Integrating EVM and ABC for developing risk/rewards sharing metrics of IPD: A web-based management system

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Abstract

Integrated Project Delivery (IPD) is highly recommended to be utilised with Building Information Management, particularly, with BIM level 3 implementation process. The literature review survey highlights that there are financial management challenges that face the proposed integration, these challenges are mainly related to the IPD compensation approach, as well as, the conventional cost control approaches that are not consistent with IPD principles. As such, this paper presents an integration of several methods to support automating sharing risk/rewards among project parties, thus, enhancing the relationship among IPD's core team members. Activity Based Costing (ABC) is integrated into Earned Value Management (EVM) to develop mathematical models that can determine the three main IPD financial transactions fairly (reimbursed costs, cost saving and profit), due to ABC abilities to distinguish between direct, indirect and overhead costs precisely. Since IPD's core team members usually receive their profits by the end of the project, regardless of the project timeline, therefore, a data sharing system is highly needed. As such, a web-based management system is developed to display the output of proposed risk/rewards sharing models, as well as, an innovative grid is developed to show the project status graphically to respect the diversity in core team members educational backgrounds. To demonstrate the applicability of the developed system, a real-life case study was used, in which, promising results were collected in regards to visualising the cost control data, and easy understanding of the accumulative status of the project cost and schedule. In addition, the case study shows that the proposed integration of different methods is interoperable and applicable, particularly, BIM and EVM-web system.

Keywords: IPD; BIM; ABC; EVM; Risk/rewards sharing

1. Introduction

Integrated project delivery (IPD) is characterised by the early, collaborative and collective engagement of key stakeholders through all phases of delivering a project (Ahmad et al., 2019). Traditional forms of IPD, such as alliancing, can be implemented without BIM. However, new forms of IPD are defined in relation to their integration with BIM (Rowlinson, 2017) which facilitates smooth data exchange between a project's packages and parties, in line with IPD's aims and objectives (AIA, 2007). The integration of BIM and IPD improves all likely outcomes of the design and construction process, including cost/profit, the schedule, return on investment (RoI), safety, productivity and relationships (Elghaish et al., 2019). Integrated project delivery (IPD) relies on open pricing techniques and fiscal transparency among participants (Ahmad et al., 2019). In addition, project stakeholders, such as designers and contractors, typically assess and determine their profit and shared risks according to the deviation between actual and target costs (AIA, 2007).Successful delivery of a project through IPD is however not easy; IPD requires fulfilling a wide range of requirements (Fischer et al., 2017). Of these requirements, the IPD compensation model, also called risk/reward compensation, is of cardinal importance (Ma et al., 2018). It is described as a key principle of IPD (Zhang et al., 2018), that plays a pivotal role in stimulating creativity, motivating collaboration, and sustaining performance (Zhang and Li, 2014). The risk and reward must be shared and allocated to all participants in core project teams, necessitating joint project control (Fischer et al., 2017). For designing the risk and reward model (hereafter referred to as the compensation approach), economic models provide a sound foundation based on the cost of projects (AIA, 2007).

The cost structure of IPD needs some improvements in order to make sure that there is no profit hidden in the estimated cost (Allison et al., 2018), to achieve the purpose of using IPD to increase the trust among project parties (Ma et al., 2018). Due to risk/rewards are not shared individually for IPD core team members (AIA, 2007, Pishdad-Bozorgi and Srivastava, 2018), therefore, any misleading in determining the individual trade package, will affect the value of the proportions of profit-at-risk percentage of each member in IPD team. One of the main principle of IPD, the allocation of Parties' profits defer to the end of the project, therefore, this represents a challenges to speed the implementation of the IPD since this requires all members to attend all meetings even if their works are completed at earlier (Roy et al., 2018). As such, using Information Technology (IT) is important to share the information among parties regardless of their geographical places.

A review of the literature shows several trends of research on the topic. Of these, a major part of the research has been allocated to exploring the potential of available tools and techniques (i.e. EVM and ABC within IPD) (Hosseini et al., 2018). These studies, for the most part, stop at providing an outline of how these methods and techniques add value to the risk/reward sharing mechanism in IPD (Pishdad-Bozorgi and Srivastava, 2018). BIM in integration with IPD practices are also discussed in several research studies (Fischer et al., 2017, Rowlinson, 2017, Allison et al., 2018). The challenges of such integrations are explored in another stream of studies; financial challenges, difference in cost accounting between participants, and the lack of risk/reward sharing mechanism that can be accepted by all participants (Zahra Kahvandi, 2018). No workable methodology is however provided to demonstrate the interrelationship among BIM tools/dimensions and IPD stages in practical terms (Roy et al., 2018). To this end, the paper outlines the design of an automated model of cost control system of IPD projects through integrating ABC into EVM to develop mathematical equations that support EVM to determine risk/rewards for owner and all non-owner parties. The EVM is extended by a grid to allocate the output of its CPR and SPR, subsequently, all parties can track their duties on the web system. The EVM-web system includes two kinds of reports (1) graphical report that shows the previous performance, as well as, the current state of the project. Each milestone is presented as a star inside the EVM grid, which is divided into four areas; each area represents a generic case. (2) A metrics report that shows three main values for owner and non-owner parties (reimbursed costs, profit and cost saving).

2. Information and Communication Technology (ICT) in construction management

Jacobsson and Linderoth (2010) state that the increasing of shared information in construction industry lead to the necessity of utilising Information and Communication Technology (ICT). There are several reasons beyond calling ICT applications in construction industry, namely, lack of integration between design and production (construction stage), facilitate communication among different disciplines (teams) whether internal the same organisation or cross different organisations (Söderholm, 2006).

Recently, BIM is considered as one of the application of ICT in construction industry (Latiffi et al., 2013), throughout last few years, BIM becomes mandatory in many countries, thus the rate of adopting ICT generally has been raised (Eadie et al., 2013). ICT web systems are proven their abilities to work efficiently and effectively in cost control tasks in construction industry, as web system enables all project participants to see the project status easily regardless of the participant geographical place (Ozorhon et al., 2014), for example, Li et al. (2006) and developed and tested web systems to manage and display the project performances through using EVM method. Web system is used in data management in construction throughout last decade, particularly the application of Map-based Knowledge Management (MBKM) for contractors (Lin et al., 2006). ICT in data management facilitated the understanding trough digitalising the knowledge as a map, therefore, information is presented graphically as symbols and huge data is embedded. Therefore, the makers and users can easily communicate through specific symbols, thus redundant texts will be minimised (Wexler, 2001).The research of utilising web systems in monitoring cost/schedule projects have received significant attentions (Chou et al., 2010), particularly, utilising EVM method to display the schedule and cost simultaneously to enable stakeholders understand and track their tasks easily (Li et al., 2006).

3. Implications of cost management within BIM and IPD

In moving towards efficient project delivery, the ultimate goal is having a database of information that is available to all project participants, with confidence in its accuracy, universal utility, and clarity (Oraee et al., 2017). The main drive for adopting BIM, is managing all project documents and stages (i.e. design, planning, and costing) in a single/dynamic context, to secure the proper exploitation of available information (Abrishami et al., 2015)). BIM design elements must contain the required information in various natures, including design or management (Banihashemi et al., 2018), to acquire smartly-designed elements, rather than traditional 3D components (Pärn and Edwards, 2017). BIM users should be capable of acquiring all the required information from a single BIM elements, to make informed decisions (Elghaish et al., 2019). Four-dimensional modelling (4D BIM) can embed progress data in 3D model objects by adjusting the task-object relationship (Hamledari et al., 2017). Application of 4D BIM leads to easily operate workflows, efficient on-site management, and assessing constructability (Hartmann et al., 2008). As for the cost management, BIM is one of the most efficient Architectural, Engineering, and Construction (AEC) tools in increasing productivity on construction projects (Wang et al., 2016) . Colloquially termed as 5D BIM (Aibinu and Venkatesh, 2013), this capability of BIM offers the preferred technique for extracting quantities from 3D models, allowing cost consultants to incorporate productivity allowances and pricing values (Lee et al., 2014). The cost estimating process starts with exporting data from 3D models to BIM-based cost estimating software (e.g. CostX®) to prepare quantity take-off. Afterwards, the Bills of Quantities (BoQ) are generated and exported to an external database (Aibinu and Venkatesh, 2013). Prices and productivity allowances can also be added to project schedule preparation (Lee et al., 2014). Such automated quantification will shorten the quantity take-off processing time, and will automatically consider any changes in design – which is likely in fast-track projects (Wang et al., 2016).

Cost estimation hence has a vital role in applying IPD (AIA, 2007, Elghaish et al., 2019), and therefore, must be tracked through a scrutinising method by core team members to determine their profit, and shared benefits/risks, according to the deviation between the actual and target costs (Zhang and Li, 2014). The compensation approach structure must be capable of drawing upon effective methods, to determine cost overrun proportions, cost underrun, and any saving in total budget under the agreed cost (Elghaish et al., 2019). That is because, risk/reward proportion rely on the degree of achievement during the entire project stages (Elghaish et al., 2019). The compensation approach has two limits ; firstly, the direct, indirect, and overhead costs, which can be nominated as agreed cost, and secondly the profit-at-risk percentage after estimating the agreed cost (AIA, 2007, Zhang and Li, 2014).

The precise determination of risk perception is critical to ensure the agreed compensation structure will be implemented correctly throughout the project, so that; the risk/reward ratio can be fairly allocated among project participants. Therefore, the participant who carries more uncertain works can be compensated with higher profit-at-risk percentage (Das and Teng, 2001).

4. Earned value management

Earned value management (EVM) is a quantitative project management technique for measuring project progress, and to provide project participants with early warnings where the project is running ‘over the budget’ or ‘behind the schedule’ (PMI, 2013). Khamooshi and Abdi (2016) provided evidence of EVM being successfully applied on several real-life projects to deliver accurate cost/schedule metrics. According to Naeni et al. (2011) “earned value technique is a crucial technique in analysing and controlling the performance of a project”. EVM, as recommend by PMI (2013), is an effective tool for supplying cost and schedule indicators, to measure performance through Cost Performance Ratio (CPR) and Schedule Performance Ratio (SPR) values. The granularity between project scheduling, represented through WBS, and the actual way, represented through the expenditures, is a problem in accurate implementation of EVM (Pajares and López-Paredes, 2011). The EVM system, therefore, needs to be smarter, provided with advanced capabilities, to enable a correlation between data from multiple sources, and also, automatically generating the cost control report (Lipke et al., 2009). The interoperability issue among various data sources, to build federated project cost control sheets, is best resolved through using advanced technologies and visualisation techniques (Chou et al., 2010).

5. Activity based costing

Construction projects typically rely on a fragmented structure – of participants, and this fragmentation, leads to an increase in overhead activities, and accordingly overhead costs (Mignone et al., 2016). There are several traditional cost accountant methods; Resource Based Costing (RBC) that relies on resources' cost, and Volume Based Allocation (VBA) that is based on allocating the cost of resources directly to the objects, regardless of the cost structure – direct, indirect, and overhead costs (Holland and Jr, 1999). Cost distortion, however occurs in using these traditional methods, due to conflating all indirect costs into one, which distorts the pricing of company products (Miller, 1996). Activity Based Costing (ABC) is a solution to such distortion, through allocating costs of multi-pools, and determining the overhead activities and the associated costs needed to transform the resources into activities that can deliver the final product (Kim and Ballard, 2001).

6. Research methodology

An amalgamation of *exploratory case study* and *experiment* is deemed a suitable method for accomplishing such an objective, following the arguments by Banihashemi et al. (2018). Therefore, the literature review is utilised to highlight the research gap in terms of the capabilities of proposed methods and processes —ABC, EVM and BIM—to be integrated for automated financial transactions within IPD. As such, the research commences by integrating ABC into EVM to develop mathematical formulas that can provide reliable metrics for IPD, so that the proposed formulas should shows the risk/rewards values for each party and for the entire project performance. Afterwards, a data visualisation technique based on EVM should be developed. The developed framework are validated a real-life case study since experiments are particularly effective in revealing whether the real data can support or refute any proposed procedure, as according to Zellmer-Bruhn et al. (2016)experiments can demonstrate the match, if any, between data and a proposed theory.

7. Developing the framework

The development of the framework is divided into sections, first section is to build a robust cost structure of IPD based on ABC, second section is to develop an EVM based ABC mathematical formulas to determine risk /rewards values, this therefore could enable determining the three financial transactions (Reimbursed costs, profit and cost saving properly). The third section is how BIM and web based information system can be utilised.

7.1. Formulating IPD's cost structure based on ABC

The compensation structure in IPD relies on distinguishing direct and overhead cost such that owners and non-owner parties can manage their activities in accordance with achievements in each Limb, that's why, ABC is adopted in this research, and therefore the cost estimation should be estimated and recorded in ABC sheet as shown in figure (1). Given that BIM is highly recommended to be utilised with IPD for successful project delivery (Elghaish et al., 2019, Rowlinson, 2017), therefore, figure (1) shows how the ABC sheet can be implemented within BIM platforms (i.e. Autodesk Navisworks). In this framework, the direct and indirect costs are determined as a summation of costs of direct activities, and similarly, the overhead costs are estimated as a summation of costs of overheard activities for each trade package, all from the ABC estimation sheet. The reason behind using ABC for articulating the compensation approach is its capability to measure the degree of savings for each participant, which accordingly leads to effective and precise computation of the risk/reward sharing ratio as shown in figure (2). Furthermore, the cost saving share for owner differs from the non-owner participants given the difference between the cost overhead saving in the organisation sustaining level and project level. Thus, the goal of determining the participants sharing risk/reward ratio using this approach is to ensure equitable and a more applicable approach.

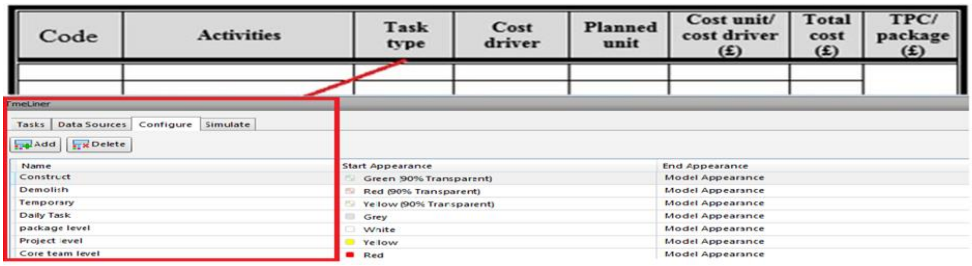

Figure 1. ABC structure sheet with correlation between 4D/5D BIM

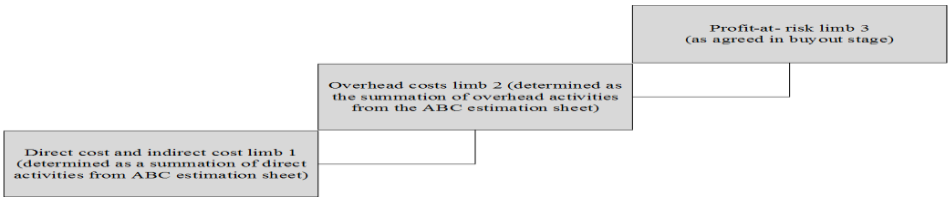

Figure 2..Compensation under the IPD approach using ABC estimation

7.2. Developing EVM based ABC extensions

Below table (1) illustrates the developed mathematical formulas based on EVM and ABC in order to determine the risk/rewards values for owner and non-owner parties. It can be seen that there are models in corresponding to each case, hence this will enable automating the payment process (recording the risk/rewards values automatically, and this could speed the rate of adopting IPD for successful project delivery.

Table 1. Proposed EVM-based ABC extensions

Case	EVO	Developed models	Terminologies
On cost/schedu-le	EVO =1	$\text{Rewards value} = \left((\text{EVO}) \times \text{P@R Per}\right) \times \text{MVoLIMB2}$ (1) $\text{MV for R or RD for each party} = \text{Rewards value} \times \text{PoO or PoNO}$ (2)	MVoLIMB2 represents the monetary value of LIMB2 (£); MV for R/RD for each party represents the monetary value for Risk or Rewards for each participant (£); and PoO/PoNO represents the proportion of owner or non-owner party (%)
Ahead of schedule and/or cost underrun	EVO >1	$\text{CSoOC for NO} = \sum \text{CSoOOA from ABC sheet} + \sum \text{CSoOPA from ABC sheet} + \text{NOARP}$ (3)	CSoOC for NO represents the overhead cost saving for non-owner participants (£); CSoOOA from ABC estimation sheet represents the overhead organisation activities costs' saving from the ABC estimation sheet (£); CSoOPA from ABC estimation sheet represents the overhead project activities costs' saving from the ABC estimation sheet

		$\text{CSoOC for O} = \sum \text{CSoOPA from ABC sheet} \times \text{OARP} \quad (4)$	(£); NOARP represents the Non-Owner Agreed Rewards Proportion (%); CSoOC for O represents the overhead cost saving of for owner participants (£); and OARP represents the owner agreed rewards proportion (%).
Behind schedule and/or cost overrun	EVO <1	$\text{DC} = \sum \text{DAC from ABC estimation sheets} \quad (5)$ $\text{Rewards value} = \left((\text{OoEVMG} - 1) + \text{P@R Per}\right) \times \text{MVoP@Rper} \quad (6)$	DC represents the direct cost (£); DAC from ABC estimation sheets represents the direct activities' costs from the ABC sheet as BCWS (£); RV represents the Rewards Value (£); MVoP@Rper represents the monetary value of Profit@Risk percentage (£).

An EVM grid is developed to display the outcome of EVM's CPR and SPR, the EVM-grid divides the project into four areas (see figure 3), where each area represents the project situation and is distinguished by a specific colour. Through allocating potential project cases on the grid, whilst considering X-axis as the schedule and the Y-axis as the cost, each area is then divided into small squares around the planned point. The user should determine the value of the CPR and SPR and enter them into the grid as positive or negative percentage to determine the project situation at each milestone or for each package. Furthermore, the quantity surveyor should mark the square in accordance with CPR and SPR percentages, to determine the cumulative progress throughout the project execution stages. Thereafter, the 'Profit-at-Risk' percentage will be shared in accordance with the output of the developed EVM-Based IPD grid.

7.3. The integration of EVM-Grid web system and BIM

The flow of data in the proposed model will be from the documentation and the buyout stage to the close out stage, with highlighting BIM integration at each stage, as described below.

During the documentation stage, core team members conduct cost estimation based on ABC and loading the costs to the corresponding activity – whether the activity is direct, indirect, or overhead. This can be implemented through estimating costs using a 5D BIM platform (i.e. Navisworks) after configuring its layers in accordance with ABC levels. Subsequently, BCWS values can be prepared through exporting data that are created through 4D/5D BIM platform to another software package like Microsoft Project. Hence, the buyout stage takes place to agree on the percentage of profit-at-risk (P@R %), as well as, risk/reward among owner/non-owner parties. Subsequently, the agreed upon P@R% is added to BCWS to develop project compensation approach, and all project data (BCWS for each package, P@R percentage, risk/reward sharing %) are recorded to enable determining the actual percentages within the construction stage. Once the construction stage begins, the project manager should start loading the project information (CPR and SPR) to the EVM-Web grid, as shown in Figure 9.

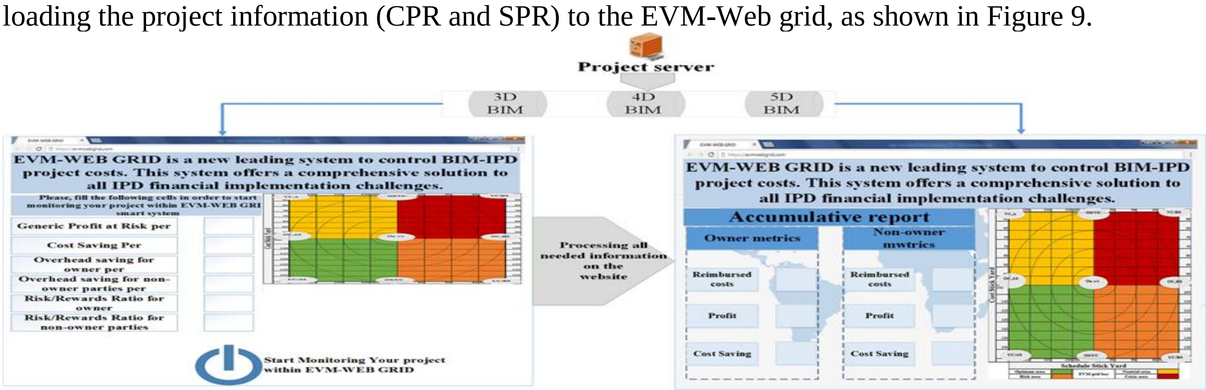

Figure 3. EVM-web system interoperability

8. Validation and result analysis

To validate the proposed methodology, the model was applied to a case study; a property development company, whose managers decided to build a new house. The costs of implementing IPD can be determined from the conceptualisation stage to buyout stages. The compensation structure was agreed upon as follows; (1) the agreed profit-at-risk percentage was 20%, (2) the saving cost allocation percentage for overhead project level cost was 70% for non-owner participants and 30% for owner, (3) the non-owner risk/reward ratio was 80% and 20% for owner party. Although, within the existing IPD model, the owner does not get any proportion from P@R%, it is assumed that the owner gets a proportion from P@R% for two reasons: providing any service such as participating in managing project workflow, and showing capabilities of the presented framework to work on various scenarios. (4) the direct and indirect cost limit (Limb 1) was £118,484.9; (5) Limb 2, which involved direct, indirect, overhead costs was £190,484.9; and (6) Limb 3, which comprises from the total cost and the profit-at-risk percentage, which was £228,581.9.

8.1. Determining the risk/rewards values

Figure 4 summarises the above-mentioned scenario steps and results of implementing the framework for both owner and non-owner parties. The benefit of implementing EVM framework is allocating the risk/reward among the core team members within the IPD approach, as discussed earlier. The scenarios displayed two scenarios for an EVM output less and greater than 1. The sharing proportion was calculated accordingly, based on the developed framework.

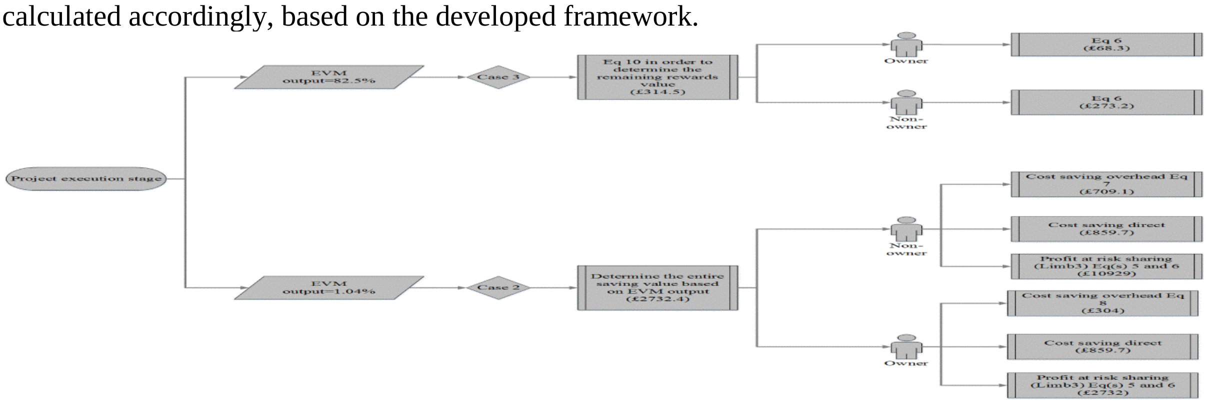

Figure 4. *Results analysis flowchart*

8.2. The applicability and integration of BIM and EVM-web system

In order to show how BIM and EVM-web can be utilised, the presented data in scenario (2) are shown in below figure 5. Figure 5 shows the BIM dimensions (3d, 4/d and 5D) that have been developed for this case study and all project data will be retrieved from these three models as the case study supports the integration of IPD and BIM. According to reviewing 4D BIM as clear in figure (11), some works have been completed and milestone 1 is by the end of week 1 in March, subsequently, the project parties should be able to follow the overall performance whether graphically or by metrics report.

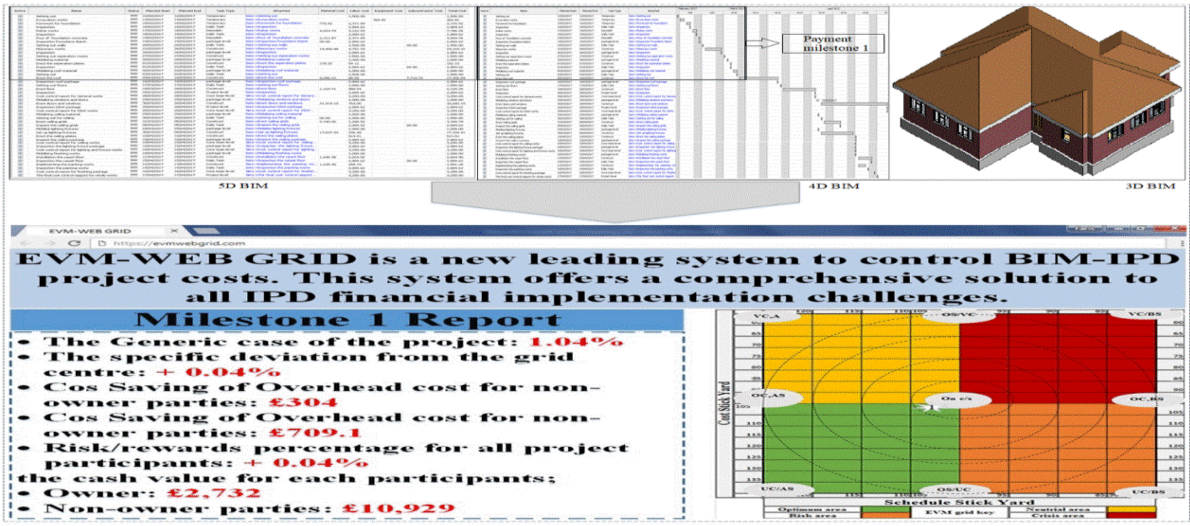

Figure 5. Result analysis of displaying risk/rewards values on EVM-web system

9. Conclusion and future directions

This research proposed a comprehensive approach to manage the financial tasks within the IPD approach, the entire IPD's cost management process is visited to identify the weak/capable points, and afterwards set of methods such as ABC, EVM and BIM are integrated into a single / dynamic process. This study is novel in several ways. That is, the paper introduces an innovative grid that locates the Cost Performance Ratio (CPR), and Schedule Performance Ratio (SPR) to provide a picture of project position in terms of cost and schedule. Furthermore, it integrates the EVM-Grid with the ABC estimating method to optimise the cost structure, which is positively reflected in the compensation structure. In addition, the findings present models that deal with risk/reward sharing, through considering new directions, to ensure fair sharing using ABC sheets and distinguish between the direct and overhead cost saving. For the overhead cost, the framework distinguishes between the sustaining/organisation level and the project level. Additionally, the EVM-Grid has been developed as a web system to allow the participants to easily track their project.
In practical terms, the findings will be invaluable for novice BIM users, given the simplicity and user-friendliness of the proposed models. All the tasks are aligned with the implementation stages and easily expressed to allow novice users to collect the required data promptly. The interventions and outcome of this research will be used to develop an automated payment platform based on Hyperledger fabric (blockchain).

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