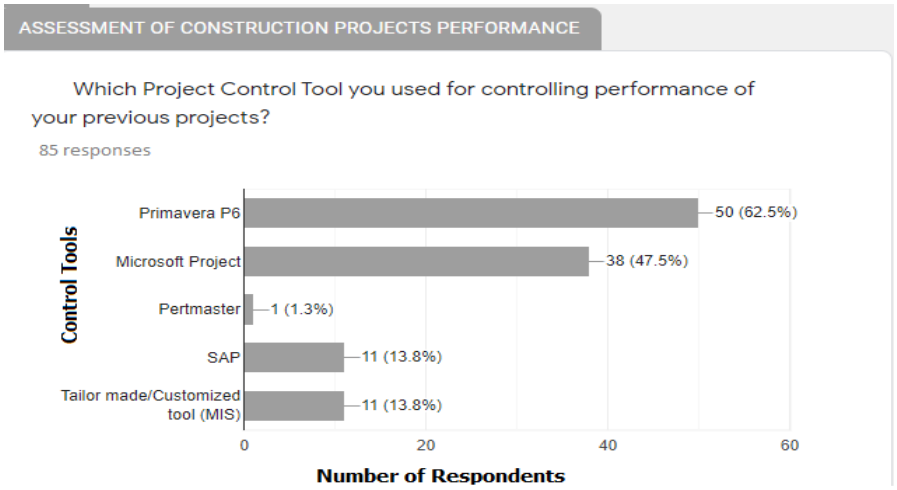
Gender of respondents. Most of the respondents were male.



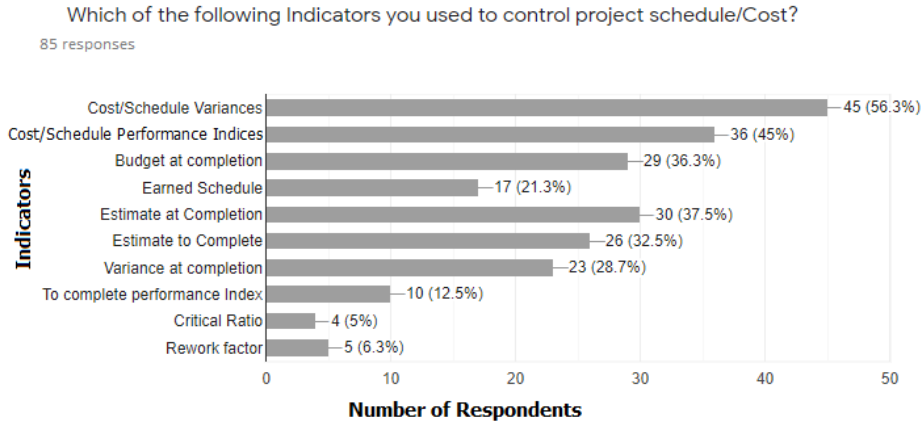
Size of projects formerly completed



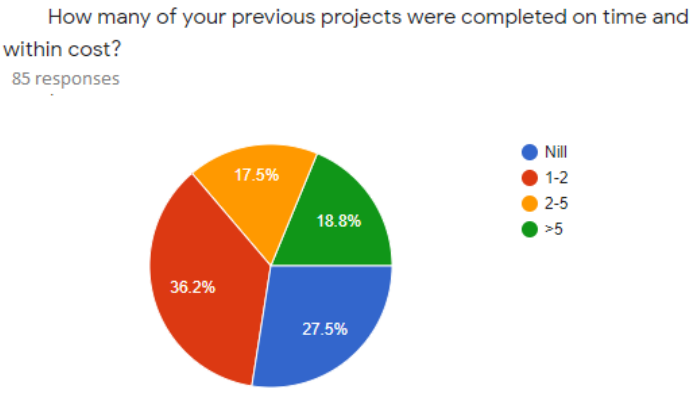
Former project management experience



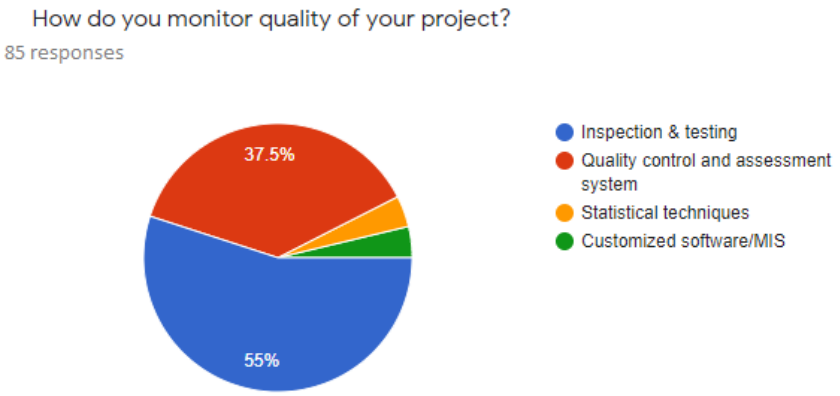
Most of the respondents used Primavera P6 and Microsoft project for controlling performance of previous projects whereas some used SAP and customized tools



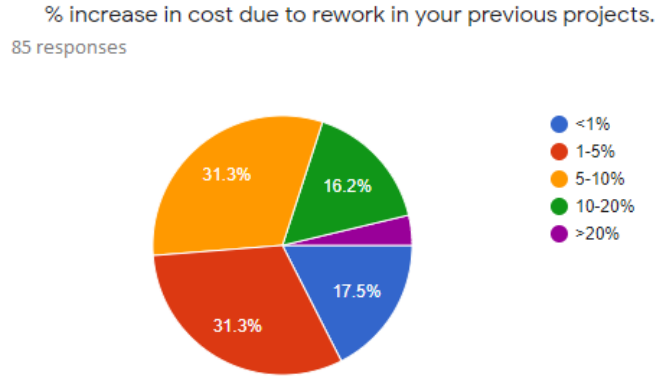
Cost/Schedule Variances were mostly used as indicators for controlling project's budget & schedule whereas forecast indicators were also used by some.



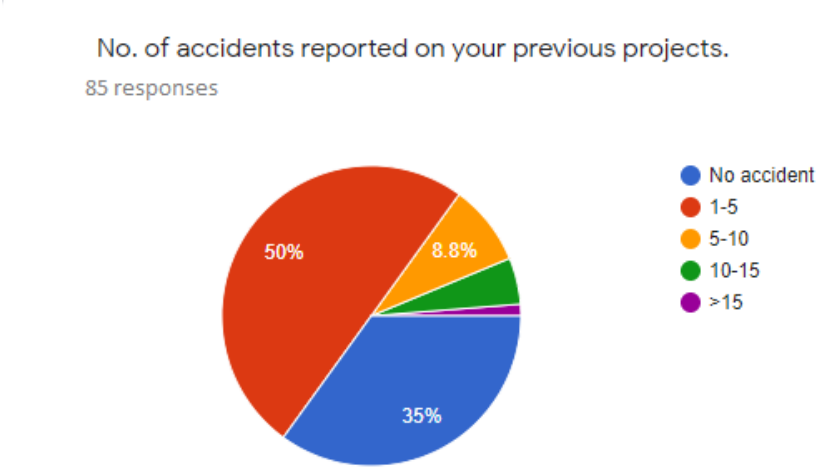
According to most of the respondents 1-2 of their previous projects were completed on time and within budget



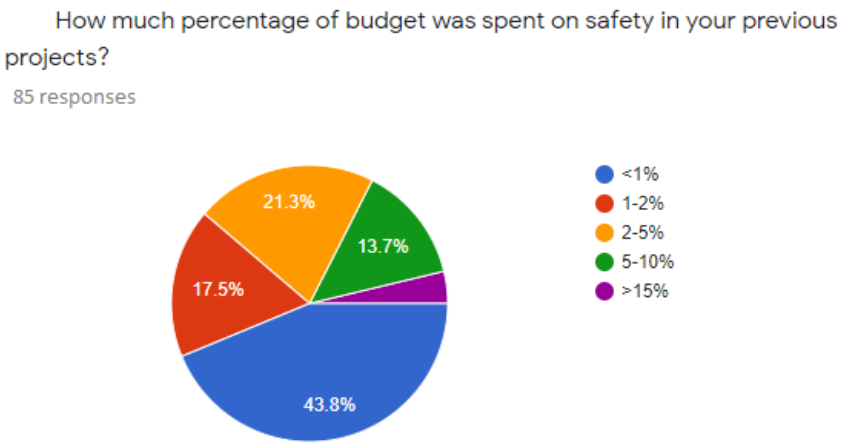
55% of the respondents used inspection & testing for monitoring quality whereas 37.5% used QCA for monitoring quality. They use a separate system for controlling quality. And their project control tool doesn't have quality control system.



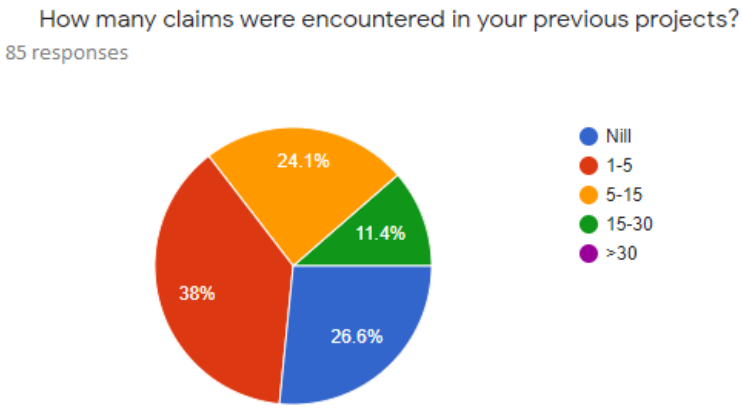
According to 31.3% respondents, 1-5% of the total budget was spent on rework in previous projects whereas according to other 31.3% respondents, 5-10% budget was spent on rework. This means that >1% budget is being spent on rework. This issue has serious effect on project cost.



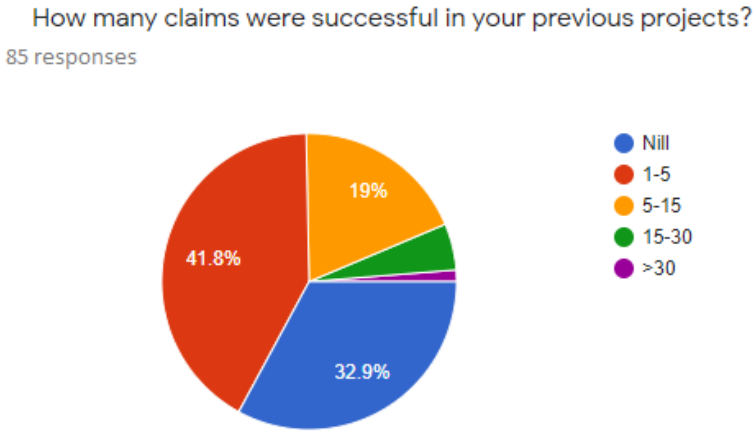
According to half of the population of respondents, 1-5 accidents were reported in their previous projects. Such accidents have strong effect on project's timely completion as planned.



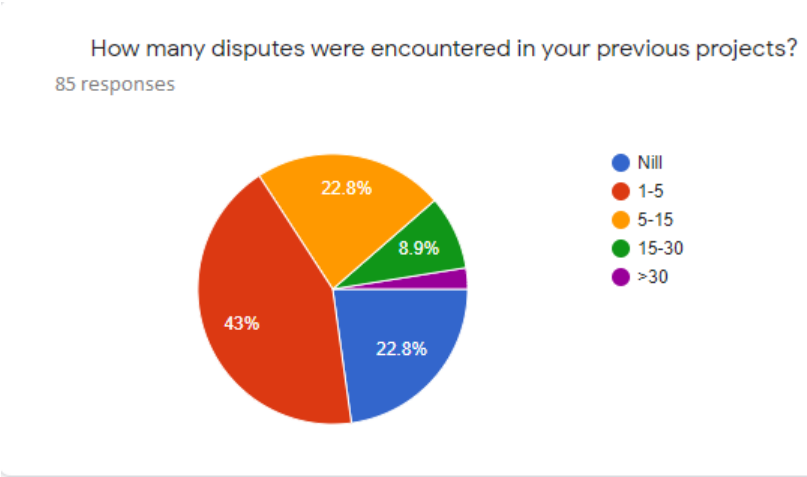
According to majority of respondents, <1% of the total budget was spent on safety. This can also have a minor impact on project's cost.



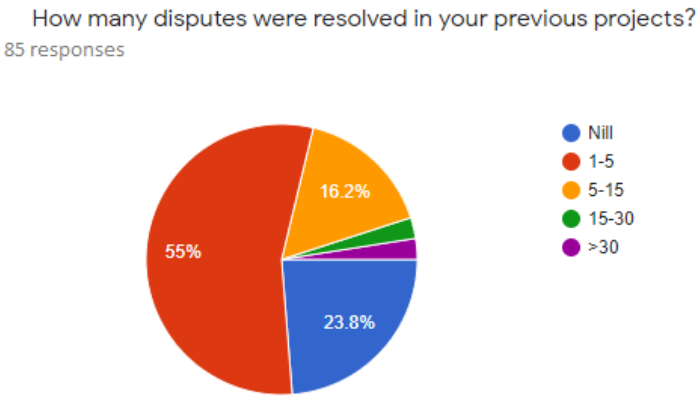
According to 38% respondents, 1-5 claims occurred in their previous projects whereas according to 26.6% none of the claim occurred in their previous projects. These claims have strong effect on project time & budget.



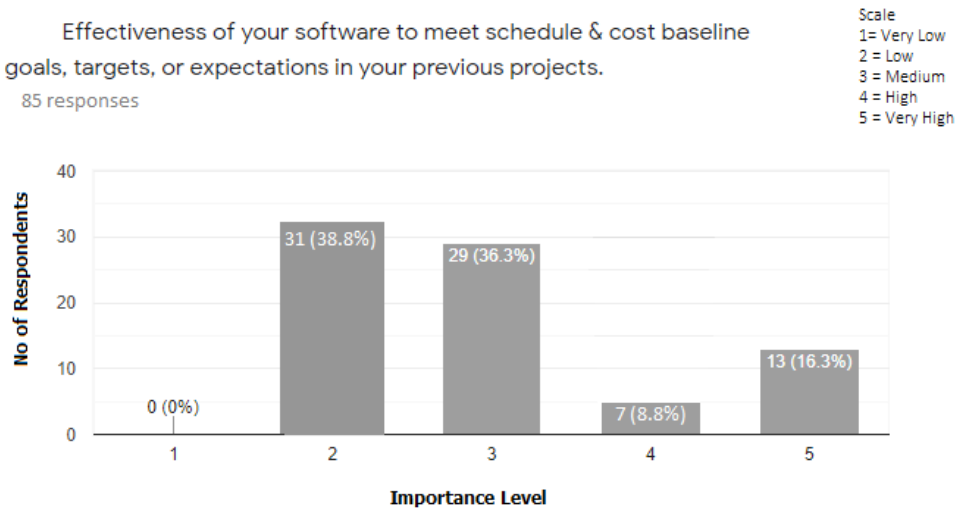
According to 41.8% respondents, 1-5 claims were resolved in their previous projects. This shows that it took project's time to resolve claims and hence has effect on project's planned time.



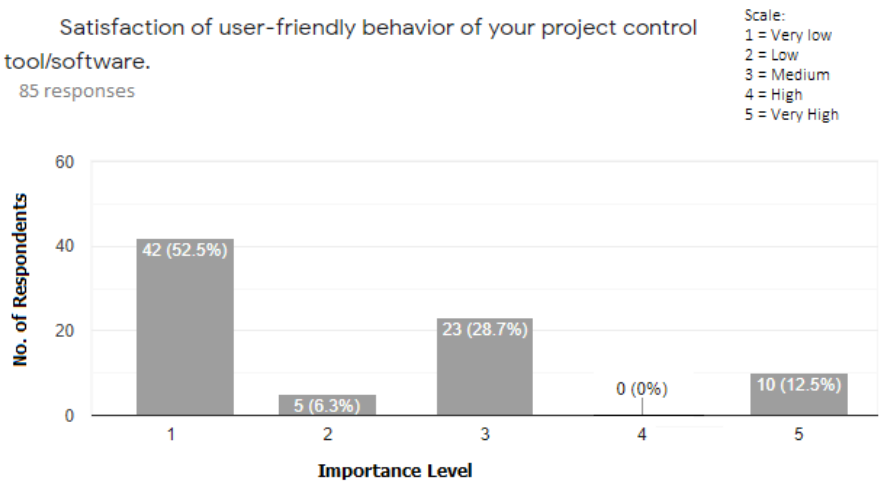
According to majority of respondents, 1-5 disputes occurred in their previous projects.



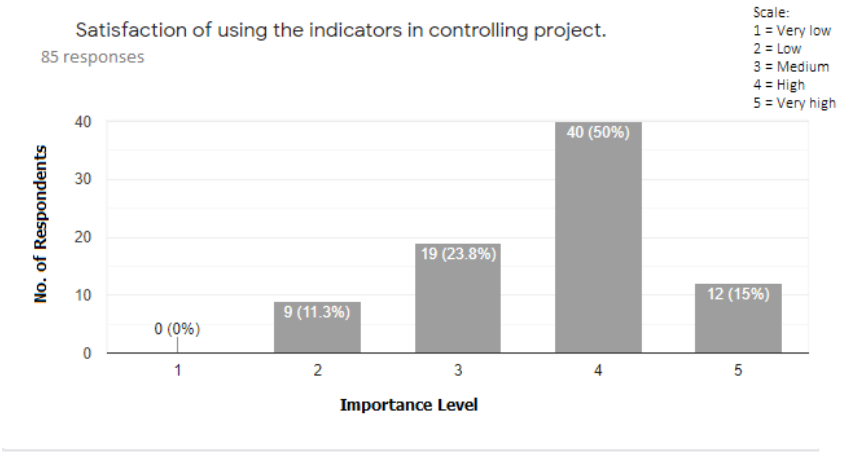
According to more than half respondents i.e. 55%, 1-5 disputes were resolved in their past projects.



According to majority of respondents, their project control tool is not efficient in meeting cost and schedule baseline goals.

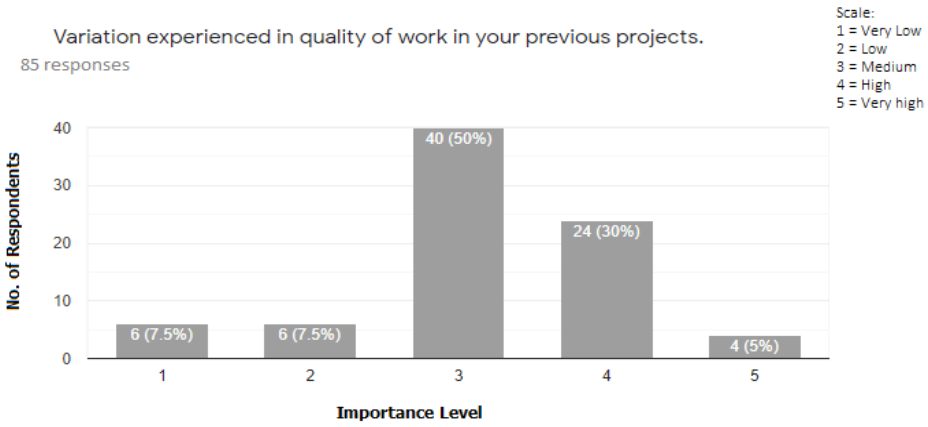


52.5% of the respondents said that their control tool is not user friendly.



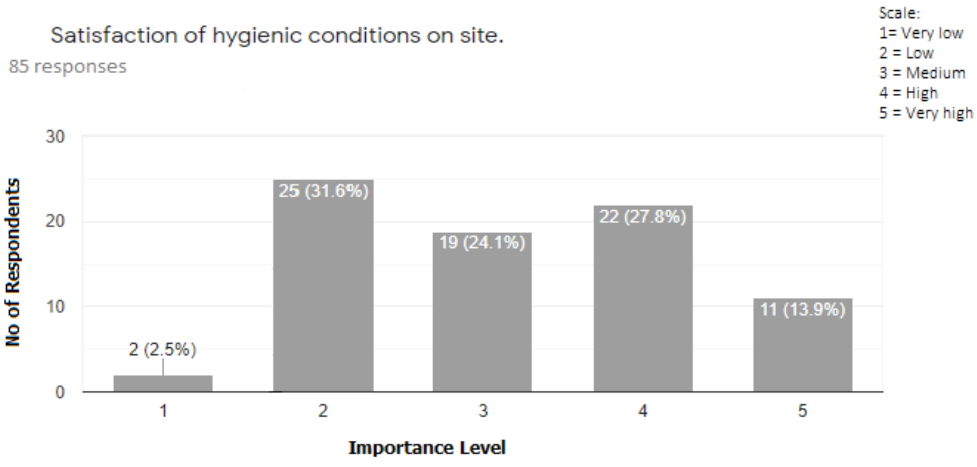
Majority of the respondents were highly satisfied by using indicators in controlling projects.

According to most of the respondents their control tool was not efficient in meeting quality objectives.

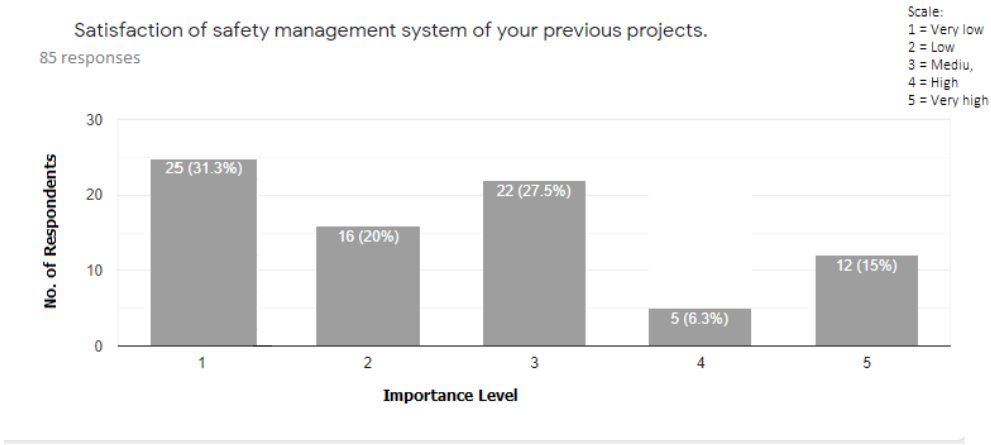


Medium to high level variation occurred in quality of work in past projects this means project's cost and budget was disturbed.

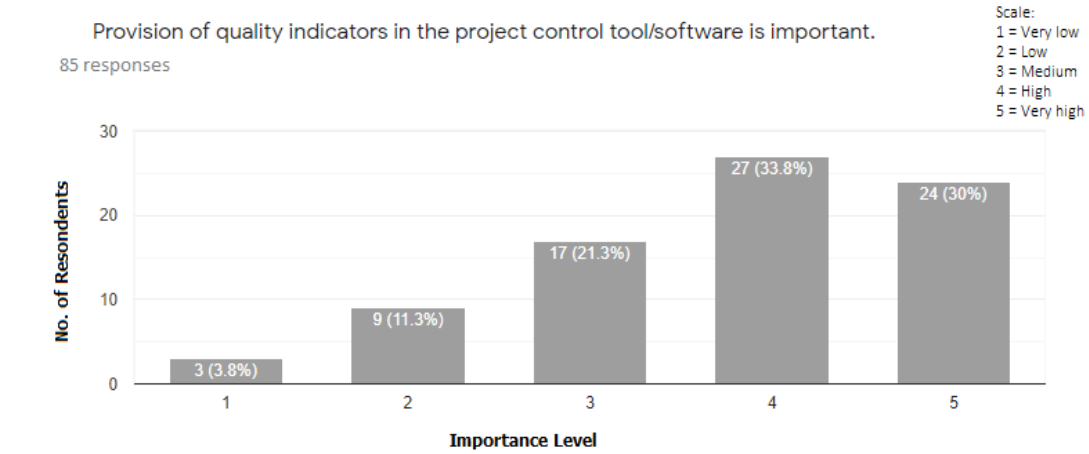
Organizations are highly serious on health & safety on sites.



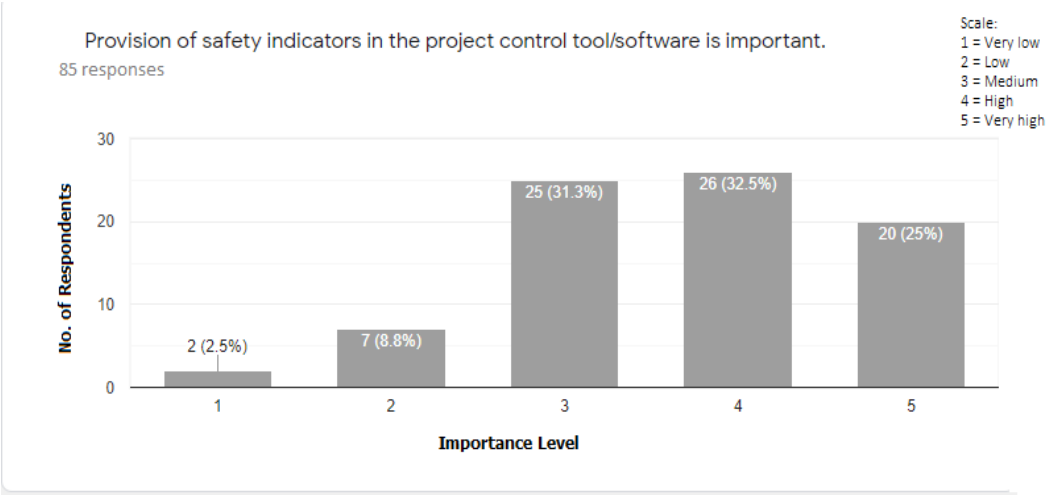
There is low level satisfaction of site's hygienic conditions.



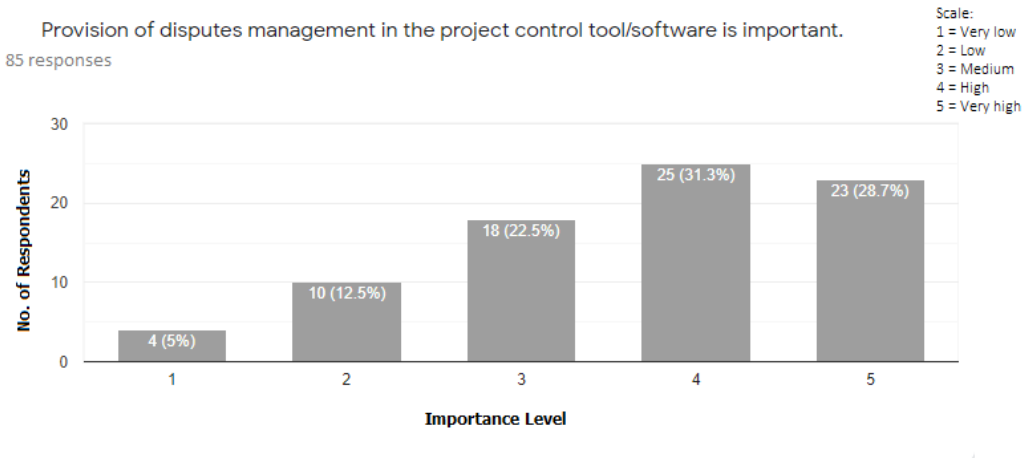
, Respondents are not satisfied on safety management system in their previous projects.



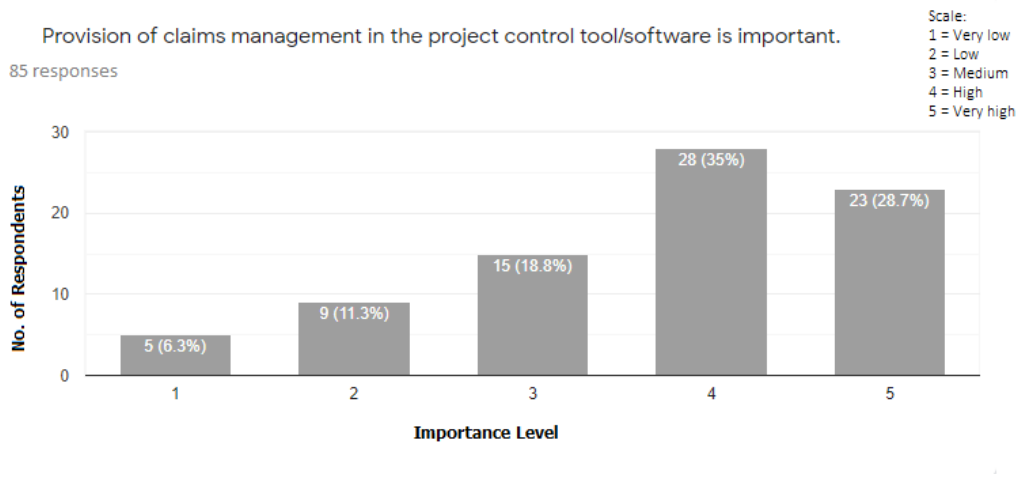
The importance of provision of quality indicators in project control tool is high. Quality should be controlled everyday with the progress of projects.



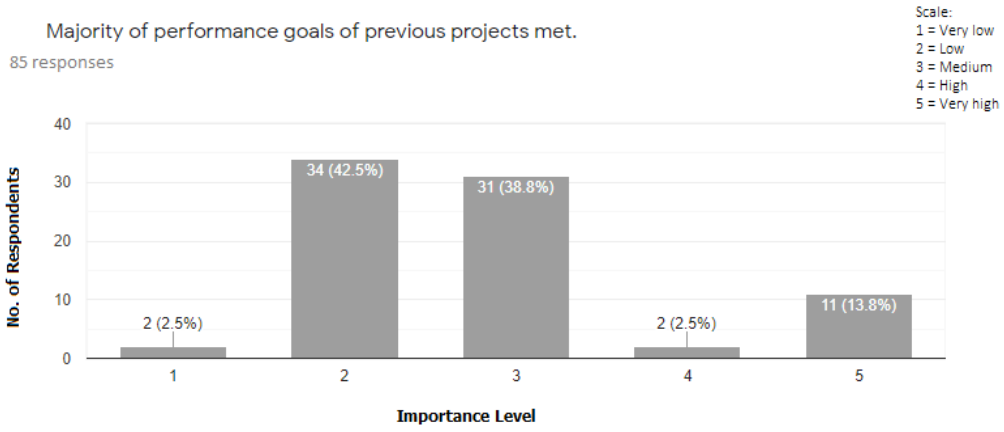
Provision of safety indicators in project control tool is highly important.



Provision of disputes management system in project control tool is highly important.

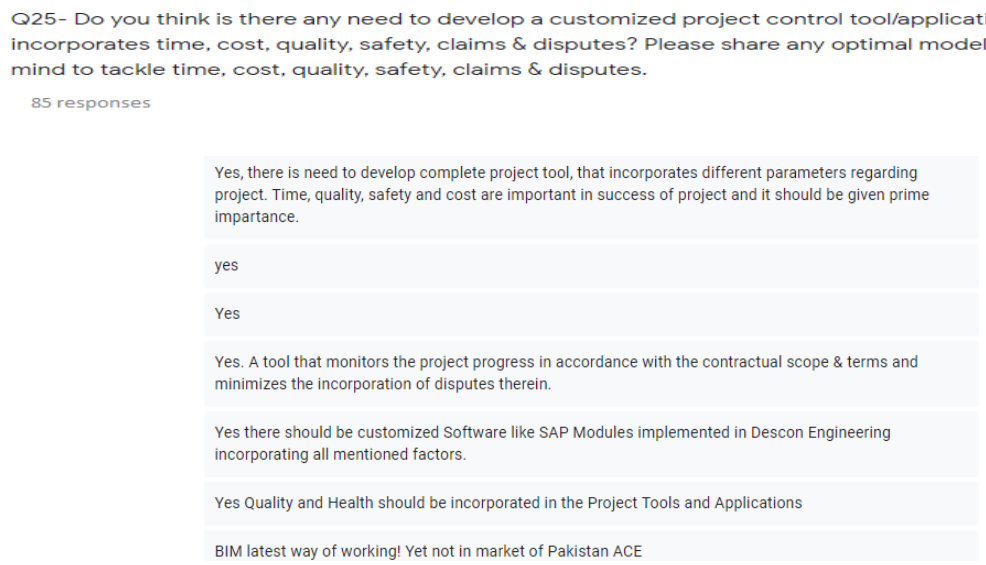


Provision of claim management system in project control tool is highly important.



In previous projects majority of performance goals were not met.

At the end of the questionnaire, an open ended question was asked in order to determine the need of control tool.



There is a dire need of a customized control tool that deals with not only time & cost but also with safety, disputes & claims. BIM is emerging which deals with all the aspects of management of project.

APPENDIX D

CONSTRUCTION PROJECT PERFORMANCE CONTROL QUESTIONNAIRE

PURPOSE OF QUESTIONNAIRE: A project is said to be successful if it is completed within the planned time, budget and other objectives. Every other project becomes victim of time & cost overrun and other issues. This research will control the performance of project in terms of time & cost by formulizing a control tool by using EVMs. The purpose of this questionnaire is to collect data of the selected projects for implementation of the formulated control tool. Your response is highly important and will be kept confidential.

PROJECT NAME: _____

RESPONDENTS DATA

Name				
Company Name				
Designation				
Gender	**a.** Male	**b**. Female		
Experience (years)	**a.**1-3	**b**. 3-5	**c.** 5-10	**d.**>15
Contact Details (Ph.# / ID)				

Note: Please, provide the required data.

Q#	QUESTIONS				
Q1-	Which Project Control Tool you used for controlling performance of this project?				
	a. Primavera P6	**b.** Microsoft Project			**c.** Pertmaster
	d. SAP	**e.** Tailor made/Customized tool (MIS)			**f.** Other
Q2-	% Cost spent on rework in this project?				
	a. 1-2%	**b.** 3-5%	**c.** 6-10%		**d.** >10 %
Q3-	% Conformance of this project to its contract specification.				
	a. 10-20%	**b.** 30-50%	**c.** 60-80%		**d.** 90-100%
Q4-	How many disputes were encountered in this project?				
	a. Nill	**b.** 1-5	**c.** 5-15	**d.** 15-30	**e.** >30
Q5-	How many claims were encountered in this project?				
	a. Nill	**b.** 1-5	**c.** 5-15	**d.** 15-30	**e.** >30
Q6-	% Cost spent due to disputes in this project?				
	a. 1-2%	**b.** 3-5%	**c.** 6-10%	**d.** 10-15 %	**e.** >15
Q7-	% Cost spent due to claims in this project?				
	a. 1-2%	**b.** 3-5%	**c.** 6-10%	**d.** 10-15 %	**e.** >15

Q8-	No. of lost time incidents reported on this project. **a.** No accident **b.** 1-5 **c.** 5-10 **d.** 10-15 **e.** >15
Q9-	No. of accidents reported on this project. **a.** No accident **b.** 1-5 **c.** 5-10 **d.** 10-15 **e.** >15
Q10-	Impact of accidents in this project w.r.t life. **a.** No loss **b.** Minor injury **c.** Permanent Injury **d.** Serious Injury **e.** Death
Q11-	Impact of accidents in this project w.r.t cost. **a.** 1-2% **b.** 3-5% **c.** 6-10% **d.** 10-15 % **e.** >15
Q12-	% of work done till date? Date _____ **a.** 10-20% **b.** 30-50% **c.** 60-70% **d.** 70-80 % **e.** 90-100%
Q13-	% of cost spent till date? Date _____ **a.** 10-20% **b.** 30-50% **c.** 60-70% **d.** 70-80 % **e.** 90-100%
Q14-	At which stage currently the project is? Date _____ **a.** Planning & Scheduling **b.** Designing **c.** Documentation **d.** Execution/Construction **e.** Closing
Q15-	Provide percentage completion of each stage of this project? (Example, Designing = 100%) **a.** Planning & Scheduling ---------- **b.** Designing ---------- **c.** Documentation ---------- **d.** Execution/Construction ---------- **e.** Closing ----------