

# 1 Development of an Approach to Support Construction Stakeholders in the 2 Implementation of the Last Planner System

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## 4 Abstract

5 The implementation of the Last Planner System (LPS) has gained prominence in the  
6 construction industry and its influence on the production system seems to be rapid and  
7 significant. However, recent studies reveal that the application of LPS principles on projects  
8 is fragmented. The aim of the current study, therefore, is to develop an approach to support  
9 construction stakeholders in the implementation of the LPS. Thirty semi-structured  
10 interviews and three in-depth case studies were conducted with construction stakeholders.  
11 The study developed a non-prescriptive but all-inclusive approach for supporting construction  
12 stakeholders in the implementation of the LPS on construction projects. This study  
13 contributes to knowledge in engineering management as it provides a new insight into how to  
14 apply the LPS holistically in the management of engineering projects. The study further  
15 provides evidence into the current practice and performance of the LPS in the management of  
16 civil engineering project as demonstrated in the case studies. Finally, the identification of the  
17 three “levels of support” (organisational, project, and external enabler) provides a focal point  
18 for construction practitioners to focus on in the implementation of the LPS in the  
19 management of civil engineering project.

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22 planning and control and implementation

### 23 **Introduction**

24 The Last Planner® System (LPS) was developed in the 1990s following a research in the  
25 industrial construction sector (Daniel *et al.*, 2015; Ballard and Howell, 1994; Ballard and  
26 Howell, 1988). In reality, it creates a platform for stakeholders on the project to plan together  
27 in order to reduce uncertainty and improve the quality of the construction programme  
28 (Ballard and Howell, 2004). Priven and Sacks (2016) assert that the nature of conversations  
29 that occur within the LPS process supports the development of social networks among  
30 stakeholders in the construction process.

31 However, recent studies reveal that the application of LPS principles on projects is  
32 fragmented (Daniel *et al.* , 2017; Dave *et al.* , 2015; Koch *et al.* , 2015). For instance, Daniel  
33 *et al.*, (2017); Dave *et al.*, (2015); Koch, *et al.*, (2015) observed that the more complex and  
34 crucial elements of the LPS are not implemented in current practice in the UK. These  
35 complex elements include lookahead planning, make ready planning, root cause analysis and  
36 learning (Daniel *et al.*, 2017; Alarcon *et al.*, 2011). It is worth noting that the fragmented  
37 implementation of LPS is not only in the UK, a Norwegian study (Kalsaas *et al.* , 2014); a  
38 Vietnamese study (Khanh and Kim, 2015) and a Danish study (Lindhard and Wandahl, 2014)  
39 have also reported it. For instance, in Norway, phase planning is the most frequently  
40 implemented element (Kalsaas *et al.*, 2014); in Vietnam, lookahead planning is done  
41 superficially (Khanh and Kim, 2015) and in Denmark lookahead planning not executed  
42 (Lindhard and Wandahl, 2014). All these shows there is a need to develop an approach to  
43 support construction stakeholders in implementing the LPS effectively. In view of this, this

44 study seeks to answer this research question: *How can construction stakeholders (client, main*  
45 *contractors, and subcontractors) be supported for rapid and successful implementation of the*  
46 *LPS?*

47 The need for supporting the implementation of new techniques, and practice using  
48 frameworks (Lindhard and Wandahl, 2014, Nesensohn, 2014; Sacks *et al.*, 2010 and  
49 roadmaps (Ballard *et al.*, 2017) has been acknowledged in the literature. Previous studies  
50 have attempted to propose an approach for implementing specific lean techniques such as  
51 LPS in construction, but they tend to focus more on the project level (Lindhard and Wandahl,  
52 2014; Hamzeh and Bergstrom (2010), Dombrowski *et al.*, 2010). For instance, Lindhard and  
53 Wandahl (2014) developed a framework that focused on supporting on-site scheduling;  
54 Dombrowski *et al.*'s (2010) framework focused more on the implementation of LPS  
55 components at the project level as it provides a detailed and compressive description of tasks  
56 that have to be done during LPS implementation as shown in LPS implementation detailed  
57 planning. Ballard *et al.* , (2007) suggested a general roadmap for lean implementation with a  
58 focus on the project level, while Hamzeh and Bergstrom's (2010) framework provided an  
59 operational guideline for LPS implementation that focused more on the project level. This is  
60 despite the fact that it has been suggested that the implementation of lean techniques should  
61 expand beyond project focus and include other organisational and human factors that could  
62 influence the process (Pavez and Alarcon, 2012). This study fills this gap by developing an  
63 approach to direct LPS implementation known as *Last Planner System Path Clearing*  
64 *Approach* (LPS-PCA) that incorporates an organisational path clearing level and external  
65 enablers alongside the project path clearing level.

## 66 **Literature Review**

### 67 ***The Last Planner System***

68 The LPS is a lean construction approach. It is a production planning and control method that  
69 ensures collaboration among those doing the work and also enhances plan reliability (Ballard  
70 and Tommelein, 2016; Priven and Sacks, 2016; Gonzalez, *et al.*, 2010). In the LPS, planning  
71 and control is an integrated process as opposed to the prevailing construction planning  
72 practice, where planning and control are viewed separately (Daniel *et al.*, 2017). Ballard and  
73 Howell (2004) assert that the LPS focuses on integrating planning and production control as  
74 opposed to directing and adjusting (cybernetic model) in the traditional project management  
75 approach. The integrated approach used in the LPS supports plan reliability and leads to a  
76 reduction in task variation at the implementation stage of projects (Russell, *et al.*, 2015;  
77 Gonzalez, *et al.*, 2010; Alsehaimi *et al.* , 2014). Wambeke *et al* 's, (2011) study found that  
78 the LPS method reduces variation in planned tasks, improves project performance and  
79 supports the achievement of higher productivity of 35% when compared to a similar project  
80 not managed by the LPS method. This finding is further confirmed in studies such as  
81 Fernandez-Solis, *et al.*, (2012), and Nietro-Morote and Ruz-Vila, (2012). These studies show  
82 that the LPS method improves the reliability of planning and the quality of completed tasks.  
83 This shows the capacity of the LPS in managing the production process effectively on  
84 projects.

85 The “Last Planner” refers to the front line supervisors (Ballard and Tommlein, 2016). The  
86 LPS is based on five key elements; (1) the master planning or milestone planning, (2)  
87 collaborative programming/phase planning, (3) the Make-ready planning, (4) Weekly work  
88 plan and (5) Measurement and learning. These processes are described extensively in (Daniel  
89 *et al.*, 2017; Ballard and Tommlein, 2016; Ballard, 2000). Through the application of these

90 elements, the LPS supports the development of a collaborative working relationship and on  
91 time delivery of construction projects.

92 However, the LPS has been criticised because the programme used in developing the phase  
93 planning is taken from the traditional programme developed with the Gantt chart (Koskela  
94 and Stratton, 2010). Additionally, Kim *et al.*, (2015) argued that too much focus on percent  
95 plan complete (PPC) in LPS implementation could make the subcontractors to modify the  
96 data. Nevertheless, the LPS process empowers the stakeholders doing work to contribute to  
97 the phase planning process so as to develop a reliable plan which makes it unique to the  
98 traditional approach to project management.

99 The LPS is based on twelve key principles and rules (Ballard and Tommelein, 2016; Ballard  
100 *et al.*, 2009) and these principles are: (1) Keep all plans, at every level of detail, in public  
101 view at all times; (2) Keep master schedules at the milestone level of detail; (3) Plan in  
102 greater detail as the start date for planned tasks approaches; (4) Produce plans collaboratively  
103 with those who are doing the work being planned; (5) Re-plan as necessary to adjust plans to  
104 the realities of the unfolding future; (6) Reveal and remove constraints on planned tasks as a  
105 team; (7) Improve workflow reliability in order to improve operational performance; (8) Do  
106 not start tasks that you should not or cannot complete, commit to perform only those tasks  
107 that are properly defined, sound, sequenced and sized; (9) Make and secure, reliable  
108 promises; (10) Learn from breakdowns; (11) Underload resources to increase reliability of  
109 work release; and (12) Maintain workable backlog. Observations of these principles support  
110 LPS implementation at the project level.

## 111 **A Review of Factors that Support Last Planner System Implementation**

112  
113 **Table 1: Factor that Supports the Implementation of LPS in Construction Project**

114  
115 Insert Table 1 here

117 In other to understand existing factors that support LPS implementation, a literature review  
118 was conducted. Table 1 presents the factors that support LPS implementation as reported by  
119 different authors. Most of the studies reviewed identified the need for training. Liker in his  
120 book “The Toyota Way” highlighted the need for training in its 9th principle (Liker, 2004).  
121 The principle states that “Grow leaders who thoroughly understand the work, live the  
122 philosophy, and teach it to others”. Training as emphasised here is not just in having mere  
123 technical knowledge of the lean techniques, but rather, a mindset change training, which  
124 could further help in the implementation. This shows that any organisation seeking to deploy  
125 lean technique across its business must be committed to training at all levels. According to  
126 Fernandez-Solis *et al.*, (2012) developing human capital within the organisation will enable  
127 the organisation to implement LPS effectively.

### 128 **Last Planner System Implementation in Construction Projects**

129 The implementation of the LPS has gained prominence in the construction industry. Its  
130 implementation in construction projects has an impact on process improvement (Castillo *et*  
131 *al.*, 2015; Ballard 2000). Fernandez-Solis *et al.*, (2012) asserted that the implementation of  
132 the LPS helps in creating overriding improvement in project programme predictions,  
133 productivity, workflow, reduces project time and site accidents, increases profit, enhances  
134 collaboration, while giving due consideration to employee satisfaction, among others. A  
135 comprehensive review of conference papers published by the International Group for Lean  
136 Construction (IGLC) indicates that the LPS has been implemented in over 16 countries  
137 (Daniel *et al.*, 2015). Also, the Lean Construction Institute (LCI) and the IGLC have  
138 documented the implementation of the LPS on many projects (Fernandez-Solis *et al.*, 2012).  
139 In addition to this, Shang and Low, (2014) identified that the LPS is among the most  
140 implemented lean construction technique on construction projects. However, the

141 implementation of the LPS is still fragmented (Daniel *et al.*, 2017; Dave *et al.*, 2015; Koch *et*  
142 *al.*, 2015).

143 ***Unpacking the Reasons for the non-Implementation of the Last Planner***  
144 ***System: The Organisational Dimension***  
145

146 Researchers in lean construction (LC) have attempted to explain the factors that contribute to  
147 the failure of the LPS implementation in construction projects (Ballard, *et al.*, 2007;  
148 Fernandez-Solis *et al.*, 2012). For instance, Fernandez-Solis *et al.*, (2012) identified 13  
149 factors that contribute to the failure of LPS implementation from the review of 26 case  
150 studies. The topmost factors identified from the review were organisational inertia or  
151 resistance to change ("This is how I've always done it" attitude), negative attitude towards the  
152 new system, lack of management support, and lack of human capital, among others.

153 Further review of the IGLC publications on the implementation identifies other factors that  
154 contribute to the failure of LPS implementation. Some of the factors identified include;  
155 resistance to change and human attitude (Fernandez-Solis *et al.*, 2012); use of incompatible  
156 procurement strategies and focus on cost (Johansen and Porter, 2003; Conte, 1998); low  
157 integration of the supply chain and subcontractors (Johansen and Porter, 2003), culture and  
158 structural issues within the organisation (Johansen and Porter 2003).

159 A closer look at the identified factors from earlier studies reveals that there are other  
160 organisational related dimensions such as, contract, culture, commercial terms, leadership,  
161 human behaviour and working relationship related factors within the industry that limit the  
162 implementation of the LPS, rather than the structure of the LPS itself. This assertion is further  
163 supported by Dave *et al.*, (2015) where they observed that majority of the factors that  
164 contribute to the failure of LPS implementation in construction projects identified from  
165 previous studies relate to the soft aspect i.e. organisation and people. It could be argued that

166 the lack of these organisational dimensions is holding back the full implementation of the  
167 LPS. For instance, Johansen and Porter, (2003) found that structural issues were among top  
168 factors holding back the full implementation of the LPS in the UK and the use of  
169 incompatible procurement strategies was one of the drawbacks from their implementation of  
170 the LPS. Furthermore, Conte, (1998) found that too much focus on cost, rather than building  
171 a relational contractual relationship contribute to the failure of the production system and  
172 Fernandez-Solis *et al*, (2012) found that organisational inertia, people attitude to the new  
173 approach and lack of leadership are among the factors holding back the full implementation  
174 of the system.

175 From the foregoing, it could be argued that the lack of consideration for the organisational  
176 dimension related factors could have contributed to the partial implementation of the LPS.  
177 More importantly, it highlights the need for path clearing at all levels for the successful  
178 implementation of the LPS on construction projects. The research question is: *How can*  
179 *construction stakeholder be supported to implement the LPS successfully in construction*  
180 *projects?* Successful implementation of the LPS requires deep-rooted organisational changes  
181 in thinking, culture and moving away from the old status quo and embracing the new way of  
182 working.

183 Hamzeh, (2009) classified the factors that contribute to the LPS implementation failure into  
184 local factors and general factors. The local factors relate to the project related challenges,  
185 while the general factors relate to the organisation implementing the LPS. This implies that  
186 the likely strategies or approach that would support the successful implementation of the LPS  
187 in construction projects should take due consideration for these classifications among others.  
188 While it is true that earlier studies have highlighted some factors that contribute to the failure  
189 of the LPS, no study has attempted offer a structured approach that incorporates the  
190 organisational level requirements, project-level requirements and external level requirements

191 in an integrated way with a view of overcoming these barriers for a smooth and successful  
192 implementation of the LPS in construction projects as proposed in this study. This study fills  
193 this gap by developing the “Last Planner System Path Clearing Approach”.

## 194 **Research Method**

195 A multiplicity of qualitative research methods were used in gathering evidence for the study.  
196 Evidence was gathered from semi-structured interviews and three case study. The qualitative  
197 research approach was used since the study focuses on understanding human behaviour and  
198 phenomena from the participant’s point of view which is contrary to the positivistic approach  
199 that tends to explain behaviour from the researcher’s perspective (Bryman, 2012). However,  
200 because the study aims to develop a model to support the implementation of the LPS, the  
201 system view as suggested by Arbnor and Bjerke, (1997) was adopted. According to Arbnor  
202 and Bjerke, (1997), the aim of the system approach is not to make a distinction between  
203 existing knowledge and the new knowledge, rather it focuses on integrating new concepts  
204 based on the current finding to the already known knowledge so as to present a better picture  
205 and solution to an existing problem. In view of this, the current study was built on existing  
206 literature that identified factors that support LPS implementation alongside empirical shreds  
207 of evidence gleaned from the semi-structured interviews and the case study conducted to  
208 develop the LPS-PCA.

209 The purpose of the literature review was to identify the underlying principles and practice of  
210 the LPS (Ballard and Tommelien, 2016; Ballard *et al*, 2009; Ballard, 2000); current level of  
211 implementation of the LPS across countries (Daniel *et al*, 2015; Dave *et al* , 2015; Koch *et*  
212 *al.*, 2015; Khanh and Kim, 2015; Kalsaas *et al*, 2014; Lindhard and Wandahl, 2014); to  
213 identify the challenges and to unpack the reasons for the non/partial implementation of the  
214 LPS in construction projects (Ballard, *et al* ., 2007; Hamzeh, 2009; Porwal, *et al* ., 2010;

215 Fernandez-Solis *et al .*, 2012; Johansen and Porter, 2003); to understand the organisational  
216 factors influencing the implementation of lean techniques and LPS in particular (Liker, 2004;  
217 Conte, 1998 ) and to understand the focus of previous approaches developed to support the  
218 implementation of lean techniques and LPS (Dombrowski *et al .* 2010; Lindhard and  
219 Wandahl 2014; Nesensohn, 2014).

220  
221 The semi-structured interview instrument consists of three sections. The first section  
222 contained questions on the background of the respondents, section 2 centred on LPS practice  
223 and section 3 centred on how LPS implementation can be supported. The observed practice is  
224 not reported in this paper. The questions were open-ended to allow the respondents to  
225 consider the phenomenon under investigation, to reduce bias and to improve the richness of  
226 the findings. However, the questions were structured to keep the respondents on track.

227 Thirty in-depth interviews were conducted over a 12 month period. The interviewees  
228 comprised of 18 main contractors, 2 clients, 4 lean construction consultants, and 6  
229 subcontractors. More main contractors and subcontractors were interviewed in the first phase  
230 of the study, this is because they are those involved in the implementation of the LPS. All  
231 respondents interviewed had over 3 years' experience in the use of LPS and were drawn from  
232 building construction, highways and infrastructures and rail sectors. Purposive sampling was  
233 adopted in selecting the respondents. Purposive sampling is a sampling approach that allows  
234 the researcher to select the appropriate population for the study so as to answer the research  
235 question adequately (Bryman, 2012). Purposive sampling was deemed appropriate for this  
236 study as there was no formal database for lean construction practitioners in the UK (Teddie  
237 and Yu, 2007). Furthermore, this ensured that only those with experience in LPS practice  
238 participated in the interview. However, Taylor and Bogdan (1984, p. 79) observed that no  
239 research method “can provide the detailed understanding that comes from directly observing

240 people and listening to what they have to say at the scene". In view of these, the semi-  
241 structured interview was supplemented with the case study approach that allows the study to  
242 observe the physical work environment, interview the people working in the environment and  
243 analyse relevant documents so as to answer the research question.

#### 244 ***The Case Study***

245 Yin, (2014) identified reasons for the choice of case study approach such as; (1) when the  
246 study seeks to answer research questions such as "how" or "why" (2) when the goal of the  
247 study is not to have full control over the phenomenon being investigated and (3) when the  
248 goal of the study is to focus on real-life situations in a given context. The case study approach  
249 has also been identified to align with the system approach adopted in the current study  
250 (Arbnor and Bjerke, 1997). In this study, the case study approach was adopted as it allows the  
251 study to understand how construction stakeholders can be supported to implement the LPS by  
252 gleaning evidence from the real-life situation (the project and its physical environment where  
253 the LPS is being implemented) and the individuals inhabiting it (the stakeholders on the  
254 project). Eisenhardt and Graebner, (2007); Amaratunga *et al.*, (2002) observe that the case  
255 study approach allows the researcher to gain a deeper understanding of the research problem  
256 or the phenomenon in relation to the context in which the study is being conducted. However,  
257 the case study approach has been criticised for lack of rigour and defined procedure for  
258 carrying out the investigation. Nevertheless, Yin, (2014) asserts that the issue of lack of  
259 rigour can be overcome when different techniques and methods are used in collecting data  
260 known as triangulation.

261 In view of this, semi-structured interviews were used in the first phase of the study while  
262 multiple case study involving different techniques was used in collecting data in phase two of  
263 the study. These techniques include semi-structured interviews, document analysis, and  
264 unstructured observation. The documents analysed include contract documents, construction

265 programme, Look-ahead plan, weekly work plan sheet, progress reports, published PPC,  
266 published reasons for non-completion (RNC), and minutes of collaborative programming or  
267 phase planning meetings. In doing the observation, one of the authors attended the LPS  
268 meetings held on the three case study projects. Arbnor and Bjerke, (1997) observed that the  
269 system approach enable a study to aggregate evidence using secondary materials,  
270 observations and interviews. The evidence gleaned from the literature review could be termed  
271 as secondary in the context of this investigation. According to Yin, (2014) triangulating data  
272 through the use of multiple techniques and methods supports the development of the  
273 converging point for research findings and, thus strengthens the validity of the study.

274

### 275 *Case Study Design*

276 Multiple case study approach was used in the investigation. A literal replication case study  
277 design that uses content analysis of qualitative interviews, documents analysis including  
278 observation of the physical environment was adopted. According to Yin (2014), literal  
279 replication enables a study to understand how a process works or function across cases. In  
280 this study, the literal replication design, enables the study to identify factors that support the  
281 implementation of the LPS on the case studies observed. However, to use literal replications,  
282 a study must have prior knowledge of the cases to be selected (Yin, 2014). In view of this, a  
283 semi-structured interview was conducted by the author(s) in the first phase of the study to  
284 develop an understanding of the use of the LPS. The case study design also built on the  
285 theoretical literature review that unpacked reasons why the LPS is not fully implemented on  
286 construction projects (Ballard, *et al.*, 2007; Hamzeh, 2009; Fernandez-Solis *et al.*, 2012;  
287 Johansen and Porter, 2003). The literal replications design was used as it allows the study to  
288 glean empirical evidence on how the LPS was supported on the case study projects

289 investigated. It is worth mentioning that the use of multiple case studies in this investigation  
290 is not for sampling logic, rather it is to identify how the LPS can be supported from the  
291 emerging themes from the interviews, document analysis, observation and the existing  
292 theory. Yin, (2014) argued that the application of sampling logic to case study research could  
293 defeat its purpose.

#### 294 *The rationale for Case Selection*

295 In selecting the cases, various factors associated with case study design as suggested in Yin  
296 (2014) and Bryman (2012) were adhered to. It is important that cases are selected carefully to  
297 avoid a condition where the evidence obtained is insufficient to answer the research question  
298 (Yin, 2014). In view of this, the authors ensured that the selected 3 cases were from the major  
299 sectors of the UK construction industry. Two of the cases are from the Highways and  
300 infrastructure and one from the building sector. No case was chosen from the rail sector as it  
301 has already been observed from the semi-structured interviews that rail projects, share similar  
302 characteristics (linear construction) with highway and infrastructure projects. The focus of the  
303 study was to develop an approach that could support LPS implementation across the UK  
304 construction industry, thus selecting case studies from the major sectors was considered  
305 appropriate. This was also to ensure that the proposed approach would be able to support the  
306 implementation of the LPS across these sectors. Purposive sampling was used in selecting the  
307 cases. Bryman (2012) stressed that purposive sampling allows the researcher to select a  
308 case(s) in order to answer the research question. The criteria used in selecting the cases are:

- 309 • The project must be managed with the LPS principles
- 310 • The project must be on-going

311 • The organisation involved should have implemented the LPS for not less than three  
312 years

313 . This was done to ensure only organisations with requisite experience in the use of the LPS  
314 were investigated. The authors were also given the opportunity to gather the required  
315 evidence through the observation of the physical environment. .

### 316 *Data Collection*

317 The case studies were conducted concurrently over a period of 12 months; this provided an  
318 opportunity to collect real-world evidence. In this study, for the purpose of confidentiality the  
319 case studies are described as CSP01, CSP02 and CSP03 (where C= case, S= study  
320 P=project). Evidence was gleaned from three major sources for each project. These are;  
321 documentary evidence, observations, and semi-structured interviews. The three approaches  
322 were used in deepening and authenticating the results (Yin, 2014). Data collection started  
323 with observations, document analysis and then semi-structured interview. This enabled  
324 further clarification on findings from observation and document analysis. Also, the first  
325 author attended the monthly Lookahead production planning meeting as an observer.

326 In each case study, senior managers (SM), middle managers (MM), operational managers  
327 (OP), and subcontractors (SC) were interviewed. Four of the SM and three of the MM  
328 interviewed were clients. This was done to ensure the views of the major stakeholders  
329 involved in managing the production process and those responsible for making a strategic  
330 decision on the construction projects were sought in the investigation. The interview  
331 instrument case consists of two sections; the background of the respondents and questions on  
332 the nature of support required for LPS implementation. A total of 28 research participants  
333 were interviewed, which include; SM = 9, MM = 6, OP = 6, and SC = 7. This shows the key  
334 stakeholders on the project were adequately involved in the study. Majority of the  
335 respondents claimed to have above 3 years' experience in the use of LPS in construction

336 projects and have over 10 years' experience in the construction industry, this means their  
337 response can be relied on.

### 338 ***Data Analysis***

339 The data collected were grouped into a dataset and placed in folders/files; for the semi-  
340 structured interviews and for each of the case study. The interviews were transcribed  
341 verbatim and cross-checked with findings from documents analysis and observation. In doing  
342 this, the data were categorised based on qualitative data analysis techniques after Miles and  
343 Huberman (1994). The themes and code used for the analysis were based on the interviews  
344 questions and themes that emerged from the transcribed interview. The data analysis process  
345 was supported by Computer-Aided Qualitative Data Analysis (CAQDAS) software known as  
346 'NVivo'. The software was used due to the large nature of the data. According to Silver and  
347 Lewin (2014); and Bryman, (2012) NVivo software does not only manage large data set, but  
348 it also supports transparency, replicability and validation of qualitative data. The emerging  
349 themes and sub-themes on the nature support required are discussed in the subsequent  
350 section.

351

### 352 ***Description of Case Study projects***

353 Table 2 presents the study projects' attributes. The table shows that the case studies on which  
354 LPS application was investigated cuts across the major sectors of the UK construction  
355 industry.

356 **Table 2: Case study project Attributes**

357 Insert Table 2 here

#### 358 ***Case Study Project One***

359 The case study project one (CSP01) is a highway infrastructure project which is an upgrade  
360 to replace a dual carriageway with a three-lane motorway. It also includes the construction of

361 associated facilities such as bridges among others. The project comprises of different facets  
362 and many stakeholders, which requires coordination and management. For effective  
363 coordination and management of the project, the project was divided into three sections; the  
364 north, the south, and the central sections. All the sections of the project were managed using  
365 the LPS with three different supervisors and one central coordinator. The researcher observed  
366 CSP01 over a period of 10 months, which started at the construction phase. This enabled the  
367 study to gain insight into the nature of support to be put in place for effective implementation  
368 of the LPS. The procurement approach used is design and build (D&B) and the contractor  
369 claimed to have used the LPS to manage the construction process on their previous project.  
370 This means their previous experience in the use of LPS could contribute to the current  
371 research.

372

### 373 *Case Project Two*

374 The case study project two (CSP02) is also a highway infrastructure project. The aim of the  
375 project was to reduce congestion on the network using technology to vary speed limits. The  
376 project was divided into two main sections; Northbound and Southbound sections. The  
377 project was managed with the LPS. A single production planning session was held for both  
378 sections at the project site office. The LPS implementation was internally facilitated by the  
379 site agent with the support of the programme manager and the work package managers. The  
380 contractor had implemented LPS on their previous project. Based on the data collected,  
381 CSPO2 was procured with traditional design-bid-build (DBB). However, the subcontractors  
382 on the project were on a framework agreement. CSP02 was observed by the research team for  
383 close to 12 months. This shows the project had progressed enough to capture useful evidence  
384 for the study.

385

386 *Case Study Project Three*

387 The case study project three (CSP03) is a new educational building project. The main  
388 contractor on the project is one of the top UK building construction contractors with over 30  
389 years' experience in the UK building construction industry. In the past, the main contractor  
390 had been involved in various construction process improvements championed by the UK  
391 Government, such as the Construction Lean Improvement Programme (CLIP) conducted by  
392 the Building Research Establishment and the Department of Trade and Industry. Also, the  
393 main contractor had been in a framework agreement with all its supply chain for over five  
394 years. The mode of procurement used is design and build (D&B). LPS principles were used  
395 in managing the production processes. The use of LPS on the project was motivated by the  
396 main contractor as it had been used on their previous projects. CSP03 was also observed for  
397 12 months.

398 **Performance of Last Planner System on the Case Study Projects**

399 Table 3 shows that the LPS practice implemented across the three case studies include, phase  
400 planning, WWP, measurement of PPC and RNC.

401 **Table 3: Performance of Last Planner System on the Case Study Projects**

402 Insert Table 3 here.

403 The study shows that a daily huddle meeting was held on CSP03 and later on CSP01, but was  
404 not done on CSP02. Although daily huddle meeting was not part of the initial elements of  
405 LPS (Daniel *et al.*, 2015, Ballard *et al.*, 2009 ), its use in monitoring how the production  
406 system is performing on the day of production on site is on the increase (Daniel *et al.*, 2015;  
407 Salem *et al.*, 2006). This could be due to its potential in checking the production system on  
408 the day of production and to also re-plan in case of any deviation. For instance, it was not  
409 done on CSP01 initially, but it was later introduced.

410 Constraint analysis was observed on all the three case study projects, however only CSP03  
411 developed a partial strategy to remove the identified constraints. On CSP03, constraints and  
412 action log were collaboratively developed by the team with actions assigned. However, the  
413 action log was only circulated via email to the distribution list at the end of the look-ahead  
414 planning meeting. It was also not published visually in the LPS meetings as expected.  
415 Publishing it visually not only improves process transparency but also keeps all the  
416 stakeholders on the project conscious of the actions required of them. On CSP01, constraints  
417 were only partially logged with no personnel given the clear action to address the identified  
418 constraints. Also, on CSP02, constraints were logged but not all the responsible persons for  
419 actions were usually available at the look-ahead planning session, especially the designers.  
420 Hence, another separate meeting had to be arranged with the team.

421 This show there is a lack of discipline in the constraint removal process on the case study  
422 projects. Previous studies have also shown that there is lack of rigour in the implementation  
423 of more complex elements of the LPS such as the make-ready process (Daniel *et al.*, 2015;  
424 Dave *et al.*, 2015; Lindhard and Wandahl, 2014; Ballard *et al.*, 2009; Alarcon *et al.*, 2011).  
425 Furthermore, Table 3 reveals that CSP01 has the least PPC average of 72.29 %. Though this  
426 may seem good, however, going by the meaning and goal of PPC in showing workflow  
427 reliability (Ballard, 2000), this may not be true on CSP01. This is because it was observed  
428 from the interview that sometimes there were cases of over and underestimation in the  
429 amount of work to be done by those doing the work. For example, a PPC of 0% and 100%  
430 were observed in some weeks on CSP01 which further attests to this fact. In some cases, PPC  
431 could be 100% with work still behind schedule when tasks are not properly made ready  
432 (Hamzeh, *et al.*, 2012). According to Kim *et al.*, (2015), too much focus on PPC could make  
433 the subcontractors to modify the data. This implies attention should be on achieving smooth  
434 workflow as good workflow would definitely improve the PPC.

435 Also, the reasons for non-completion RNC of tasks were recorded on all the three case  
436 studies. The main causes of RNC on CSP01 were previous work not done and  
437 underestimation, while on CSP02 it was the design changes and change of priority. On  
438 CSP01, the lack of rigour in the make-ready or constraint removal process could have  
439 contributed to the frequent occurrence of previous work not been completed on the project  
440 and also the lack of honesty in making promises. Dishonesty and insincerity in promising  
441 were seen as a barrier to LPS implementation on the three case study projects.

442 The study reveals that among the many LPS metrics, only PPC was measured on the projects.  
443 Metrics such as Task Made Ready (TMR), Task Anticipated (TA), and frequency of plan  
444 failure were not measured on any of the projects (Ballard, 2015; Ballard *et al.*, 2009). This  
445 could be due to the ignorance of the existence of such metrics and the level of maturity of the  
446 use of LPS. According to Hamzeh *et al.*, (2015); Ballard *et al.*, (2009), the above mentioned  
447 LPS metrics are less practised even on projects that claim to use LPS, this implies the  
448 situation is not peculiar to the UK construction industry alone.

449 The study reveals that some form of learning occurs on all the projects, however, the amount  
450 of rigour required to actively translate the learning to practice is inadequate. For instance, on  
451 CSP01, though RNC was recorded, one of the respondents stated that not much was done  
452 with it. Also, developing workable backlog was not done on any of the case study projects.

## 453 **Results and Discussion**

454 The aim of the current study is to develop an approach to support the client, main contractors,  
455 and subcontractors for the successful implementation of the LPS on a construction project.  
456 The emerging themes and sub-themes from the semi-structured interviews and the three case  
457 studies are presented and discussed.

458 **Emerging themes and sub-themes from the semi-structured Interviews and the**  
459 **Case Studies.**

460 From the analysis of the initial semi-structured interviews and semi-structured interviews on  
461 the three case studies, three core themes and other sub-themes emerged on the nature of  
462 support required for effective implementation of the LPS. These themes are:

- 463 1. Support required at the organisational level
- 464 2. Support required at the project level
- 465 3. External enablers

466 **Support Required at the Organisation Level**

467 The emerging sub-themes on the nature of support required for LPS implementation at the  
468 organisational level identified from the semi-structured interviews and case study are  
469 presented and discussed below.

470 ***The inclusion of LPS Practice in Contract Clause***

471 The inclusion of LPS in the contract was mentioned in all the case studies and in the semi-  
472 structured interviews. For instance, one of the clients that participated in the semi-structured  
473 interview (EI) stated that:

474 *We include LPS practice in the contract with our supply chain; they know they will be*  
475 *doing it. This means we have paid for it. [Client, Semi-structured interview].*

476 Another respondent observed that because the LPS was part of the contract, it motivated  
477 everyone on the project to get committed to the process [CSP03, Senior Planner]. Also, a  
478 subcontractor on CSP03 stated that: *"It is part of the main contractor's policy, so if we do not*  
479 *want to do it, we can't go away with it. "By signing into it in the contract supports my*  
480 *commitment to it and it benefits us as subcontractors"* [Subcontractor's, Senior Site  
481 **Manager].**

482 This view was further reiterated from other research participants on CSP01 and CSP02.  
483 *"There should be a point where it has to be mandated and written into the contract and*

484 *benefits should be shared*” [CSP01, Excellence Manager]“. Respondents on CSP02  
485 suggested that the process should be formally included in the contract by the organisation  
486 [CSP02, Site Engineer; CSP02, Site Agent]. Doing this is essential as it makes it a formal  
487 process on the project, thus encouraging more commitment to the process. Also, it would  
488 ensure that all the required stakeholders get engaged in the process as expected.

489

490 Furthermore, construction is filled with many formal processes (Kadefors, 2004), which  
491 sometimes may not even support the goal of the project. However, the goal of LPS is to  
492 engender collaboration among the project team, while also focusing the team to achieve the  
493 common goal of the project (Ballard and Howell, 2004). According to Kadefors (2004),  
494 formalisation of the construction process should not be in relation to cost alone, but should  
495 include other practices that would support the actualisation of the project objectives. The LPS  
496 should be considered to be among such formal practices or processes too.

#### 497 ***Involvement of the Commercial Arm of the Business in LPS Meetings***

498 The inclusion of the commercial arm of the business in the LPS implementation loop by the  
499 organisation was considered to support the implementation of the LPS. Some of the  
500 interviewees on CSP03 believed that the inclusion of the commercial team such as the  
501 quantity surveyor, commercial managers, cost controllers, and cost engineers among others in  
502 the LPS process would further support the system. One of the respondents stated that on  
503 CSP03:

504 *“I think the built environment team and the planning team are involved in this*  
505 *process, the commercial side of the business tends not to be in the loop in term of*  
506 *delays or acceleration in the programme. The commercial side of the business should*  
507 *be kept in the loop*” [Subcontractor’s, Contract Manager].

508 The place of involving the commercial team in the process cannot be overemphasised, since  
509 every change in the programme from the LPS meetings as a result of reliable promising has  
510 its own commercial implication to the project. Hence, their involvement in the production  
511 planning meeting as and when required could reduce the time required in making decisions  
512 that relate to commercial matters (cost, contractual implication etc.) during the make-ready  
513 and look-ahead planning sessions. However, this must be done with caution, as it has been  
514 observed that when the production shifts too much attention to cost, the production system  
515 could fail (Conte, 1998).

### 516 ***Provision of Training***

517 Some of the respondents suggested that the organisation must be committed to the training of  
518 its employees on the new approach. The respondents on CSP01 stated that:

519 *“There is need to educate others on the project on LPS and invite other site*  
520 *representatives to be involved in the process” [CSP01, Section Engineer].* Also, the  
521 main contractor stated that: *“for an organisation that is venturing into it, there is need*  
522 *to provide training and demonstration of tangible benefits from previous*  
523 *implementation” [Main contractor, semi-structured interview]*

524 On the CSP02 majority of the respondents, including the subcontractors identified the need  
525 for the provision of training by clients and main contractors. For instance, some of the  
526 respondents stated that: *“There is a need for guidance on LPS right from conception by the*  
527 *management, we do receive some training on LPS” [CSP02, Project Manager].* The need  
528 for the provision of training was also identified by the programme manager *“Training is very*  
529 *essential, without it the facilitation would not work” [CSP02, Senior Manager,*  
530 **representing the client].**

531 This shows that at the organisational level, a procedure should be put in place to support  
532 training and facilitate the practice of LPS across different business units. The nature of

533 training to be provided should be tailored for each stakeholder on the project. For example,  
534 the initial training for the smaller subcontractor should be to explain the benefits of the  
535 process to them in order to get their buy-in before full implementation. Previous studies have  
536 shown that training, management support, and early involvement of stakeholders are essential  
537 for LPS implementation in construction projects (Hamzeh and Bergstrom 2010 and Ballard *et*  
538 *al.*, 2007).

### 539 **Support required for LPS Successful Implementation at the Project Level**

540 The emerging sub themes on the nature of support required for LPS implementation at the  
541 project level identified from the semi-structured interviews and case study are presented and  
542 discussed below.

#### 543 ***Last Planner System Facilitator and Champions***

544 At the project level, the need for a facilitator and the appointment of champions to drive the  
545 process was identified in the three case studies. On CSP02, some of the respondents  
546 interviewed stated that:

547 *“A facilitator is needed to promote the benefits of LPS, an external facilitator within*  
548 *the 1-4 weeks and internal facilitation to continue the process. Also, appoint lean*  
549 *managers, both at the project and organisational levels to promote the practice*  
550 *across the business” [CSP02, Programme Manager]. “The LPS session should be*  
551 *facilitated by someone who has knowledge of the work involved to present a bigger*  
552 *picture” [CSP02, Site Agent]. “Have a champion to promote it” [CSP02, Section*  
553 **Engineer].**

554 This was also echoed by research participants on CSP01, one of the middle managers stated  
555 that: *“A facilitator is needed to coordinate the process for the initial start, this is an early*  
556 *stage support” [CSP01, Section Engineer].* A client in the semi-structured interview stated

557 that: “A facilitator is required within the organisation and on the project to drive the entire  
558 process across the business” [**Client, semi-structured interview**]. This is because the  
559 process cannot really progress if it is not duly facilitated. However, some of the respondents  
560 were of the view that facilitators should be limited to the early stage only [**CSP01,**  
561 **Programme manager**]

562 The above statements from respondents show the need for facilitators and champions for  
563 driving the process. The statement further suggests that the facilitator should have some level  
564 of understanding on the nature of work executed. This is crucial as the process would not  
565 progress if there are no capable and experienced personnel to manage the process. Previous  
566 studies have also identified the importance of facilitators in the implementation of the LPS  
567 (Alarcon *et al.*, 2011). On all the case study projects investigated, the process was internally  
568 facilitated. However, on CSP01, it was argued that after the initial facilitation, the process  
569 should be left with the team. As good as this may seem, it could lead to the abandonment of  
570 the entire process as each member of the team has a specific role to perform on the project.  
571 Leaving the process to the team to do it, means no one would be held accountable. However,  
572 on all the three projects, LPS facilitation was the primary responsibility of the facilitators  
573 which yielded better results.

#### 574 ***Honesty, Transparency and Reliable Promising***

575 The need for discipline, transparency, and truthfulness, especially in conversation and making  
576 promises by the stakeholders in production planning sessions were considered essential at the  
577 project level on all the three case studies. Some of the respondents interviewed on CSP03  
578 stated that honesty in making promises and giving out of information, especially at the  
579 production planning meetings is essential. Some of the respondents stated that: “*Some*  
580 *subcontractors agree dates knowing they cannot achieve it!!!*” [**Subcontractor’s, Senior**  
581 **Site Manager**]. “*The process is fine, one of the barriers is people committing to things they*

582 *cannot do and also unrealistic expectation from the main contractor” [Subcontractor’s,*  
583 **Contract Manager].**

584 The statements above further highlights why the stakeholders at the project level should not  
585 be pressurised into making promises or commitments, as such promises could turn out to be  
586 unrealistic sometimes. In making promises in the LPS approach of managing construction  
587 projects, workers are not pressured into making promises, rather, they are empowered to  
588 make promises of what they can do. This approach supports reliable promising. This  
589 underscores the importance of realistic expectations and promises. Macomber and Howell,  
590 (2003) identified five elements in making a reliable promise among project stakeholders.  
591 These are: (1) understanding the condition of satisfaction (2) competency to perform the task  
592 (3) capacity to perform the task (4) sincerity and (5) commitment to clean the mess, if failing.  
593 This clearly suggests that in making promises during production planning sessions, the team  
594 must be transparent and sincere that the capacity required to deliver the task is available  
595 before making the promise. It is through reliable promising in the LPS that trust and  
596 confidence increases/develops among the project stakeholders (Issato *et al.*,2015).

### 597 ***Involvement of all the Required Stakeholders***

598 The respondents believed that full engagement of all “required stakeholder” (those that have  
599 the required capability to make decisions during production planning meetings), is essential  
600 for its success at the project level. Some of the respondents stated that:

601 *“The collaborative programming sessions should involve the client, the designers,*  
602 *main contractors, and subcontractors” [CSP02, Manager]. “Based on my experience*  
603 *from previous of LPS implementation on our past projects, having the right people in*  
604 *the room is essentials” [Client, semi-structured interviews]*

605 Again, this call by the respondents shows that not all the required stakeholders are engaged in  
606 the collaborative programming sessions. For instance, it was observed on CSP02 that the  
607 designers were not usually involved in the session due to the nature of the procurement used.  
608 The implication of this *non*-all-inclusive engagement of the stakeholders in the process is that  
609 the make-ready and constraint removal process would be incomplete. This increases the level  
610 of uncertainty in the activity scheduled.

611 ***Pre-planning by the Team before Production planning session.***

612 The respondents interviewed on CSP02 observed that pre-planning by the subcontractors and  
613 work packages managers before the Last Planner session is essential for success at the project  
614 level. Some of the respondents stated that:

615 *"The subcontractors must come with a realistic programme, not just the duration on the*  
616 *contract programme"* [CSP02MM02, Site Agent]. *"Prepare a plan before the collaborative*  
617 *planning session (base programme)"* [CSP02SM02, Production Planning Manager].

618 The need for pre-planning before the collaborative production planning sessions cannot be  
619 overemphasised, as it keeps the team in the right state to make a meaningful contribution  
620 during the session. On CSP03, the need for the team to make a realistic plan before coming to  
621 the session was also echoed. One of the subcontractors stated that: *"The way the process is*  
622 *facilitated supports our buy-in and it is great to see that some subcontractor use to do some*  
623 *homework before coming to the Last Planner meeting but some are not willing which*  
624 *prolongs the conversation.* [Subcontractor's, Contract Manager].

625 **External Support Required for LPS Implementation**

626 The emerging sub-themes on the external support required for the implementation of the LPS  
627 as identified from the semi-structured interviews and case study are presented and discussed  
628 below.

629 ***Process Standardisation***

630 On CSP02, the respondents observed that a common or standard approach to LPS  
631 implementation would support its rapid implementation. Some of the respondents  
632 interviewed are of the opinion that the approach seems to vary from one project to another.  
633 One of the subcontractors stated that: "*People tend to view or practice the Last Planner*  
634 *differently, there is a need to have one format or approach. There should be one approach*  
635 *across projects*" [CSP02SC01, Subcontractor's Project Manager].

636 Again, this shows that there are variations in the current implementation of LPS principles on  
637 the projects investigated in the UK. Previous studies in the UK and elsewhere have also  
638 reported the partial implementation of the LPS in construction project (Daniel *et al.*, 2017;  
639 Dave *et al.*, 2015; Koch *et al.*, 2015; Khanh and Kim, 2015; Lindhard and Wandahl, 2015).

640 These shows that external support is needed as it will be too simplistic to conclude that the  
641 LPS does not need improvement. Studies have shown that the LPS is dynamic and it is now  
642 being incorporated with BIM, Location-based management, and Takt planning among others  
643 (Daniel *et al.*, 2015; Seppanen *et al.*, 2010; Sacks *et a .*, 2009). Also, it is interesting to note  
644 that the LPS has been benchmarked by Glenn Ballard with input from current practitioners,  
645 research institutes, consultants, and the academia to improve the initial framework on which  
646 it was developed (Ballard and Tommelein, 2016).

647 ***The partnership between the Industry and the Academia***

648 A partnership between the construction industry and academic institutions on research, with a  
649 focus on LPS, was suggested as an external support required. One of the managers on CSP01  
650 suggested that:

651 *"There is a need for more alliance between the academia and the industry. More*  
652 *articulation and pro-activeness in communicating improvement and findings to the*  
653 *industry. More emphasis should be placed on the correlation between the industry*

654 *and the institution” [CSP01, Excellence Manager]. A client also stated that: “Our*  
655 *partnership with Universities is helping us to support our supply chain in the*  
656 *implementation of the LPS on our projects” [Client, semi-structured interviews]*

657 This partnership is important, as academic institutions would be able to communicate recent  
658 developments on its application and principles to the industry practitioners. For example, in  
659 Brazil, it was reported that the active engagement between construction companies and  
660 academic institutions in the LPS principle implementation on projects has yielded positive  
661 results and similarly in Chile (Alarcón *et al .*, 2011; Formoso *et al .*, 2002). In the UK,  
662 institutions such as Nottingham Trent University, University of Cardiff, University of  
663 Salford, Lean Construction Institute, UK and Costain Plc among others are into such research  
664 partnership with Highways England.

665 Some of the respondents believed that higher education institutions which provide training in  
666 construction project management, and civil engineering among others, have a role to play in  
667 passing on the knowledge to their students. This could support the implementation of the  
668 process. One of the respondents argued that:

669 *“There is a need to adopt some of this concept such as the Last Planner in their*  
670 *training and teaching. The curriculum should be updated with what is happening in*  
671 *the industry, LPS should be included in the construction project management*  
672 *programme” [CSP02SM02, Production Planning Manager].*

673 This shows that construction management and civil engineering training should not only  
674 focus on the hard or technical skills alone, but other soft management skills such as those  
675 encouraged in lean principles should also be taught.

676 **Results from Documents Analysis and Physical Observations on the Case Studies**

677 To understand how LPS implementation can be supported, the first author participated in  
678 various LPS meetings held on the case studies project investigated and observes the physical  
679 environment. The observation was unstructured; this was to allow the study to capture a wide  
680 range of relevant evidence as they emerge. Relevant documents were also analysed. The  
681 emerging themes are discussed as follow:

682 ***Provision of Production Planning Control on the Site***

683 On all the three projects observed (CSP01, CSP02 and CSP03) the first author observed that  
684 there were designated permanent rooms for LPS meetings. The respondents were of the view  
685 that a designated room for LPS meetings should be provided on site. One of the  
686 subcontractors stated that: “*Allow for a suitable rooms/facility on site for LPS meetings and*  
687 *session*” [CSP01, Project Manager]. This is essential as such room/facility could further  
688 provide information visually to other members of the team who were unable to participate in  
689 meetings in real time. Also, visiting the room would give everyone an idea of project  
690 activities on site. However, setting the room outside the project site could reduce such  
691 benefits and could contribute to non-value adding activities. This is because it would require  
692 site workers travelling to the head office to view the board. But the siting of the production  
693 planning and control centre on site would create a feeling of belonging to the site team.

694 ***Proactive Involvement of Construction Manager***

695 The result of the physical observation reveals that on CSP01 north section, CSP01 central  
696 section, CSP02 and CSP03, the construction managers were actively involved in the LPS  
697 meetings. However, this was not the case on CSP01 south section. Also, the participation of  
698 the subcontractors in LPS meeting in CSP01 south section was poor compared to the north  
699 and central section on CSP01. This could be due to none active involvement of the  
700 construction manager. The involvement of the construction or project manager at the project

701 level would help the project team to see the process as the company process of delivering its  
702 business. Practically, this entails attending and contributing in production planning meetings  
703 by the project manager. According to Hamzeh and Bergstrom, (2010), when a process on a  
704 project is viewed as external or ad hoc, there would be less commitment from the team.

#### 705 ***Use of Collaborative Form of Procurement***

706 The result of document analysis and physical observation in the three case studies indicates a  
707 form of collaborative procurement was used. The collaborative form of procurement include;  
708 early contractor involvement (ECI); framework agreement, Design and Build and joint  
709 venture. Evidence from the investigation shows that on CSP02, design bid build (DBB) was  
710 used in procuring the project. However, because the supply chain had been in a framework  
711 agreement, the collaborative relationship had developed which enhanced and supported the  
712 implementation of the LPS on the project. The contractual behaviour that occurs there could  
713 be better explained with relational contracting theory. Macneil, (1980) observed that as  
714 parties to the contract have more and frequent conversation on the project, the relationship  
715 begins to develop. Furthermore, the assurance of the possibility of securing a future job, for  
716 example, in a framework agreement, could motivate the team to get committed to each other  
717 on the project. According to Harper, (2014) when there is shared expectation between teams  
718 on a project, it would influence their behaviour on the project. This means the use of a  
719 collaborative form of procurement at the organisational level would support LPS  
720 implementation in a construction project.

#### 721 ***Development of the Last Planner System Path Clearing Approach***

722 The approach to support LPS implementation in construction projects was developed based  
723 the literature review on the LPS presented in the literature review section, the evidence  
724 gathered from the 30 semi-structured interviews, and the three case studies conducted as  
725 presented and discussed in the result and discussion section. The developed approach is

726 known as *the Last Planner System Path Clearing Approach* (LPS-PCA). It is called LPS-  
727 PCA because it clearly shows what needs to be in place for a rapid and successful  
728 implementation of the LPS on construction projects.

### 729 ***The rationale for the Last Planner System-Path Clearing Approach***

730 As earlier mentioned in the literature review, the need for supporting the implementation of  
731 new techniques has been acknowledged in the literature (Nesensohn, 2014; Sacks *et al.*,  
732 2010, Ballard *et a .*, 2007). However, studies that have attempted to propose an approach for  
733 implementing specific lean techniques such as LPS in construction tend to focus more on the  
734 project level (Lindhard and Wandahl, 2014; Hamzeh and Bergstrom 2010; Dombrowski *et*  
735 *al.*, 2010). The absence of a holistic approach to supports construction stakeholders in the  
736 implementation of the LPS informed the development of the LPS-PCA. The objectives of the  
737 proposed Last Planner System Path Clearing Approach (LPS-PCA) are as follows:

- 738 • To highlight the foundational factors or path levels that need to be in place for  
739 the rapid and successful implementation of the LPS in construction.
- 740 • To offer a structured and holistic view on LPS implementation in construction.
- 741 • To offer an insight on how to sustain the implementation of the LPS in  
742 construction using a systemic view.

### 743 ***Theoretical Overview of the Proposed Approach***

744 The proposed approach is built on various theories that have been used to explain the  
745 working of LPS in construction. Some of these include: Transformation, Flow, and Value  
746 theory (Koskela, 2000); management-as-planning (Johnston and Brennan, 1996) and Hayek's,  
747 (1945) comment about the way knowledge needed for planning is dispersed among  
748 individuals. The proposed approach is also explained by a relational contracting theory  
749 perspective (Macneil, 1980).

750 Koskela developed the *Transformation Flow and Value* (TFV) theory mostly referred to as  
751 TFV theory (Koskela, 1992; Koskela, 2000). It has been observed that the current approach  
752 used in managing construction project tends to support only the *transformation view*. The  
753 transformation view focuses on the conversion of input into output with less regard to what  
754 happens in the project environment (Koskela and Howell, 2008). However, such view is false  
755 and counterproductive due to the uncertainty and variability inherent in the construction  
756 environment. In view of this, Koskela, (2000) proposed that the Flow and Value concept  
757 should be added to the Transformation concept on which the current theory of project  
758 management is conceptualised. The understanding and usefulness of the flow concept have  
759 been demonstrated in lean construction and in the LPS (Liu and Ballard, 2011; Sacks, 2016,  
760 Koskela and Howell, 2008). The LPS uses the flow concept to identify and ensure task  
761 preconditions are satisfied before sending them to the work phase. The flow concept is  
762 applicable in the proposed LPS-PCA at the project level which relates to the alignment of the  
763 current practice within the organisation to LPS standard practice that supports workflow at  
764 the project level. The practice that supports smooth workflow at the project level is the Make-  
765 ready planning where the project team collaboratively identifies constraints and develop  
766 strategies to remove them within the six weeks lookahead window before the actual  
767 commencement of the task (González *et al*, 2010). This practice supports workflow at the  
768 project level in the proposed LPS-PCA.

769 Furthermore, the management-as-organising (MAO) view as presented in Johnston and  
770 Brennan, (1996) supports LPS implementation. In this approach, it is believed that each sub-  
771 unit in the system has the capacity to plan, sense and act, thus, the planning decision should  
772 not be left with “the managerial part” alone. This theory further justifies the inclusion of all  
773 the required stakeholders in the LPS meeting as an essential requirement for LPS  
774 implementation at the project level in the proposed LPS-PCA. In reality, the engagement of

775 the required stakeholders supports the development of the reliable plan (Javanmardi *et al*,  
776 2017). For instance, Javanmardi *et al*, (2017) found that synergy between subcontractors  
777 reduces variability and improves plan reliability. A related theory that supports this view is  
778 that proposed by Hayek, (1945) in economics where it was argued that the knowledge needed  
779 for making a decision is dispersed among people. This goes to show that the decision on  
780 planned construction activities should not be left to the chief planner alone, but should also  
781 include those doing the work as advocated in the LPS (Kalsaas, 2012) and proposed in the  
782 LPS-PCA. These two theories align with the theme that emerged from the current study on  
783 the need to involve all required stakeholders in the LPS meetings at the project level.

784

785 The relational contracting theory proposed by Macneil, (1980) posits that as parties to the  
786 contract have more and frequent conversation on the project, the relationship begins to  
787 develop. This view aligns with the result of the document analysis and the physical  
788 observation where it was observed that most of the contractors are into one form of  
789 collaborative relationship such as framework agreement. This means the use of a  
790 collaborative form of contract that allows the project organisation to develop a long-term  
791 relationship supports LPS implementation. This emanates from the better understanding the  
792 project organisations would have developed about each other over time.

793

#### 794 **Description of the Composition of the LPS-PCA**

795 The LPS-PCA comprises three main components (known as path clearing levels) as shown in  
796 Figure 1. These include:

- 797 1. Organisational level
- 798 2. Project level
- 799 3. External enablers level
- 800 4.

801 **Figure 1: Last Planner System Path Clearing Approach**

802 Insert Figure 1 here

### 803 **Organisational Level Path Clearing**

804 Organisations play a central role in the implementation of lean principles and techniques. At  
805 the organisational level, it is essential to create an enabling environment that supports a long-  
806 term relationship that is built on collaborative practice and process. The theory that aligns  
807 with this is the relational contracting theory proposed by Macneil, (1980). The theory argued  
808 that collaborative relationship develops between different organisation and parties when they  
809 work together over a long period of time. Harper, (2014) argued that when there is shared  
810 expectation between parties in a contract, it would influence their action and commitment.  
811 This explains why -the inclusion of LPS in the contract, use of a collaborative form of  
812 contract, relational contracting and collaborative working culture supports LPS  
813 implementation at the OL.

814

815 The conditions required at the organisational level (OL) for rapid and successful  
816 implementation of LPS as shown in Figure 1 are categorised into (1) *organisational process*  
817 *input factors* and (2) *organisational contextual input factors*. The process input factors are  
818 discussed below.

### 819 **Organisational Level Process Input Factors**

820 This refers to the processes that need to be created and practised at the organisation level in  
821 the implementation of LPS. As it is called, it defines the processes that need to be in place at  
822 the organisational level (OL) for the LPS implementation. These include;

- 823 • identifying the imperative for LPS implementation/ leadership
- 824 • identifying and understanding the drivers for LPS implementation
- 825 • strategic capability commitment to support LPS implementation
- 826 • creating awareness on the strategic capability across the business

827 *a. The Imperative for LPS Implementation and Leadership*

828 An organisation must identify the imperatives for the implementation of the LPS in its  
829 business. The imperative here is beyond having a goal of fulfilling an expectation from the  
830 client. For instance, in the UK, the demand from some public sector clients seems to be  
831 among the top imperative factors driving some supply chain companies in the implementation  
832 of the LPS. Such an imperative factor or driver cannot sustain the implementation of the LPS  
833 and indeed is a weak imperative factor.

834 Ideally, the imperative for LPS implementation should be based on the desire to become an  
835 active agent to support collaborative behaviour among employees. This implies that both the  
836 client and supply chain have a role in championing the LPS implementation. Also, it shows  
837 that the LPS implementation should not be championed by client companies alone, as  
838 perceived by some supply chain companies. In addition to this, a high-level leadership  
839 support is required to drive the process. Previous studies have shown that top management  
840 support and leadership are essential in the successful implementation of lean techniques such  
841 as the LPS (Hamzeh and Bergstrom 2010).

842 *b. Identify and Understand the Drivers and Benefits for LPS Implementation*

843 The specific drivers for the implementation of LPS should be identified. This is important as  
844 the drivers for LPS implementation in a client organisation could vary from that of a  
845 contracting organisation and even from one client or contracting organisation to another. This  
846 implies each organisation must identify its own drivers. The early identification of these  
847 drivers is an essential process input which should be in place, as it has the capacity to put  
848 pressure on organisations (client and supply chain companies) to create the needed change  
849 that could support the implementation. According to Ogunbiyi, *et al.*, (2014) identifying the  
850 drivers for lean implementation could support the change in the organisation.

851 *c. Strategic Capability Commitment to Support LPS Implementation*

852 After identifying the imperatives and drivers for LPS implementation, it is important to  
853 develop a clear strategy and capability to support the implementation. Without a clear  
854 strategy, the LPS implementation cannot be sustained in the organisation. Both construction  
855 clients and supply chain companies must create their own strategy. This should focus on  
856 deliberate commitment to developing the required capability at the OL that would support the  
857 implementation. Findings from this study reveal that cultural issues were among the most  
858 reported barriers to the implementation of the LPS. This could be minimised through the  
859 development of the right strategy and creating policies that could influence the organisational  
860 culture in the implementation process. This implies that the strategy should not be selected in  
861 isolation. Karim and Arif, (2013) observed that selection of the wrong strategy in the  
862 implementation of lean principles could lead to the disruption of the process it intends to  
863 improve. The strategy could include the provision of training for staff and the supply chains,  
864 supply chain assessment, changes to the contract, and the creation of a lean business  
865 department, among others.

866 *d. Create Awareness on the Strategic Capability Commitment for LPS*

867 The identified strategic commitment capability for LPS implementation and the process  
868 created to formalise them at the OL must be communicated through training at all levels. This  
869 could entail the use of company intranet to communicate such an approach and information.  
870 The information guiding such an approach should be located in areas where it would be  
871 prominent and accessible. Also, workshops and training on the strategic capability and  
872 commitment required should be organised at all levels. Specific avenues and approaches that  
873 could be used to create awareness on this include:

- 874 • company intranet, newsletters, updates from formal project meetings
- 875 • workshops, training, and

876       • monthly project briefing among others

877 This would enable all the departments within the business to understand what the  
878 organisation is doing, which would influence their own individual commitment to the  
879 strategic capability identified at the OL. The importance of creating awareness on company  
880 strategy at all levels has been emphasised in the literature (Elving, 2005).

881 *Contextual Inputs Factors (Behaviours arising from the contract)*

882 As shown in Figure 1, contextual input factors are the appropriate behaviours that should be  
883 in place at the OL to support the strategic capability commitments for LPS implementation. It  
884 focuses on the behaviours arising from the contract and its application in the process. The  
885 importance of having the right behaviour in the implementation of lean techniques cannot be  
886 overstressed as previous studies have shown that cultural and structural issues are among the  
887 factors that contribute to the failure of implementation of lean techniques. Johansen and  
888 Porter (2003), found that cultural and structural issues are the factors impeding the  
889 implementation of the LPS in the UK. Having the right behaviour in place helps in  
890 formalising the strategic capability identified. Thus, it should form the key components of the  
891 strategic capability commitment process. The behaviours arising from the contract include:

- 892       • the inclusion of LPS in the contract
- 893       • use of a collaborative form of contract
- 894       • use of relational contracting
- 895       • collaborative working culture and
- 896       • keeping the business arm of the organisation in the LPS loop

897 *a. The inclusion of LPS in the Contract*

898 Findings from this research reveal that LPS practice was formally included in the contract  
899 agreement between the main contractor, client, and subcontractors on most of the projects  
900 investigated. The essence of its inclusion in the contract was to encourage all the required

901 stakeholders to get involved and benefit from the process. This is necessary because of the  
902 numerous formal processes that dominate the construction industry. It has been suggested  
903 that the formal process should not be in relation to cost alone, rather it should include other  
904 soft practices that contribute to the project success (Kadefors, 2004). Undeniably, the LPS  
905 process is not an exception to this, and thus should be formalised.

906 *b. Use of Collaborative Form of Contract*

907 The use of a collaborative form of contract is an essential element in the contractual  
908 behaviour that needs to be in place at the OL for LPS implementation. Empirical evidence  
909 from this study reveals that on most of the projects investigated, a collaborative form of  
910 contract was used. This include; framework agreement, ECI, D&B and joint venture. The  
911 study reveals that even when design bid build (DBB) is used on a project, and the supply  
912 chains are into a framework agreement. This implies that a collaborative relationship would  
913 still develop. The contractual behaviour that occurs there could be better explained with  
914 relational contracting theory. According to Macneil, (1980) as parties to the contract have  
915 more and frequent conversation on the project, the relationship begins to develop.

916 *c. Inclusion of the Commercial Arm of the Business in the LPS Loop*

917 Another contractual behaviour that should be keyed into the organisation's strategy is the  
918 inclusion of the commercial arm of the business in the LPS implementation loop. Although  
919 this was only mentioned on one project, it seems to be an essential pre-condition to be  
920 considered at the OL. Currently, the commercial arms on projects are less involved in the  
921 production planning meetings in the LPS process. The involvement of this business group in  
922 the production planning session could improve the make-ready process, as it could enable the  
923 team to make real-time decisions that require commercial judgements.

## 924 **Project Level Path Clearing**

925 The project level (PL) factors are linked to the organisational level factors. The implication of  
926 this is that the strategic capability commitment for LPS implementation at the OL must be  
927 allocated appropriately at the project level. The two theories that explain the working of LPS  
928 at the PL are; the TFV model (Koskela, 2000) and the management as organising (MAO)  
929 (Johnston and Brennan, 1996). The “F” in the TFV model shows that in the LPS  
930 implementation the focus is in achieving smooth workflow rather than on converting the  
931 input to output which is the common practice in the traditional approach to project  
932 management. The smooth workflow is usually achieved through the make ready and  
933 lookahead planning (El-Sabek and McCabe, 2018b). Additionally, the MAO view explains  
934 why the inclusion of the subcontractors (i.e. the subunits) in the decision-making process on  
935 tasks contribute to the development of a reliable programme at the PL. For instance, Rincón  
936 et al, (2019) found that LPS implementation influences the behaviour of subcontractors as an  
937 autonomous agent. While El-Sabek and McCabe, (2018b) found that relationship building  
938 and communication among the last planners support the coordination of activities.

939 The PL is sub-divided into pre-project and project implementation activities as shown in  
940 Figure 1. Similar to the OL, the project level (PL) consists of the process input factor and  
941 contextual input factor.

### 942 ***Project Level Process Input Factors***

943 This refers to the processes that need to be created and practised at the project level in the  
944 implementation of LPS. It defines the processes that need to be in place at the project level  
945 (PL) for LPS. This includes:

- 946 • Project level strategic capability commitment
- 947 • Identify and understand production planning practice on the project
- 948 • Evaluate practice with LPS principle and theory

- 949 • Adopt standard approach
- 950 • Create enabler for implementation
- 951 • Implement and gauge implementation

952 *a. Align and Allocate Strategic Capability with Project Level Strategy*

953 It is essential for a strategy to also be developed at the PL, and aligned with the OL strategy.  
954 This is important as the team on the project would be coming from different organisations.  
955 For example, an organisation can tell its employees it wants them to embrace a process and  
956 educate them on why. However, projects should develop their own identity due to the vast  
957 array of companies required to deliver a project. In view of this, the project set-up; the  
958 companies involved including client, contractor, suppliers and designer should establish a  
959 joint strategy that considers the unique characteristics of the project. This should be aligned  
960 with the strategic support for LPS implementation.

961 *b. Identify and Review Production Planning and Control Practice*

962 At this point, it is essential for the production planning and control practice to be understood  
963 and streamlined to meet the strategic support allocated to the PL for the LPS implementation.  
964 To achieve this, the current production planning practice should be evaluated with an  
965 enhanced production planning and control principles such as the LPS principles.

966 *c. Evaluate and Review Practice Using the LPS Principles*

967 The LPS is a production planning and control method developed for the construction industry  
968 and it is among the most used lean techniques in construction (Ballard and Tommelein, *et al*,  
969 2016; Daniel, *et al*, 2015). Thus, the production planning and control practice on the project  
970 could be evaluated and reviewed for alignment with the advocated principles/theory of the  
971 LPS (Ballard, 2000). The underlying theories of the LPS revolve around planning, execution,  
972 and control (Ballard *et al.*, 2009). The LPS is based on 12 principles (Ballard and

973 Tommelein, 2016). Evaluating the practice based on the LPS principles would enable the  
974 identification of areas that need improvement in the actual implementation.

975 *d. Adoption of Standard Approach (Specific Capability commitments required)*

976 Based on the evaluation and review, a standard LPS approach should be adopted. The  
977 absence of such typical approach could result in a varied implementation of the process  
978 across projects executed in the same organisation. This means a project could be reinventing  
979 its own wheel which could hinder the intended benefits from the system. It is worth noting  
980 that the standard approach is not rigid, thus, it could be positioned to meet the reality of the  
981 project. However, since the LPS has standard components (Ballard, 2000), the team should  
982 develop the specific capability commitments required for the implementation of the  
983 components on the project.

984 *e. Create Implementation Enablers for LPS implementation*

985 For the adopted standard approach to work, implementation enablers should be created. The  
986 implementation enablers are grouped into two: physical and human factor enablers. The  
987 physical factors entail the allocation of designated room for production planning and control.  
988 This should include creating physical space such as co-location for working and visual  
989 production planning and control centre. Such location should be readily accessible to all the  
990 required stakeholders on the project including the subcontractors. The human factor, on the  
991 other hand, is concerned with the appointment of facilitators and lean champions in driving  
992 the process on site. In the context of this study, all the research participants identified  
993 facilitation as an essential process that needs to be in place for the successful implementation  
994 of the process at the project level. It includes both external and internal facilitation. External  
995 facilitation such as the use of proven lean construction consultants could prove useful at the  
996 initial start. However, over-reliance on consultants should be avoided.

997 *f. Gauge Practice*

998 As the implementation process continues, it is important that the practice is constantly gauged  
999 using both internal and external mechanisms. To gauge the practice internally, the Planning  
1000 Best Practice (PBP) guide that has been used to assess the level of implementation of the LPS  
1001 in different parts of world such as Brazil, Israel Chile, and UK among others (Daniel *et al.*,  
1002 2017; Priven and Sacks, 2016 Alarcon *et al.*, 2011) could be used.

1003 In addition, the LPS implementation maturity guide could be used. The guide was originally  
1004 developed by Gregory Howell in 2005; one of the inventors of the LPS (Lean Project  
1005 Consulting, 2005). Through this, the efficacy of implementation could easily be assessed  
1006 internally and areas that need improvement could be identified and addressed appropriately.  
1007 Gauging of the practice also requires input from the external enabling factors.

1008 ***Project Level Contextual Input Factors (Social Behaviour)***

1009 To successfully implement the adopted common approach, contextual input factors  
1010 embedded as social behaviours are required at the project level. Social behaviours are those  
1011 soft skill behaviours that need to be practised by the team on the project for the successful  
1012 implementation of the LPS at the PL. These factors include:

- 1013 • transparency and discipline,
- 1014 • honesty, trust and truthfulness in promising,
- 1015 • selection and involvement of all the required team,
- 1016 • pre-planning before production planning, and
- 1017 • proactive involvement of the construction manager and subcontractors

1018 These are among the social behaviours that should be in place at the PL for the rapid and  
1019 successful implementation of the LPS. The need to be cautious about lack of honesty and  
1020 poor promising in the implementation of the LPS has been explained theoretically from the  
1021 Language/action perspective theory (Issato *et al.*, 2015). Practically, it entails making

1022 promises that are realistic and achievable within the timeframe. This suggests that no  
1023 stakeholder on the project should be pressurised into making undue commitments. The five  
1024 conditions for making reliable promise should be adhered to in LPS implementation (Issato *et*  
1025 *al.*, 2015). The action expected here is informed by social information exchange  
1026 (conversation) (Priven, and Sacks, 2016) as opposed to the technical information exchange  
1027 that dominates traditional project management (Ballard, 2000). In such social conversations,  
1028 as advocated in the LPS, every stakeholder is empowered to make promises which could be  
1029 YES! or NO!.

### 1030 **External Enablers (External Level Path Clearing)**

1031 External enablers can help in gauging practice and can bring in new strategies and  
1032 innovations to improve current practice both at PL and OL as shown in Figure 1. The theory  
1033 that shows the need for the external level path clearing is the economic theory proposed by  
1034 Hayek, (1945) where it posits that the knowledge needed to solve a problem is usually  
1035 dispersed among different people. However, sometimes this knowledge may exist outside the  
1036 project environment. This shows the importance of engaging with the external enabling  
1037 factors. In reality, it supports innovation and sustains the implementation of the LPS.

1038 These external enablers include:

- 1039 • research partnership between the industry and the academia
- 1040 • CPD training courses on LPS
- 1041 • engagement with proven lean construction consultants, and
- 1042 • Lean Construction Institute events.

1043 There is a need to deliberately engage with the identified external enabling factors presented  
1044 above. This is essential as it has been observed that the LPS is dynamic and it uses various  
1045 avenues to improve practice, for example, its use of theory to explain practice (Daniel *et al.*,

1046 2015). Such external forum and partnership could be an avenue for communicating and  
1047 learning about improvements or findings. Research partnership with the industry and  
1048 facilitation of the process supports the implementation of the LPS. Previous studies have also  
1049 shown that research partnership with the industry and facilitation of the process by proven  
1050 facilitators could support the success of the LPS implementation in construction (Formoso *et*  
1051 *al.*, 2002).

### 1052 ***Continual Learning Action and Feedback Loop***

1053 The continual learning action is the loop that sustains the implementation of the LPS.  
1054 According to Mohd-Zainal et al., (2013) there is a strong relationship between organisational  
1055 learning and sustaining of lean practice. It focuses on learning and taking action at each  
1056 level. The continual action learning advocated occurs at every point in the process as shown  
1057 in Figure 1. This implies that learning does not just occur at the end of the entire process only  
1058 since there is an internal feedback loop. As shown in Figure 1, there is an internal feedback  
1059 loop between the OL and PL; this is done to ensure issues that need addressing are attended  
1060 to before the process is rolled out completely. For instance, with the rollout of a set of  
1061 strategies, unintended consequences may occur and it is helpful to understand these sooner  
1062 than later. This shows the importance of creating an internal feedback loop as shown in  
1063 Figure 1. In the implementation of the LPS “bad news early could be said to be good news”.

### 1064 **Conclusion**

1065 The aim of the current study is to develop an approach to support construction stakeholders in  
1066 the implementation of the LPS. Accordingly, the study developed a non-prescriptive but all-  
1067 inclusive approach for supporting construction stakeholders (client, main contractors and  
1068 subcontractors) in the implementation of the LPS in construction project known as “Last  
1069 Planner System Path Clearing Approach” that includes organisational, project and external  
1070 path clearing levels. This expands previous approaches to the implementation of the LPS in

1071 construction which focused more on the project level. Additionally, the developed LPS-PCA  
1072 would potentially minimise the fragmentation observed in the implementation of the LPS  
1073 because of its capacity to inform the various stakeholders involved in the implementation  
1074 process to recognise what is required of them at each point.

1075 This study contributes to knowledge and the future application of production planning and  
1076 control principles in construction engineering and management as follows: The proposed  
1077 approach provides a new insight into how to apply the LPS holistically in the management of  
1078 engineering projects. These include civil engineering and infrastructure projects and other  
1079 complex construction projects. Furthermore, the current study adds to the existing body of  
1080 knowledge in production planning and its application in management engineering by  
1081 identifying and categorising the nature of support required for a rapid and successful  
1082 implementation of the LPS gleaned from the literature review and the empirical study. The  
1083 study also provides insight into the current practice and performance of the LPS in the  
1084 management of civil engineering project as evidenced in the two case study reported from the  
1085 highways and infrastructure projects.

1086 In terms of contribution to practice; the practical application of the developed LPS-PCA  
1087 would enable construction stakeholders (clients, main contractors, and subcontractor, among  
1088 others) to understand what needs to be in place for the successful implementation of the LPS  
1089 in the management of civil engineering and infrastructure projects. This includes both  
1090 intending and current users of the LPS thus, enabling them to make the right decision with  
1091 regard to the process and the behaviour required in the LPS implementation process.  
1092 Furthermore, the identification of the three “levels of support” (organisational, project, and  
1093 external enabler) provides a focal point for construction practitioners to focus on in the  
1094 implementation of the LPS in the management of civil engineering project.

1095 The LPS-PCA developed reveal that the organisational level, project level and external  
1096 activities identified should be done by every contributing organisation so as to clear the path  
1097 for smooth implementation of the LPS. This means LPS-PCA is not just for the main  
1098 contractor or client, rather it is for all the organisations involved in the project, including the  
1099 subcontractors. This further shows how complex applying the LPS is, in particular for smaller  
1100 subcontractors which participate in several projects at the same time.

1101 Although the LPS-PCA developed is limited to empirical evidence gathered mainly from the  
1102 UK, it could be adopted and serve as a lens to direct future implementation of the LPS  
1103 elsewhere in the world. Furthermore, it is worth noting that the use of LPS-PCA in  
1104 construction project would require experienced LPS facilitators embedded within the  
1105 organisation which may be an additional cost to the project. An extended implementation of  
1106 LPS-PCA in construction has been reported in Ebbs *et al.*, (2018).

#### 1107 **Data availability acknowledgement:**

1108 Data generated or analysed during the study are available from the corresponding author by  
1109 request.

1110

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