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# 1 Implementation of 3D Integration Model for Project Delivery Success: 2 A Case Study

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8

## 9 Abstract

10 The means for assessing what constitutes successful project delivery is a controversial topic in the  
11 literature, with many approaches and frameworks in play. This paper extends Langston's existing  
12 3D Integration Model to include an assessment of triple bottom line (TBL) performance and applies  
13 it, for the first time, to a real-life case study. A subway station mega-project in Tehran, one of the  
14 busiest cities in the world, is retrospectively tested to evaluate its success. The new subway system  
15 is an important infrastructure project in Iran, and no research to date has evaluated its delivery from  
16 a project management perspective. This paper provides governmental and private sector agencies  
17 with a procedure to calculate the project delivery success (PDS) score for the construction of this  
18 subway or similar infrastructure projects, enabling a unique means to compare performance with  
19 other developments in Iran or elsewhere. From field data, it is shown by the researchers and verified  
20 by both the site project manager and client's representative that the subway's construction is an  
21 unsuccessful project. The findings quantify what could have been done, based on advice generated  
22 from the model, to deliver a successful outcome. The benefit of Langston's 3D Integration Model is  
23 its applicability to any project type or context, enabling them to be effectively compared and ranked  
24 by the percentage change between planned and actual PDS score. Given the introduction of TBL as  
25 a fifth core project constraint, an optimum solution can be found via the application of several  
26 heuristics (or rules) that define the boundaries within which a successful solution lies. The extended

27 model contributes to knowledge through its ability to quantify success and optimize performance,  
28 ideally during the delivery of the project rather than as a post-mortem exercise.

29 Keywords: *project delivery success, PMBOK® Guide, project integration, construction, Iran*

### 30 **Introduction**

31 An increasing number of organizations are implementing their business operations through projects  
32 (Kerzner, 2001). Delivering project outcomes on time and within budget has been a main concern  
33 of project managers for many years (Ika, 2009). But by its very nature, the construction industry  
34 involves an overwhelming number of risks in delivering successful outcomes. Current construction  
35 project management practices, in the public sector specifically, do not always lead to favorable  
36 outcomes (Alias et al., 2014).

37 Dr. Martin Barnes (1969) is credited with the notion of core constraints that underpin successful  
38 delivery. He promoted cost, time and output as the iron triangle (or triple constraint) of project  
39 management. He argued that making a change to one constraint affects the other two. Many  
40 variations ensued, including output sometimes being renamed as quality, scope or performance.  
41 Others preferred the terms of ‘budget, schedule and scope’, or simplified it further as ‘cheap, fast  
42 and good’. Jha and Iyer (2007) found that the commitment, coordination and competence of project  
43 players were key factors that underpin the iron triangle. These were argued as bearing on time, cost  
44 and scope respectively, and when nurtured, successful performance outcomes were more likely to  
45 occur (Todorovic et al., 2015). But the basic ‘law’ of project management can be broken, and it can  
46 be argued there is a need for a more complete paradigm representing the many facets of delivery  
47 success (Langston, 2013).

48 There have been calls for a new paradigm (e.g. Weaver, 2012) and yet plenty of support for the old  
49 one. There is confusion between terms such as ‘project success’ and ‘project management success’,  
50 and between ‘success factors’ and ‘success criteria’ (de Wit, 1988; Rockart, 1982; Gibson and  
51 Hamilton, 1994; Munns and Bjeirmi, 1996; Fortune and White, 2006). As articulated by the Project

52 Management Institute (PMI, 2013), projects are temporary in nature, and project management  
53 success should be measured in terms of criteria related to completing the project within scope, time,  
54 cost and risk baselines as approved between the project manager and the client's representatives.  
55 Successful delivery is a key outcome on any project, but measuring success remains controversial.  
56 International standards such as the *PMBOK® Guide* appear to increasingly avoid the issue and  
57 focus more on practice and procedure for the discipline (Langston, 2013).

58 This study aims to contribute to measuring successful performance of a mega construction project  
59 in Iran using a new 3D Integration Model (introduced in Langston, 2013) in order to understand the  
60 relationship between specific key performance indicators (KPIs) based on all core knowledge areas  
61 contained in the PMI's *PMBOK® Guide* (PMI, 2013), integration of environmental concerns (as an  
62 emerging area of professional responsibility) and the objective measurement of overall project  
63 delivery success.

64 The specific contribution to knowledge presented in this paper is threefold, namely:

- 65 1. to further develop Langston's 3D Integration Model by extending it to incorporate triple  
66 bottom line (TBL) reporting and verifying the application of the model to an actual mega  
67 project,
- 68 2. to retrospectively compare the planned and actual performance of the project using this  
69 model and recommend possible corrective actions that might improve its success, and
- 70 3. to authenticate the model that has, until now, never been tested in practice.

71 This paper is divided into five further sections. The underpinning theory for measuring project  
72 success is dealt with next. Then Langston's 3D Integration Model is summarized and extended to  
73 incorporate TBL considerations. The methodological approach of the research is presented,  
74 followed by an analysis and discussion of the case study. The final section reflects on the model's  
75 application to the case study and makes some recommendations for future practice.

76 **Context**

77 *Mega Infrastructure Projects*

78 Mega infrastructure projects are worthy of research and investigation not only because of their  
79 exceptional physical scale, cost, impact and the specific institutional arrangements involved to  
80 develop them, but also their comparison with the more regular practices of local actors often reveals  
81 insights into the wielding of power and influence (Altshuler and Luberoff 2003; Kennedy et al.,  
82 2011, Robbins, 2015). The US Federal Highway Administration defines mega projects as major  
83 infrastructure that costs more than US\$1 billion, or projects of a significant cost that attract a high  
84 level of public attention or political interest because of substantial direct and indirect impacts on the  
85 community, environment, and budgets (Flyvbjerg, 2003).

86 Subway projects in Tehran have significant impact on all aspects of social life in the world's  
87 seventeenth largest city with the largest annual growth in Asia (World Gazetteer, 2012), and hence  
88 can be deemed as a mega project. They have the characteristics of large scale, diverse goals, long  
89 implementation cycles, uncertainties, multi-technology integration, strong innovation, complex  
90 industry association and enormous economic and social environment impact, which makes them  
91 significantly different from other construction (Zhang and Xue, 2014). Flyvbjerg (2003) stated that  
92 numerous mega infrastructure projects have suffered from surprisingly poor performance records  
93 and cost overruns. Researchers and practitioners have long searched for ways of improving delivery  
94 success in these mega projects and argued that the prevalence of project failures may be due to the  
95 problems associated with traditional project management theory (Chang et al., 2012).

96 *Project Success*

97 Project success has been discussed for years in project management literature (de Carvalho and  
98 Rabechini Jr, 2015), revealing the socio-political criteria that govern project performance (Sage  
99 et al., 2014). The traditional view of project success is associated with fulfilling time, cost and  
100 scope objectives. Financial criteria have been used to measure project performance, including

101 economic return, cost-benefit analyses and profit (de Carvalho et al., 2015), but it is now  
102 acknowledged that social and environmental criteria are also important.

103 Project success may be measured by its efficiency in the short term and its effectiveness in  
104 achieving medium and long-term benefits (Jugdev et al., 2001; Müller and Jugdev, 2012). There  
105 seems to be no simple definition for this construct – it can be measured differently for  
106 various types of projects, from a range of perspectives, at numerous points in time, and in  
107 absolute or relative terms (Samset, 1998). It is a multidimensional construct (de Carvalho  
108 and Rabechini Jr, 2015; Samset, 1998; Shenhar and Dvir, 2007). Therefore, different stakeholder  
109 groups have their own perceptions of project success (Chou and Yang, 2012; de Vries, 2009;  
110 Davis, 2014; Toor and Ogunlana, 2010). Every project could be different.

111 To help define the characteristics of project success, Lim and Mohamed (1999) argued that there  
112 are two possible viewpoints: macro-level success and micro-level success. The macro-level  
113 viewpoint involves the question of whether the project delivers the intended (designed)  
114 performance and therefore meets or surpasses original expectations. Usually the end users and  
115 project beneficiaries (perhaps society in general) are the ones looking at project success from this  
116 perspective. The micro viewpoint deals with the construction/delivery parties such as consultants  
117 and contractors. Cooke-Davies (2002) offers a difference between project success, which is  
118 measured against the overall project objective, and project management success, which is  
119 measured against the traditional measures of cost, time, and scope. Alarcón et al. (2001) have  
120 argued that the triple constraint is not adequate for continuous improvement since it is ineffective  
121 in identifying the causes of productivity and quality risks. These parameters do not provide an  
122 adequate vision of the potential for improvement and the information obtained usually arrives too  
123 late for corrective action to be taken.

124 Limitations of the traditional way of measuring success are clearly known (Alarcón et al., 2001;  
125 Shenhar et al., 1997; Shenhar, 2004; Al-Tmeemy et al., 2011), and researchers have started to talk

126 about introducing new success measures, such as participant satisfaction (Al-Tmeemy et al., 2011;  
127 Pocock et al., 1996). Shenhar et al. (2001) offered the four criteria of project efficiency,  
128 customer's benefit, organizational success and future potential to the organization. Bryde and  
129 Robinson (2005) have used five sets of success criteria, including cost, time, meeting the technical  
130 specifications, and customer and stakeholder satisfaction. Crawford and Pollack (2004) grouped  
131 construction project success criteria into objective measures (e.g. time, cost, safety and  
132 environment) and subjective measures (e.g. quality, functionality and satisfaction of different  
133 project participants). Frödell et al. (2008) offered an empirical approach that defined success  
134 measures like keeping the project on time, within budget, maintenance costs and project goals as  
135 well as ensuring overall profitability. Even a trilogy perspective framework for construction  
136 projects was suggested by Elattar (2009), where the client's perspective (e.g. time, cost,  
137 functionality, end result, quality, aesthetic value, profitability, marketability, less aggravation), the  
138 designer's perspective (e.g. satisfied client, quality, cost and profit, professional related issues like  
139 staff fulfillment, marketable product, less construction problems, no liability, socially accepted,  
140 client pays and well defined scope of work) and the contractor's perspective (e.g. time, cost,  
141 quality, free from claims, clearly defined expectation from all parties, client satisfaction, as well as  
142 less surprises during delivery) are all considered criteria for project success. So a confusing array  
143 of competing frameworks for analysis of project success currently exists.

144 Some researchers have merged the strategic impact of projects with other dimensions of project  
145 success (Al-Tmeemy et al., 2011). Baccarini (1999), for example, has split project success into  
146 two components. The first one is project management success, which consists of the basic criteria,  
147 project management process and stakeholder satisfaction. The other component is product success,  
148 which comprises owner strategy, user satisfaction, profitability and market share. Similarly, Chan  
149 and Chan (2004) proposed two groups of KPIs for construction project success. The first group  
150 was objective indicators (time, cost, safety, and environment) and the second group was subjective  
151 indicators (quality, functionality and satisfaction of diverse project stakeholders).

152 Blindenbach-Driessen and van den Ende (2006) conducted research to evaluate the performance of  
153 development projects and came to a similar position. They proposed a project success model that  
154 included two constructs. The first construct was project success, which related to the development  
155 process of new products and services. The second one was market success, which covered the  
156 commercial outcome of a development project. In the latter case, Takim and Adnan (2008) also  
157 defined five groups: learning and exploitation, client satisfaction, stakeholder objectives,  
158 operational assurance and user satisfaction. Qureshi et al. (2009) presented a model called project  
159 management performance assessment (PMPA) for construction projects that introduced KPIs as a  
160 prerequisite for measuring achieved project performances. Ngacho and Das (2014) developed a  
161 multi-dimensional performance evaluation framework comprising time, cost and scope to capture  
162 economic dimensions while safety and site disputes accounted for societal risks and site impact  
163 accounted for environmental risks. Todorovic et al. (2015) offered a framework based on critical  
164 success factors, project performances, KPIs and project environment methods and models  
165 developed so far. Finally, Ofori-Kuragu et al. (2016) offered a suite of nine KPIs including quality,  
166 client satisfaction, cost, time, business performance, health and safety, environment, productivity  
167 and people, developed for Ghanaian contractors that can be used for performance measurement.

168 Langston (2013) argued that it is vital to ensure the criteria upon which success is judged is clear  
169 from the outset. Businesses use KPIs for this purpose. Bryde (2005, p.119) argued that the general  
170 absence of KPIs in project management should be redressed. He concluded that this is “*seen to*  
171 *contribute to a failure by organizations to manage necessary increases in their project*  
172 *management capability and to be acting as a possible barrier to long-term, sustainable*  
173 *improvements in performance*”. A detailed search of the *PMBOK® Guide* shows that discussion of  
174 KPIs is virtually absent.

175 An important consideration, however, is to develop an approach that is generic and hence able to  
176 be applied to any type of project in any industry. It should focus on successful delivery (i.e. the



177 role of the project manager) and not be confused with other perspectives of success such as design  
178 innovation, aesthetics and comfort, and matters that relate to functional performance, such as long  
179 life (durability), loose fit (adaptability) and low energy (sustainability). It should also enable the  
180 delivery success of different projects to be compared objectively at any chosen level of  
181 clusterization.

182 From a typical project manager's perspective, it is often contended that successful delivery is  
183 characterized by the following criteria:

- 184 1. within budget
- 185 2. on time
- 186 3. as specified
- 187 4. no surprises

188 This can be alternatively described in the context of cost, time, scope and risk respectively. These  
189 criteria (or core project constraints) form the foundations of the 3D Integration Model (Langston,  
190 2013).

### 191 **3D Integration Model**

192 Langston's model (shown in Fig. 1) for describing project integration takes the form of a  
193 tetrahedron containing all knowledge areas existing in the *PMBOK® Guide* (Fifth Edition), plus a  
194 new area of project environmental management to recognize the emerging importance of  
195 sustainability in modern projects. He contends this model can be used to assess the performance of  
196 project teams in delivering successful outcomes at various stages in the project life cycle through  
197 the identification of core project constraints (occupying the four vertices of the model) and six KPIs  
198 (represented by the edges of the model). KPIs express the relationships between constraints, are  
199 relevant to any type of project, and are capable of objective measurement (Langston, 2013).

200 Insert Fig. 1 here

201 This 3D project integration model includes six generic KPIs that are related to project delivery  
202 success (PDS), and comprise:

203 1. *Value*. Defined as the ratio of scope over cost (objective: maximize). Value is a function of  
204 Project Stakeholder Management, namely meeting expectations and fostering engagement.  
205 Scope is treated as an output and cost is treated as an input, so the more utility per unit of  
206 cost the greater is the value for money.

207 2. *Efficiency*. Defined as the ratio of cost over time (objective: maximize). Efficiency is a  
208 function of Project Human Resource Management, namely team performance and  
209 leadership. Cost in this case is treated as an output (value of work completed) and time as an  
210 input, so the more money spent per unit of time the more efficient is the delivery process.

211 3. *Speed*. Defined as the ratio of scope over time (objective: maximize). Speed is a function of  
212 Project Procurement Management, namely outsourcing strategies and parallel supply chains.  
213 Scope is treated as an output and time as an input, so the more utility provided per unit of  
214 time the faster is the delivery process.

215 4. *Innovation*. Defined as the ratio of risk over cost (objective: maximize). Innovation is a  
216 function of Project Communications Management, namely knowledge management and  
217 research-informed learning. Risk is treated as an output (innovation leads to development  
218 risks) and cost as an input, so a higher level of risk per unit of cost reflects the search for  
219 better ways of doing things.

220 5. *Complication*. Defined as the ratio of risk over time (objective: minimize). Complication  
221 (originally ‘complexity’) is a function of Project Quality Management, namely excessive  
222 quality assurance paperwork and engineering over design. Risk is treated as an output and  
223 time as an input, so a higher level of risk per unit of time is a sign of project difficulty that  
224 should be avoided.

225 6. *Impact*. Defined as the ratio of risk over scope (objective: minimize). Impact is a function of  
226 Project Environmental Management, namely adverse sustainability outcomes and  
227 unnecessary resource consumption. Risk is treated as an output and scope as an input, so a  
228 higher risk level per unit of utility reflects unwanted environmental disruption.

229 The relationships among the core project constraints of cost, time, scope and risk and the KPIs of  
230 value, efficiency, speed, innovation, complication and impact are illustrated in Fig. 2. A 2D version  
231 of the model is presented here for ease of comprehension, but it turns into a 3D tetrahedron by  
232 ‘folding’ along the dotted lines. Core project constraints, which are equally weighted, are shown in  
233 upper case. Clearly it is impossible to optimize all KPIs given that most constraints act as outputs in  
234 some cases and inputs in other cases (Langston, 2013).

235 

236 Overall success (computed as the change in PDS between planned and actual performance) is given  
237 by the following formula (Langston, 2013):

238 
$$Project\ Delivery\ Success\ (PDS) = \frac{s^3}{ctr}$$

239 where  $s$  = scope baseline,  $c$  = cost baseline,  $t$  = time baseline and  $r$  = risk baseline

240 In recent years, the importance of environmental sustainability has emerged and captured the  
241 attention of project management teams (e.g. Fernández-Sánchez and Rodríguez-López, 2010;  
242 Ebbesen and Hope, 2013; Hwang and Ng, 2013). The construction industry has a significant  
243 influence on the environment and society, and is a major sector involved in achieving sustainability  
244 (Shi et al., 2012), but environmental impact applies to all activities regardless of industry sector.  
245 Not only are environmental controls likely to impact on project outcomes and choices, but the wider  
246 moral imperative of a sustainable future has led to concern that the balance between economic,  
247 social and environmental criteria (i.e. TBL thinking) is not well served by the current *PMBOK®*  
248 *Guide*. In much the same way that stakeholder management was separated from communications

249 management and elevated to higher importance in Edition 5 of the guide, so too will environmental  
250 management need to be extracted from scope, quality, procurement and risk management and given  
251 more prominence and coherence. Sustainability considerations are paramount to our collective  
252 future (Langston, 2013).

253 Langston (2013) uses the four vertices of the tetrahedron to represent core project constraints of  
254 scope, cost, time and risk and the six edges to represent KPIs of value, efficiency, speed,  
255 innovation, complication and impact. The four faces of the tetrahedron were not ascribed meaning.  
256 In this paper, Langston's 3D Integration Model is extended to add TBL as an integral part of the  
257 measurement of project delivery success, effectively forming a fifth core project constraint.

258 Each face of the tetrahedron can reflect an aspect of sustainable development. Beech (2013)  
259 proposed the '4Ps' approach to measuring sustainability: profit, people, planet and progress. When  
260 applied to the model, the three KPIs bounding each face simplify to respective performance indices  
261 (as shown in Fig. 3). For example, the face called 'profit' is bounded by the KPIs of value,  
262 innovation and impact. Value (scope over cost) and innovation (risk over cost) need to be  
263 maximized, while impact (risk over scope) needs to be minimized. When multiplied together, this  
264 reduces to  $s^2/c^2$ . Projects should be progressive, not regressive, and this can be assessed by the  
265 average of profit, people and planet indicators being positive. Balancing TBL forms a fifth  
266 constraint to measuring success by embedding ethical behavior into procurement decisions. Indeed,  
267 'doing the right project' is arguable more important than 'doing the project right'.

268 Insert Fig. 3 here

269 As explained, 'profit' is a function of both scope and cost (i.e.  $s^2/c^2$ ), and hence has similarities with  
270 the measurement of the value KPI, which seems perfectly reasonable given a context of economic  
271 performance. Likewise, 'people' is a function of scope and time (i.e.  $s^2/t^2$ ) with connections to the  
272 speed KPI, and contributes to social performance by ensuring that projects are procured in a timely  
273 fashion so that their benefits to society are realized sooner. From an environmental perspective,

274 'planet' combines scope and risk (i.e.  $s^2/r^2$ ) and hence displays similarities to the impact KPI. In all  
275 three cases, if scope increases and either cost, time or risk decrease, then TBL performance is  
276 enhanced.

277 Ethical behavior by project managers is modeled by the computed value of 'progress'. Progress is a  
278 combination of efficiency (i.e.  $c/t$ ), innovation (i.e.  $r/c$ ) and complication (i.e.  $r/t$ ), where the latter is  
279 minimized while the others are maximized. Progress has no unit, as is seen by multiplying  $c/t$  with  
280  $r/c$  and dividing by  $r/t$ . For this reason, the average of profit, people and planet is used to measure  
281 progress. The answer must be positive.

282 Furthermore, not only should profit, people and planet be equally weighted, but an even balance  
283 between them would be ideal. This may not always be possible or even desirable. For some  
284 projects, profit may be a low priority. Where it is appropriate, however, balance might be judged by  
285 ensuring the percentage change between planned and actual performance for the highest scoring  
286 criteria is not more than double the lowest scoring criteria, assuming both are positive numbers.

287 The inclusion of TBL into the 3D Integration Model completes it conceptually, and enables projects  
288 to be assessed not only in terms of their PDS score (higher the better) but also on their TBL score  
289 (positive and balanced). This is a new contribution to the existing work described in Langston  
290 (2013) introduced here for the first time.

291 Project Integration Management, a key knowledge area in the *PMBOK® Guide*, is intended to  
292 ensure that the right balance between all other parts of a project is achieved. In essence, it assesses  
293 scope, time, cost, quality, human resource, communications, risk, procurement, stakeholder (and  
294 now environment) holistically. The 3D nature of the model itself reflects how such integration is  
295 handled. By incorporating all *PMBOK® Guide* knowledge areas together, all aspects of project  
296 delivery and sustainability are embedded, so the argument to include further issues is diminished.

297 The key point here is that the four core project constraints (scope, cost, time and risk) and six KPIs  
298 (value, efficiency, speed, innovation, complication and impact) in the 3D Integration Model are

299 generic and apply to every project type. While the PDS score is based on the generic set of KPIs,  
300 there is no reason why secondary KPIs cannot be used to also measure success. These can be  
301 treated separately. For example, if the level of disputes on site is important (perhaps due to  
302 industrial relations or design change), then a new KPI can be employed based on the number of  
303 disputes per month. Obviously minimizing this KPI would be of benefit, and a target of one dispute  
304 per month might be a goal of the project manager. However, the six KPIs described early should be  
305 considered as mandatory and form a mechanism to enable projects to be compared and ranked for  
306 project success within an organizational portfolio, or ultimately at a regional, national or  
307 international level. This is a benefit no previous success model or paradigm can claim. The addition  
308 of TBL makes the model even more powerful.

309 The literature, however, does frequently note that project satisfaction is an important criterion for  
310 success. Obviously, satisfaction is a generic concept and can apply to all project types. It is  
311 undoubtedly relevant. Logically stakeholder satisfaction will be realized when the PDS score is  
312 better than forecast. Yet it is conceivable that even if all KPIs are delivered, one or more  
313 stakeholder groups may remain dissatisfied. Perhaps specific stakeholders had objectives that  
314 conflicted with the way the project manager made decisions based on the recognized power and  
315 influence of most stakeholders. Therefore, the question arises as to whether stakeholder satisfaction  
316 is a success criterion or a phenomenon. The latter is suspected. Given that satisfaction of the  
317 project's designed performance can be difficult to untangle from satisfaction with the delivery  
318 process, attempting to embed satisfaction formally in the 3D Integration Model is considered  
319 unwise.

320 Finally, it is worth pointing out that changes occur during project delivery. Planned performance  
321 will seldom equal actual performance. Changes are normally agreed and approved and lead to  
322 revised baselines for scope, cost time and risk. Overall success, as represented by comparing  
323 planned and actual PDS scores, is presented as a percentage change and may be positive, negative

324 or zero. A question arises whether the model is measuring the success of the project manager or the  
325 effect of decisions largely influenced by external factors. This question requires further analysis.

## 326 **Research Method**

### 327 *Case Study*

328 To explore this question, Langston's 3D Integration Model is applied to a mega subway  
329 construction project in Iran that involved significant change to the original plan. Computed planned  
330 and actual performance is used to determine whether project delivery success is achieved, and the  
331 result is compared to participant judgment and reflection.

332 The case study lies in the heart of Tehran's metropolitan area. This capital city of 8 million people  
333 is one of the most populated urban centers in the Middle East and forms the backbone of socio-  
334 economic development in Iran. The authors have worked on this construction project for several  
335 years. Site visit, analytical observations and data collection were carried out during the execution  
336 phase. Basic project data such as contract value and size of construction, and essential data such as  
337 detailed technical specifications, construction techniques and other onsite control practices were  
338 collected and recorded. Some interview sessions with key personnel such as the site manager and  
339 the head of the technical office were also performed.

340 A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-  
341 life context, especially when the boundaries between the phenomenon and context are not evident  
342 (Yin, 1994). Moreover, Benbasat et al. (1987) emphasized that a case study is a strong methodology  
343 that allows researchers as well as practitioners to study information systems in natural settings,  
344 learn about the state of the art, and generate theories from actual performance. A case study allows  
345 the researchers to explain the nature and complexity of the process that is taking place and gain an  
346 in-depth understanding of the phenomenon under investigation. In this regard, a case study is used  
347 for exploring new phenomena where quantitative research methodologies are not possible or  
348 appropriate (Benbasat et al., 1987; Yin, 1994). Typically, a case study research approach is flexible,

349 and may include multiple data collection methods such as documentation, interviews,  
350 questionnaires and field observations. In this case, the data collection methods included gathering  
351 archival material, analyzing project outcomes and conducting face-to-face interviews. Therefore,  
352 the use of a case study approach is appropriate to answer the question about what the 3D Integration  
353 Model is in fact measuring, as it is a conceptual framework that to date has never been adopted or  
354 used on a real project. The selected case study was chosen on the basis that it involved significant  
355 change external to the project team, potentially leading to an outcome that the project team could do  
356 little about.

### 357 *Tehran Subway Development*

358 Subways are constructed in major cities like Tehran to overcome the transportation problems  
359 associated with urbanization. The Tehran Urban and Suburban Railway Operation Company  
360 (TUSROC) believe that the Tehran subway development will result in savings of up to USD 18  
361 billion per annum in terms of time and energy. The economic benefits of subway construction are  
362 clear considering the cost of constructing 20 km of subway tunnels and stations is around USD 650  
363 million (Darvish, Head of TUSROC, 2015). Subway construction projects are essential in Tehran in  
364 view of the city's traffic congestion. The success of such projects is vital for sustaining economic  
365 growth and social wellbeing (Ghanbaripour et al., 2015). The ability to travel efficiently inside the  
366 city and connect to suburbs in a safe environment whilst reducing environmental pollution and  
367 creating a calm and relaxed social atmosphere for travelers are some of the attractions of this type  
368 of infrastructure. It facilitates the optimum deployment of urban transportation, decreases commuter  
369 travel times and reduces accidents (Yousefi and Ghanbaripour, 2015).

370 This research focuses on the construction of one of many underground stations. The case project is  
371 located beneath some of the most crowded streets in Tehran. The construction method is a general  
372 procedure that has been used in Tehran subway projects for many years. The main ribs comprising  
373 21-meter spans (see Fig. 4) are to bear the weight of the soil above the station, and this weight is



374 transferred through piles into the foundation material. The main structure of the station is shown in  
375 Fig. 5, while Fig. 6 provides insight into the design including a cross-section of the subway station  
376 and the construction sequence adopted from the first stage (denoted as step 1) to the final structure  
377 (denoted as step 8).

378 Insert Fig. 4, 5 and 6 here

379 Subway construction projects like any other social project involve public funds, follow set  
380 procedures and almost always require multiple entities such as contractors, subcontractors,  
381 engineers, architects, project management firms and government agencies who work together to  
382 deliver the required outcomes. Achieving success in public projects is difficult because it requires  
383 economy, efficiency, quality, fairness and transparency (Tabish and Jha, 2011).

384 Langston's 3D Integration Model is implemented and tested on one of the new subway station  
385 contracts that was initially estimated to cost USD 25 million and take 24 months to complete. The  
386 authors interviewed the site manager, technical office manager, and seven engineers from the site  
387 who have been involved in core management, engineering and contractual processes. Since  
388 information on many aspects of the project including scope, time, cost and risk was required,  
389 several meetings were held with the project and site managers, client's consultant, technical office  
390 director, and many of the contractor's engineers working in diverse sections of the site. This  
391 enabled the researchers to extract the necessary data to measure planned and actual performance for  
392 the project. All people interviewed had more than 10 years of professional experience in this field.

### 393 **Data Collection**

#### 394 *Scope Baseline*

395 Constructing a subway station includes a wide range of technologies, equipment and expertise in a  
396 range of specialist fields, and usually takes a long time from design to completion. The most  
397 important work in this project was the construction of the base plate, top arches, side beams and

398 piles that comprise the main structure of the station. In this study, total volume of the concrete is  
399 adopted as the scope of the project for the following reasons:

- 400 1. Concrete work is the main element of the underground subway station. All structures are  
401 made of concrete and it also includes embedded reinforcement and shuttering.
- 402 2. Concrete work is the largest factor affecting the project's expected construction cost and  
403 time to complete.
- 404 3. It is easily measured as the volume ( $m^3$ ) delivered to site and cast in place.

405 So, by using concrete volume as the defining element of the project's scope, an effective way to  
406 describe the project's scale is captured. It is considered a better method for measuring scope than  
407 plan area or footprint. The design team documented a volume of 40,000  $m^3$  of concrete necessary  
408 to complete the project.

409 Actual scope was increased during the construction of the project, culminating in about 43,000  $m^3$   
410 of concrete being placed. This was beyond the control of the project team and was due primarily to  
411 economic impacts, design amendments, stakeholder conflict and latent ground conditions. An  
412 increase in project scope usually means that pressure is exerted on cost, time and risk baselines  
413 unless the delivery team can find offsets through smarter procurement or implementation solutions.  
414 In this case study, such offsets did not appear to have eventuated.

#### 415 *Cost Baseline*

416 The contract sum for the case study project was USD 25 million. The price comprised the  
417 contractor's cost, margin and contingency. Based on the data obtained, the final cost was nearly  
418 USD 27 million ignoring inflation.

#### 419 *Time Baseline*

420 The project's timeframe was September 2008 to September 2010 inclusive (24 months). Since  
421 subway projects aim to improve public transportation, timely completion that minimizes disruption

422 to the local community is critical. A detailed Gantt chart was prepared in the planning phase with  
423 several milestones that had to be achieved. Based on the data collected, the actual time from  
424 commencement on site to project completion was 36 months and many of the milestones were not  
425 delivered on time. This led to an overrun of 12 months or 50%.

#### 426 *Risk Baseline*

427 To extract the planned risks of the project, the researchers reviewed the risk register that was  
428 prepared during the initiation phase. Although this document was a preliminary one, it provided  
429 some useful data. In order to obtain the list of actual risks, face-to-face interviews with the director  
430 and members of technical office were conducted. The interviews were audio-recorded and hand-  
431 written notes were also taken. A list of actual risks and impacts was then produced. In this case,  
432 actual risk was calculated by assuming each identified risk had a probability score of 5 (i.e.  
433 probability was now 'certain'). Any unforeseen risks would have been added to the calculation,  
434 although there were none in this case. If a risk event had little or no impact on the project, then it  
435 was scored 1, while at the other end of the scale a score of 5 indicated that a significant impact had  
436 happened. The risk register is summarized in Table 1.

437 Insert Table 1 here

438 Risk level was computed as the multiplication of probability and impact, and hence may be a value  
439 between 1 and 25 inclusive. A 5x5 assessment matrix was applied in this process, although this is  
440 irrelevant to the method. The planned and actual risk baselines were computed as the mean of  
441 individual risk levels. Based on the data collected, the expected mean risk score was 7.32 and the  
442 actual mean risk score was 9.03. The increase in actual risk suggests that cost and time pressure  
443 were also likely to occur.

444

445 **Analysis and Discussion**

446 *Planned versus Actual*

447 Table 2 shows the calculation method for each KPI in the 3D Integrated Model, and computes the  
448 percent increase or decrease between planned and actual performance. The change in PDS score  
449 (combining all six KPIs) is negative, and therefore indicates the delivery of the project was not  
450 successful. TBL scores are also shown, suggesting that profit, people and planet criteria were all  
451 adversely impacted, and hence the case study might be interpreted as regressive. Innovation and  
452 complication show positive outcomes (+14.22% and +21.59%), while value, efficiency, speed and  
453 impact are negative (-0.46%, -28.00%, -28.33% and -12.86%).

454 Insert Table 2 here

455 Value for money was considered the most important objective for this case study, and therefore the  
456 value KPI should display the highest positive % change of any KPI. In an ideal scenario, the  
457 number of negative KPIs should be minimized (normally no more than two should be negative).  
458 Furthermore, it would be ideal if profit, people and planet scores are both positive and balanced (i.e.  
459 highest score no more than double lowest score). Projects must be progressive (i.e. have a positive  
460 ‘progress’ score), not regressive. Most importantly the change in PDS scores between planned and  
461 actual should be positive and as high as possible. These heuristics collectively help to define  
462 optimum performance.

463 Change in PDS can be used to compare the success of this case study against sections of the subway  
464 project, other government projects of different types and scales, and across industries or even  
465 countries, regardless of time. The higher the percent change in PDS the better. Individual KPIs and  
466 TBL scores add further insight into actual project performance.

467

468 *Stakeholder Perceptions*

469 To obtain a practical point of view, the authors conducted face-to-face semi-structured interviews to  
470 recognize whether, from the perception of the main stakeholders, the project was considered  
471 successful or not. Following is the opinion of the project manager as collected during the interview  
472 process:

473 *There are both social and economic expectations out of subway projects like any other*  
474 *public project. Such projects are initiated based on the demand of general public end-*  
475 *users and most of the time involve multiple stakeholders and are also accountable to*  
476 *external financial audit and careful governmental agencies. Hence, late and over*  
477 *budget completion would harm the expected results, excessive loss of money and efforts*  
478 *and scratch the credibility of project itself.*

479 *This subway construction project suffered from several unexpected surprises that had a*  
480 *huge effect on actual cost and time of the project. Diverse conflicts among main*  
481 *stakeholders, such as client, consultant, contractor, and nearby residents took place,*  
482 *and an overwhelming number of changes to scope were made accordingly. Overall,*  
483 *although this subway station is serving as a public facility and the perception of success*  
484 *or failure is sometimes time-dependent, from the view of project delivery, this project*  
485 *must be considered unsuccessful.*

486 Moreover, the result of interviews with the client's representative showed that:

487 *From the project management point of view, indeed, this project was unsuccessful.*  
488 *There were two kinds of factors that affected the project. Firstly, the factors that could*  
489 *not be controlled by the contractor like inflation. It made serious changes to the prices*  
490 *of resources, and this could be seen in initiating and planning phases. Moreover, due to*  
491 *lack of adequate information from the soil recognition, many obstacles, aqueducts and*  
492 *holes were found during the excavation process that led to scope creep and cost*

493 *overruns. Secondly, numerous conflicts among the project's stakeholders led to many*  
494 *time-consuming meetings, and these conflicts led to some added risk on the project.*

#### 495 *Alternative Actions*

496 So what would a successful outcome for this case study actually look like? To explore options that  
497 were available to the project team, the 3D Integration Model is used to find the cost, time and risk  
498 values that would have led to a successful outcome. Actual scope was assumed to be 43,000 m<sup>3</sup> of  
499 concrete work to reflect changes to the design of the project as demanded by circumstances and  
500 which, in this case, were largely beyond the control of the project manager.

501 This case study highlights that factors largely external to the project led to pressure on scope, cost,  
502 time and risk baselines and ultimately to an unsatisfactory outcome. The change in PDS score and  
503 the negative value for many KPIs indicates that the project's delivery should be considered as  
504 unsuccessful. The progress score also suggests actual performance on site is regressive and fails to  
505 contribute to profit, people or planet objectives.

506 However, this does not mean that the project is unsuccessful from other perspectives. Perhaps the  
507 people of Tehran are grateful for the provision of new infrastructure. Perhaps the subway solves  
508 numerous social problems, such as safety and loss of time due to traffic congestion. Perhaps air  
509 pollution is lowered and the new underground structures can provide shelter in time of military  
510 conflict or natural disaster. These issues highlight the distinction between project success and  
511 project *delivery* success, which in turn demonstrates why some potential success criteria (such as  
512 functionality) are not relevant to the assessment of delivery. Further, criteria that relate specifically  
513 to construction (such as worker safety) should be evaluated separately to the generic attributes of  
514 project delivery success to enable comparison of performance not just on different sections of this  
515 project, or on other projects by the same contractor, but across projects of quite different typologies.

516 Assuming the value KPI was still the main objective here, Table 3 summarizes an example of an  
517 optimal performance outcome. Cost would need to be restricted to USD 26 million, extensions of

518 time would need to be no more than one extra month, and risk would need to be restricted to a mean  
519 score of 7.62. In this case the change in PDS is computed at +10.16%. It should be noted that profit,  
520 people and planet are quite balanced and the project is now considered progressive. This  
521 perspective would inform the project manager of what would be needed to deliver the project  
522 successfully given the increase in scope, and could form the basis of a plan to get the project back  
523 on track before it was too late.

524 Insert Table 3 here

525 This is an optimal solution, but not the optimum solution. A higher PDS score can be obtained by  
526 reducing cost and/or risk while ensuring that the defined heuristics are observed. Sensitivity testing  
527 determines the best combination of constraints that delivers the highest PDS score while complying  
528 with the rules described earlier. The highest PDS score found is +16.50%. This arises when scope  
529 equals 43,000 m<sup>3</sup> (given), cost equals USD 25,281,315, time equals 25 months and risk equals 7.41.

530 It must be remembered that the scope (i.e. volume of concrete) has increased 7.5% over its baseline  
531 while cost has increased only 1.1% over its baseline, plus risk needs to be reduced from 9.03 to 7.41  
532 and probably can be achieved only by spending more on mitigation. In both cases, therefore, further  
533 cost savings must be found. It is recommended that a value engineering process would have been  
534 necessary to identify where those savings might lie.

535 The level of scrutiny and quantification afforded by the model distinguishes it from other forms of  
536 analysis that are less integrated or overly time consuming to implement. It is hence argued that  
537 normal post-project review may have shown that the project was unsuccessful and highlighted the  
538 cause(s), but not facilitated a proactive adjustment during project delivery to arrive at a successful  
539 outcome (albeit different from the original plan). While the retrospective study undertaken in this  
540 paper cannot influence what occurred on site, in normal circumstances application of the model  
541 would occur in real time and be able to adapt the project's trajectory towards a superior result.

542 This case study has shown that the 3D Integration Model is capable of not just describing the  
543 outcome of external factors, which may or may not be welcome, but how the project team deals  
544 with these matters to ensure that success remains a clear objective. Despite the change in scope,  
545 other actions could have been pursued to minimize the impact on cost, time and risk and still deliver  
546 a successful outcome. Agreed variations to scope, therefore, are not directly responsible for success  
547 or failure. Scope, cost, time and risk are related together and dictate what successful project  
548 delivery might look like.

549 So the key point here is that projects change over their delivery period, and this may be for good  
550 reason and with mutual consent. It is the ratio of scope, cost, time and risk constraints that  
551 determines if the change was well handled or if it resulted in poor performance overall or in specific  
552 areas. Unforeseen events that lead to different outcomes can be explored, with outcomes assessed in  
553 terms of delivery success or failure. Ultimately the 3D Integration Model measures the performance  
554 of the project manager and team despite changes that may arise from external sources, enabling a  
555 'progressive' (not regressive) delivery outcome to be secured.

## 556 **Conclusion**

557 Performance measurement is one of the most important aspects of project management, especially  
558 for public sector projects. In recent years, there has been much effort applied to measuring success.  
559 These developments show that no consensus view has emerged to date. In a world of intense  
560 competition, projects are no longer seen as routine tasks or business-as-usual. Instead, projects are  
561 increasingly seen as powerful strategic weapons that organizations can use to enhance their  
562 competitive advantage, increase market share, compete in a dynamic and highly commercial  
563 environment, be good corporate citizens and create value for their clients and other stakeholders.  
564 The mindset of project performance management must transform from an operational/functional  
565 nature to more of a strategic focus. As there are different needs and different goals for any given  
566 project, performance measurement should also be capable of generic application.



567 Theoretically, implementing the 3D Integration Model and the insights accrued from the subway  
568 project case study provide empirical support to the view that measures for project success need to  
569 be broadened beyond the traditional iron triangle.

570 New empirical knowledge to the relatively recent research on project success is added by applying a  
571 practical evaluation model to a real project. Such knowledge can provide guidance for project  
572 managers to measure their projects' performance objectively. This paper makes a practical  
573 contribution through the analysis of a mega infrastructure project's performance illustrating a range  
574 of optimal PDS scores and what actions are necessary to achieve them. The findings of this study  
575 suggest that the management of future mega projects should focus more on KPIs, and actively  
576 engage with stakeholders throughout the project construction period to ensure a successful outcome.

577 While the modeling might highlight strategies that are obvious or even common sense, one must  
578 ask the question why action was not taken to correct the trajectory of the project before it was too  
579 late. Perhaps use of the model might have helped the team to assert more control or provided them  
580 with insight into how various success factors interact with each other. But more importantly, the  
581 model can establish a measure of success to judge relative performance against other projects  
582 regardless of size, type, location and sector.

583 This paper presents the results of implementing Langston's 3D Integration Model, extended to  
584 include TBL objectives, as a framework for assessing project success. It is based on a comparison  
585 of planned and actual performance using numeric values for scope, cost, time and risk constraints.

586 This model is presented in the form of a tetrahedron containing all existing knowledge areas in the  
587 *PMBOK® Guide* plus project environmental management. The six mandatory KPIs express the  
588 relationships between constraints, are relevant to any type of project and are capable of objective  
589 measurement. From the case study explored in this paper, Langston's 3D Integration Model  
590 matched the opinion of the project manager and confirmed that the subway station project was  
591 unsuccessful. But significantly, the model produced an optimum profile that may have been useful

592 in trying to get the project back on track before it was too late. If this advice had been applied  
593 during construction of the project, a better outcome may have still been possible, notwithstanding  
594 the increase in scope that was beyond the team's control. A set of heuristics is established and  
595 tested to help guide the identification of optimum performance based on the well accepted  
596 constraints of scope, cost, time and risk, and the new constraint of progress in delivering TBL  
597 objectives.

598 The model can be used to measure the success of what happened, or the success of various possible  
599 scenarios. In determining the optimum solution for the subway station, heuristics were developed  
600 and applied that led to a focus on value as the priority KPI, a need to minimize the number of  
601 negative KPIs (no more than two), pursuit of a positive percent change in PDS score (higher the  
602 better) and a positive progress score (ideally with profit, people and planet all positive and well  
603 balanced). Table 3 provided a blueprint for how a change in scope from 40,000 to 43,000 m<sup>3</sup> of  
604 concrete, with its implied pressure on cost, time and risk, can lead to an improvement in success  
605 over the original plan. If used dynamically during project delivery, the model can show how to  
606 reclaim lost stakeholder satisfaction, in much the same way that delays in time led to actions to  
607 recover and meet agreed deadlines.

608 It is a key point that the PDS score can be compared across different projects regardless of type or  
609 size or industry to measure project management performance. The percent change in PDS between  
610 planned and actual outcomes is the ranking index for success across a portfolio of projects. One  
611 could compare a garden shed with an opera house, or a software project with a government policy  
612 initiative. Hence this model enables people to assess project management performance over time.  
613 This paper makes a contribution to knowledge by testing Langston's approach, for the first time, on  
614 a real-life case study.

615 For further studies, it would be interesting to implement this model in non-construction projects  
616 (e.g. software development or service delivery) to compare the results and measure the performance

617 of the project team. This will help in the use of practical decision-making and measurement systems  
618 that will enable contractors and managers make better decisions that more consistently lead to  
619 successful projects.

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758 **Table 1.** Risk register for subway station construction

ID	Major risk events	Planned			Actual		
		<i>P</i>	<i>I</i>	<i>Risk Level</i>	<i>P</i>	<i>I</i>	<i>Risk Level</i>
1	Economic crisis	3	2	<b>6</b>	5	4	<b>20</b>
2	Inflation volatility	4	3	<b>12</b>	5	4	<b>20</b>
3	Unavailability of client funding	4	4	<b>16</b>	5	5	<b>25</b>
4	Land problems (i.e. permissions)	2	3	<b>6</b>	5	1	<b>5</b>
5	Conflict with governmental departments	3	2	<b>6</b>	5	1	<b>5</b>
6	Conflict with public stakeholders	2	2	<b>4</b>	5	1	<b>5</b>
7	Wrong site selections	1	2	<b>2</b>	5	1	<b>5</b>
8	Major contractual issues	3	3	<b>9</b>	5	1	<b>5</b>
9	Delay in solving disputes and conflict resolution	4	2	<b>8</b>	5	3	<b>15</b>
10	Change orders from diverse stakeholders	5	3	<b>15</b>	5	3	<b>15</b>
11	Conflict between project consultants	5	1	<b>5</b>	5	3	<b>15</b>
12	Inappropriate national standards	2	1	<b>2</b>	5	1	<b>5</b>
13	Inaccurate data	3	1	<b>3</b>	5	3	<b>15</b>
14	Problems with detailed design	4	2	<b>8</b>	5	1	<b>5</b>
15	Major mistakes in design	2	2	<b>4</b>	5	1	<b>5</b>
16	Major variations in construction phase	3	2	<b>6</b>	5	1	<b>5</b>
17	Time overruns in design phase	3	2	<b>6</b>	5	1	<b>5</b>
18	Delay in obtaining governmental permissions	3	3	<b>9</b>	5	1	<b>5</b>
19	Major accidents and injuries	2	5	<b>10</b>	5	1	<b>5</b>
20	Delay in approving drawings by government	3	3	<b>9</b>	5	1	<b>5</b>
21	Delay in procurements	3	3	<b>9</b>	5	1	<b>5</b>
22	Complex geological and hydrological conditions	3	5	<b>15</b>	5	3	<b>15</b>
23	Unclear subsurface utility layouts	4	2	<b>8</b>	5	3	<b>15</b>
24	Conflict with subcontractors	2	2	<b>4</b>	5	1	<b>5</b>
25	Subsurface obstacles (rocks, holes, etc.)	2	2	<b>4</b>	5	1	<b>5</b>
26	Underground water	4	4	<b>16</b>	5	3	<b>15</b>
27	Damage to adjacent buildings	2	4	<b>8</b>	5	1	<b>5</b>
28	Incompetency of team	1	3	<b>3</b>	5	1	<b>5</b>
29	Rough construction plan	2	2	<b>4</b>	5	1	<b>5</b>
30	Untrained human resources	1	4	<b>4</b>	5	1	<b>5</b>
31	Poor materials	1	5	<b>5</b>	5	2	<b>10</b>
32	Undesirable sample testing results	2	3	<b>6</b>	5	2	<b>10</b>
33	Inappropriate construction methods	1	4	<b>4</b>	5	1	<b>5</b>
34	Scope creep	3	4	<b>12</b>	5	2	<b>10</b>
35	Poor construction programming	2	2	<b>4</b>	5	1	<b>5</b>
36	Lack of sufficient rules	3	2	<b>6</b>	5	1	<b>5</b>
37	Major conflicts with neighbors	3	3	<b>9</b>	5	3	<b>15</b>
38	Lack of competent consultants	4	3	<b>12</b>	5	3	<b>15</b>
39	Lack of effective communication	2	2	<b>4</b>	5	3	<b>15</b>
40	Change of key personnel	4	2	<b>8</b>	5	1	<b>5</b>
41	Worker strike	3	3	<b>9</b>	5	1	<b>5</b>
<b>Mean risk score:</b>				<b>7.32</b>	<b>9.03</b>		

759 *P = probability; I = impact; Risk level = P × I*

760

761 **Table 2.** Calculated performance of case study as built

KPI		RATIO	PLANNED		ACTUAL		% CHANGE
<b>value</b>	maximise	scope	40,000	m3 concrete	43,000	m3 concrete	<b>-0.46%</b>
		cost	25,000,000	USD	27,000,000	USD	
<b>efficiency</b>	maximise	cost	25,000,000	USD	27,000,000	USD	<b>-28.00%</b>
		time	24	months	36	months	
<b>speed</b>	maximise	scope	40,000	m3 concrete	43,000	m3 concrete	<b>-28.33%</b>
		time	24	months	36	months	
<b>innovation</b>	maximise	risk	7.32	mean risk level	9.03	mean risk level	<b>14.22%</b>
		cost	25,000,000	USD	27,000,000	USD	
<b>complication</b>	minimise	risk	7.32	mean risk level	9.03	mean risk level	<b>21.59%</b>
		time	24	months	36	months	
<b>impact</b>	minimise	risk	7.32	mean risk level	9.03	mean risk level	<b>-12.86%</b>
		scope	40,000	m3 concrete	43,000	m3 concrete	
<b>PDS =</b>	<b>maximise</b>	<b>s<sup>3</sup> ctr</b>	<b>14,571.95</b>		<b>9,058.40</b>	<b>KPI unachieved</b>	<b>-37.84%</b>

INPUTS		PLANNED	ACTUAL	UNIT	
<b>scope (s)</b>	=	40,000	43,000	m3 concrete	<i>When using this on a project, 'planned' refers to the baselines in your PMP and 'actual' refers to the final result or a hypothetical model of what would lead to an optimal delivery outcome*.</i>
<b>cost (c)</b>	=	25,000,000	27,000,000	USD	
<b>time (t)</b>	=	24	36	months	
<b>risk (r)</b>	=	7.32	9.03	mean risk level	
					<i>(actual risk: probability = 5 and reassess impact)</i>
<b>profit</b>	=	0	0		<b>-0.92%</b>
<b>people</b>	=	2,777,778	1,426,698		<b>-48.64%</b>
<b>planet</b>	=	29,860,551	22,675,737		<b>-24.06%</b>
<b>progress</b>	=	-	-		<b>-24.54%</b>
					<i>(average)</i>
					<i>*i.e. maximum PDS score</i>

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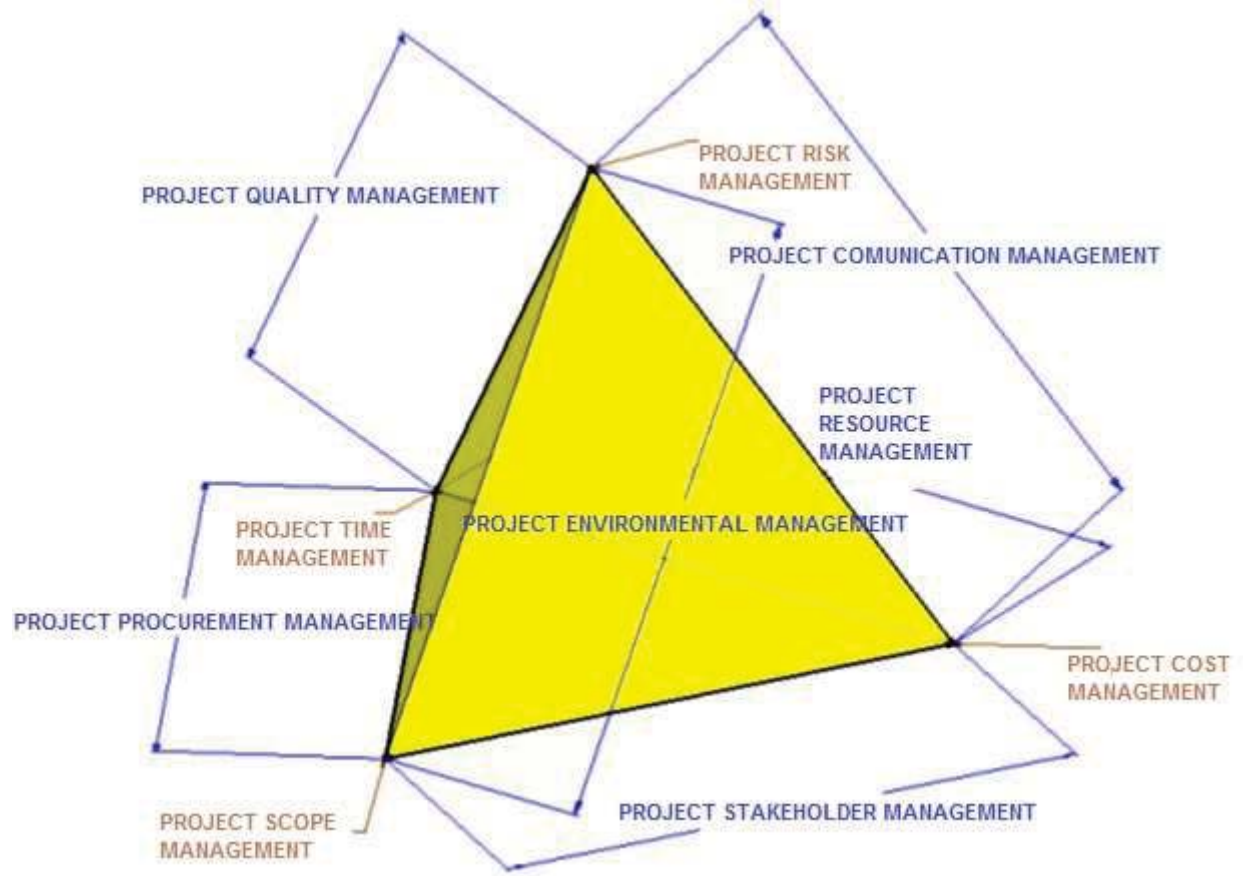
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764 **Table 3.** Calculated performance of case study to be considered successful

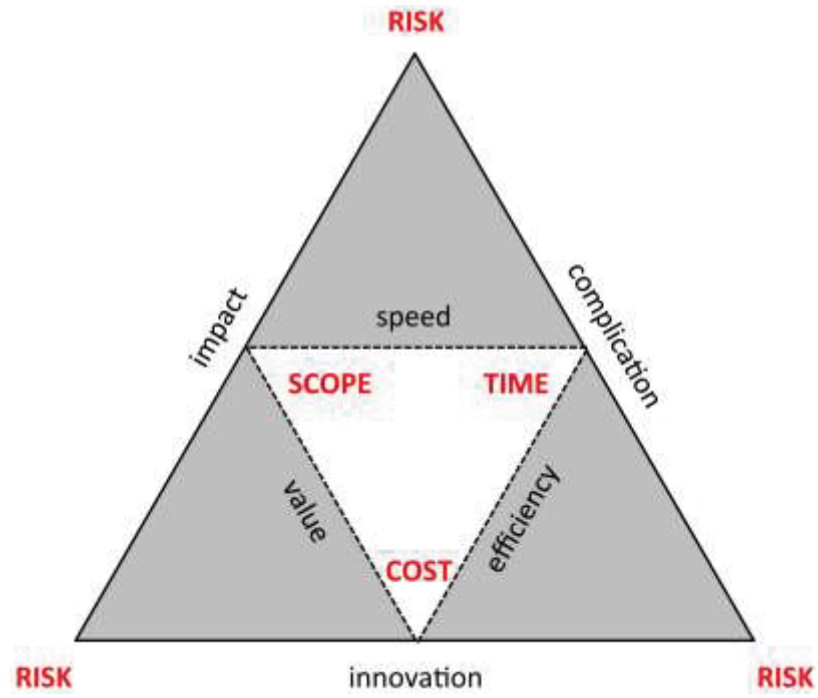
KPI		RATIO	PLANNED		ACTUAL		% CHANGE
<b>value</b>	maximise	scope	40,000	m3 concrete	43,000	m3 concrete	<b>3.37%</b>
		cost	25,000,000	USD	26,000,000	USD	
<b>efficiency</b>	maximise	cost	25,000,000	USD	26,000,000	USD	<b>-0.16%</b>
		time	24	months	25	months	
<b>speed</b>	maximise	scope	40,000	m3 concrete	43,000	m3 concrete	<b>3.20%</b>
		time	24	months	25	months	
<b>innovation</b>	maximise	risk	7.32	mean risk level	7.62	mean risk level	<b>0.09%</b>
		cost	25,000,000	USD	26,000,000	USD	
<b>complication</b>	minimise	risk	7.32	mean risk level	7.62	mean risk level	<b>0.07%</b>
		time	24	months	25	months	
<b>impact</b>	minimise	risk	7.32	mean risk level	7.62	mean risk level	<b>3.27%</b>
		scope	40,000	m3 concrete	43,000	m3 concrete	
<b>PDS =</b>	<b>maximise</b>	<b>s<sup>3</sup> ctr</b>	<b>14,571.95</b>		<b>16,052.29</b>	<b>Good job!</b>	<b>10.16%</b>

INPUTS		PLANNED	ACTUAL	UNIT	
<b>scope (s)</b>	=	40,000	43,000	m3 concrete	<i>When using this on a project, 'planned' refers to the baselines in your PMP and 'actual' refers to the final result or a hypothetical model of what would lead to an optimal delivery outcome*.</i>
<b>cost (c)</b>	=	25,000,000	26,000,000	USD	
<b>time (t)</b>	=	24	25	months	
<b>risk (r)</b>	=	7.32	7.62	mean risk level	
<b>profit</b>	=	0	0		<b>6.84%</b>
<b>people</b>	=	2,777,778	2,958,400		<b>6.50%</b>
<b>planet</b>	=	29,860,551	31,843,953		<b>6.64%</b>
<b>progress</b>	=	-	-		<b>6.66%</b>
				(average)	<i>*i.e. maximum PDS score</i>

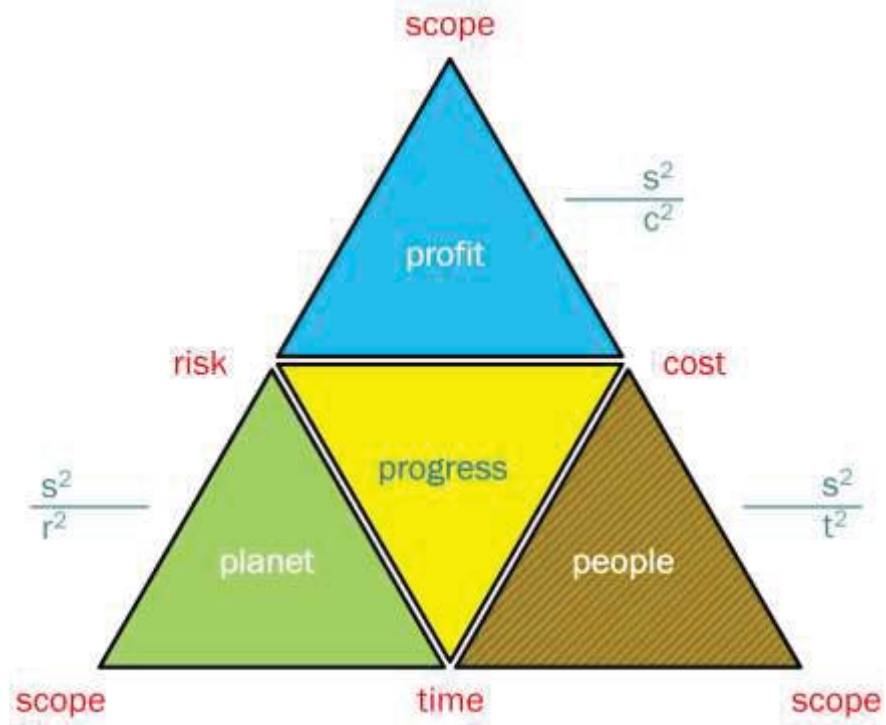
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**Fig 1.** 3D Project integration model (Langston, 2013)



**Fig 2.** Project constraints and key performance indicators (Langston, 2013)



**Fig 3.** TBL reporting applied to 3D Integration Model

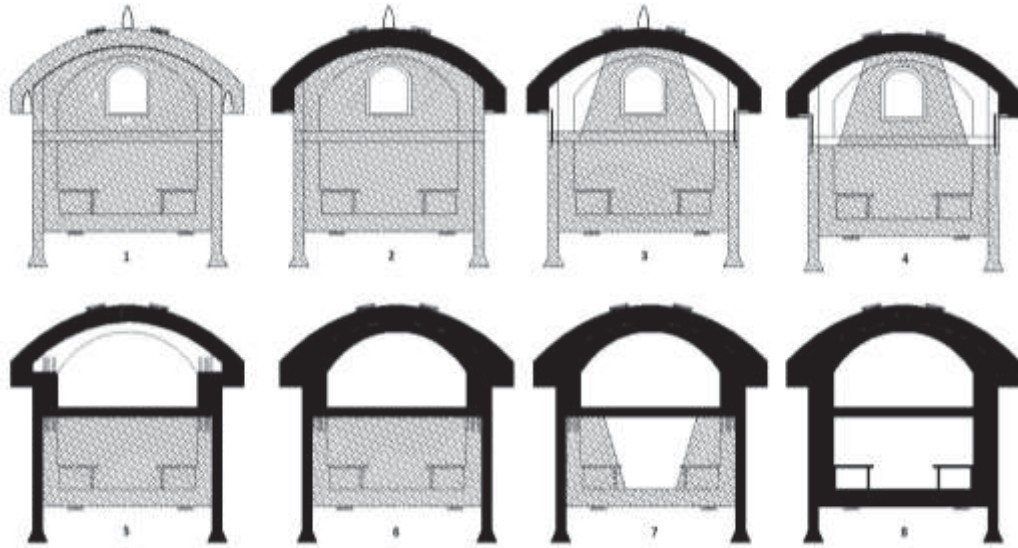


**Fig 4.** Construction of concrete ribs



**Fig 5.** Main structure of the underground station





**Fig 6.** Construction phases and method

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Fig 2. Project constraints and key performance indicators (Langston, 2013).....	10
Fig 3. TBL reporting applied to 3D Integration Model .....	11
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Fig 6. Construction phases and method .....	15