SOCIAL NETWORK DEVELOPMENT IN LAST PLANNER SYSTEM™ IMPLEMENTATIONS

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ABSTRACT

Observations on construction sites have shown that even when the Last Planner System™ (LPS) is implemented only partially, it can still achieve positive results. We hypothesize that part of the explanation for this is that the weekly work meetings engender a social network among the subcontractors, with concomitant improvement in communication, reliability and trust, and in this way enhances coordination and results in better workflow. In the first step of research designed to test this idea, eight construction projects were monitored over time, using social network analysis (SNA), to explore the relationships between the extent of LPS implementations and the strength of the social networks that developed. Positive correlation was found between the two. Weekly work planning meetings appear to be the main catalyst for strengthening the social networks. Communication between construction crews from different ethnic groups was found to be strongly dependent on the LPS implementations. The next steps will seek to isolate the relationship between the strength of the social networks and the resultant work flows, both in the presence of and without LPS, to better explain the social mechanism of the LPS.

KEYWORDS

Last planner system, work flow, communication, collaboration, reliability, trust.

INTRODUCTION

How does the Last Planner System™ (LPS) work? Lean system thinking concerning the 'mechanics' of construction production systems suggests that it improves workflow by creating pull flow of resources and that it eases bottlenecks by filtering out work packages that are not ready for execution (Ballard 2000). Economic game theory modelling has shown that it reduces the information gap between project managers and subcontractors, thus improving the reliability of resource allocation decisions (Sacks and Harel 2006). However, observations on construction sites have shown that even when LPS is implemented only partially, e.g. without look-ahead planning, a make-ready process or feedback (measurement of PPC), it can still achieve positive results. Many authors have reported LPS implementations that are partial, reducing sometimes to the weekly work planning meeting alone, either because they began as WWP and did not progress, or because full-scale implementations degraded over time (Hamzeh 2009, Viana, Mota et al. 2010).

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We hypothesize that part of the explanation for this is that the weekly work meetings engender a social network among the subcontractors, which improves trust and communication and in this way enhances coordination and results in better workflow. Figure shows a typical weekly work planning meeting held on site.

Barnes (1954) was the first to use the term "social network" to denote patterns of ties, concepts usually used by social scientists: bounded groups (e.g., tribes, families) and social categories (e.g., gender, ethnicity). Social network analysis (SNA) is the methodical analysis of social networks. SNA views social relationships in terms of network theory, consisting of nodes (representing individual actors within the network) and ties (which represent relationships between the individuals, such as friendship, kinship, organizational position, sexual relationships, etc.) (D'Andrea, Ferri et al. 2010). These networks are often depicted in a social network diagram, where nodes are represented as points and ties are represented as lines.

Figure 1: Typical LPS weekly work planning meeting at the Yavne 1-2-3 project.

METHOD

To test the hypothesis that the LPS in general, and weekly work meetings in particular, engender a social network among the subcontractors, the project teams performing the interior finishing works in eight residential building construction projects were monitored. The independent variables measured were the depth of the social network in each team and the level of implementation of the LPS on each site (the dependent variable for the overall research, the resulting project workflow for each project, is beyond the scope of this paper). The eight projects were selected from three large-scale residential developments to reflect a range of degrees of LPS implementation (in three of the projects, LPS was not implemented at all). All of the buildings were of similar size and design, used the same construction methods, and all were at the same stage of construction (the teams had typically worked together for 4-5 months).

SOCIAL NETWORK MEASUREMENT

The formation of the social network among the teams in each project was measured by interviewing subcontractor crew leaders and general contractor (GC) staff using a structured questionnaire based on the method used by Zeffane, Tipu et al. (2011) in their research of the triad of communication, commitment & trust., and through observation as part of action research. Table 1 lists the key actors in the social networks. All of the roles were present in all of the projects.

Table 1: Key actors at the interior finishing works stage.

ID	Crew/Role	Number of workers per crew	Subcontractor or GC employee
BLD	Builder (masonry walls)	1-2	Subcontractor
ELE	Electrician	2-5	Subcontractor
PLM	Plumber	2-4	Subcontractor
AC	Air-conditioning installer	2-3	Subcontractor
TLN	Tiling crew	2-5	Subcontractor
PLS	Plastering crew	2-3	Subcontractor
DRY	Drywall crew	2-3	Subcontractor
CCC	Client changes coordinator	1	GC employee
SI	Site Superintendent	1	GC employee
PM	Project Manager	1	GC employee

The questions were designed to explore three aspects of behaviour that are of relevance in this context and by which we can measure the cohesiveness of the social networks that are formed among construction project teams:

- The depth and extent of **communication**.
- **Reliability** in the sense of the extent to which people rely on one another. This implies that they are perceived to fulfil their commitments in the working relationship (to do what they say they will do when they say they will do it). This is significant in production because it is essential for stability in planning.
- The degree of **trust** among people.

The questionnaire is provided for reference in Appendix I.

MEASURING THE DEPTH OF LPS IMPLEMENTATION

A simple scale that awarded a single point for each aspect of the LPS™ was used to quantify the level of implementation for each project. This scale, called the 'Planning Best Practice' (PBP) index, was developed in a series of academic studies (Soares, Bernardes et al. 2002, Sterzi, Isatto et al. 2007, Viana, Mota et al. 2010). It comprises a checklist of 15 planning and control practices. The resolution of measurement for each practice, and the associated scores, were none (✗), partial (½) or complete (✓), yielding a maximum possible score of fifteen. The levels recorded are listed in table 2.

Table 2: Planning Best Practice (PBP) index scores for the projects.

Practice	Yavne 1-2-3	Yavne 6-7	Yavne 20-21	Dan 2	Dan 3	Ir Yamim 1	Ir Yamim 2	Ir Yamim 3
Formalization of the planning and control process	✓	✓	✓	✓	✓	½	½	½
Standardization of short-term planning meetings	✓	✓	✓	✓	✓	×	×	×
Use of visual devices to disseminate information in the construction site	✓	✓	✓	✓	✓	×	×	×
Corrective actions based on the causes non-completions of plans	½	×	½	½	½	×	×	×
Critical analysis of data	½	×	½	✓	✓	×	×	×
Correct definition of work packages	½	×	×	✓	½	×	×	×
Systematic update of the master plan, when necessary	×	×	×	✓	✓	×	×	×
Standardization of the medium-term planning	×	×	×	✓	✓	×	×	×
Inclusion of only work packages without constraints in short-term plans	×	×	×	½	×	×	×	×
Participation of crew representatives in decision making in short-term planning meetings	✓	✓	✓	✓	✓	×	×	×
Planning and controlling physical flows	½	×	×	½	½	×	×	×
Use of indicators to assess schedule accomplishment	✓	×	×	✓	✓	×	×	×
Systematic removal of constraints	×	×	×	½	×	×	×	×
Use of an easy to understand, transparent master plan (e.g. LOB)	✓	✓	✓	✓	✓	×	×	×
Scheduling a back-log of tasks	×	×	×	½	×	×	×	×
Total scores	8	5	6	12.5	10.5	0.5	0.5	0.5

SOCIAL NETWORK ANALYSIS RESULTS

COMMUNICATION

Figure 2(a-c) shows sociograms for three of the projects in the sample, one from each site. They show the actors as nodes and the active communication channels between them as links between the nodes. A communication event is defined as communication between members in a formal meeting, in an informal face-to-face meeting or a phone call. The width of each link represents the number of communication events per week in that channel. The threshold value for showing a

link is two events per week, which filters out channels where the only communication between the actors takes place in a single formal site meeting.

Figure 2(d) shows a benchmark sociogram that represents the set of communication channels that are essential for effective coordination between project actors to achieve smooth workflows. This minimum set of *essential* communication channels represents connections between actors whose work is interdependent in terms of flows of work, space, information, etc. The benchmark set of essential channels was compiled using a second questionnaire, reproduced in Appendix II, with nine site superintendents and subcontractor crew leaders. The superintendents were asked to define the values (numbers of events) for every cell of the matrix of possible communication channels, whereas crew leaders were asked only about the channels between themselves and others.

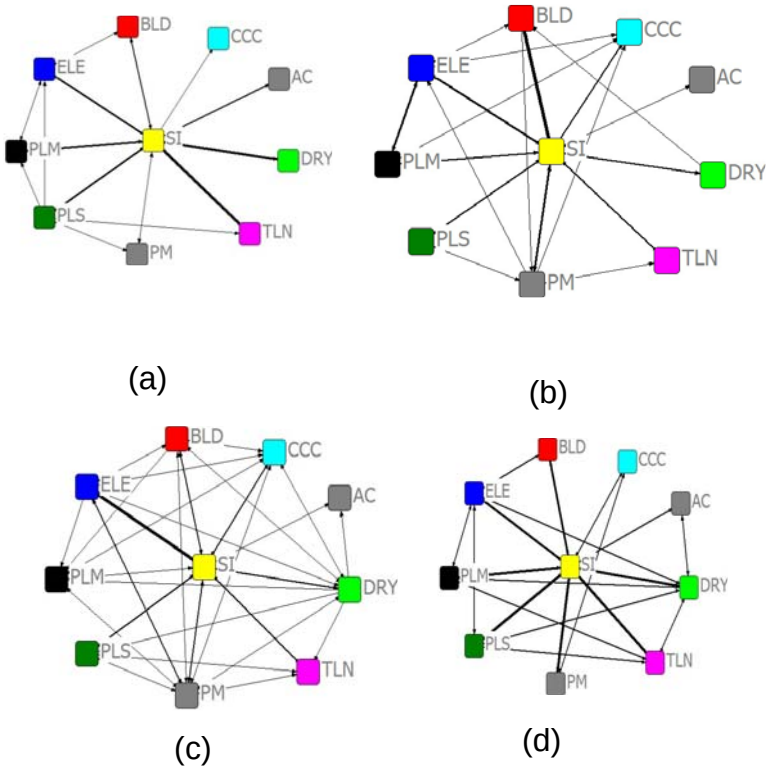


Figure 2: Communication sociograms for (a) Ir Yamim 1, (b) Dan 2, (c) Yavne 1-2-3 and (d) an idealized minimally effective project. Communication channels are shown for a threshold of two communications per week.

The figures clearly reveal the differences between the projects. In Ir Yamim 1 (Fig. 2a) the communication is centralized around the superintendent (SI), whereas the other networks are less centralized. This implies a highly centralized management control system for Ir Yamim 1, where almost all communication between trade crew actors flows through the site superintendent.

Figure 3 highlights the importance of considering the threshold number of communications per week for determining the nature of the social network. The vertical axis measures the density of communications, which is computed as the number of active channels divided by the number of possible channels. One can see that there is a significant difference between communications at least once a week

and communication at least twice. This suggests that communication once per week may be incidental, or occur only during a formal site meeting, whereas those who communicate more than once do so frequently. For this reason for the social network communication density should be measured at thresholds of at least two communications per week.

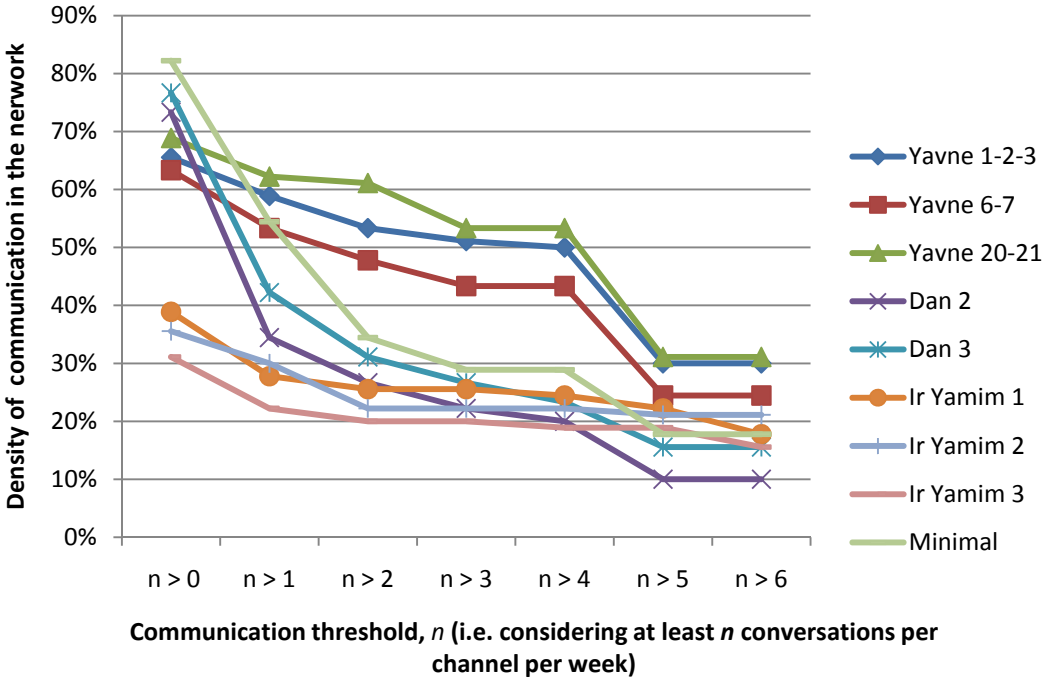


Figure 3: Density of the communication network for different threshold communication levels

A limitation of the density measurement is that it includes all communication, some of which may be non-essential. This can skew the results. A better representation can be obtained by indexing the observed communication within the essential channels only. Two measures are shown in Figure 4:

- The proportion of the essential communication channels that was active, using a threshold of at least one communication per week.
- The density of communication over all active channels only, considering all communication events.

As can be seen, on sites without LPS (Ir Yamim projects) approximately 60% of the essential communication channels are inactive, as opposed to only 20% on the sites that use the LPS.

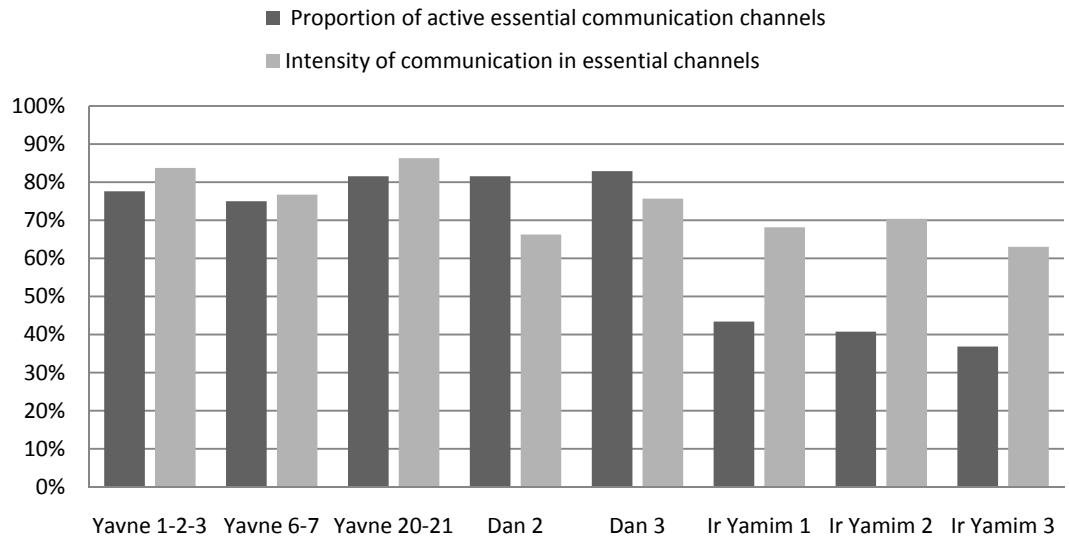


Figure 4: Actual communication on essential channels as a proportion of total essential communication

RELIABILITY

Figure 5 shows the measurement of the actors' perceptions of their colleagues' reliability for three projects. The widths of the link lines represent the relative degree of perceived reliability (thicker lines indicate greater reliability). A 'reliability index' was computed for each project, as the average value over all of the links for each network, with a range from 0 to 1. The values for the Ir Yamim projects ranged from 0.77 to 0.9, for the Dan projects from 0.87 to 0.94, and for the Yavne projects from 0.83 to 0.9.

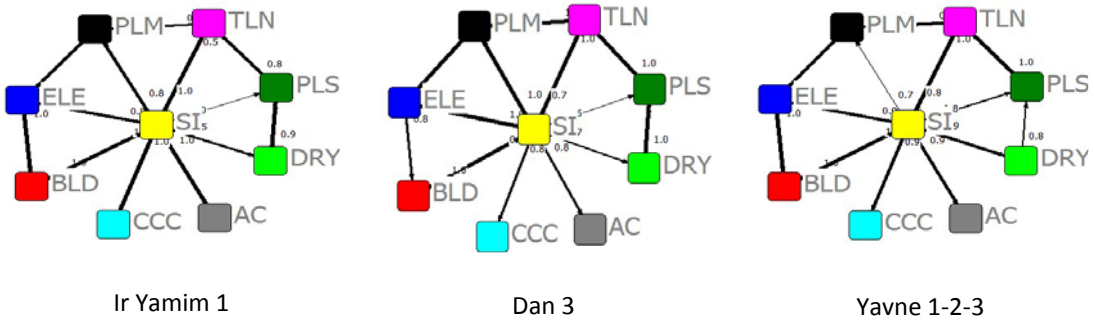
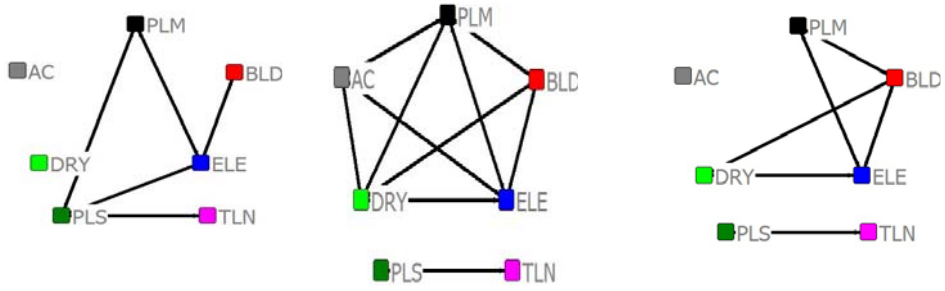


Figure 5: Reliability perception networks for Ir Yamim 1, Dan 3 and Yavne 1-2-3.

TRUST

Figure 6 shows the results for the trust-related questions for three of the projects. The arrow links represent trusting relationships. As can be seen, the Dan project has significantly more trusting relationship than the other two projects shown.



Ir Yamim 1 Dan 3 Yavne 1-2-3

Figure 6: Trust networks for Ir Yamim 1, Dan 3 and Yavne 1-2-3.

SOCIAL NETWORK LINKS ACROSS ETHNIC GROUPS

On typical Israeli construction sites, the crews are generally homogeneous in their ethnic composition. Crews from four ethnic groups worked on the projects in the sample group (we denote them A, B, C and D). As can be seen in Table 3, the spread of ethnic groups across trades is fairly diverse. The communication and trust between subcontractors depend strongly on their ethnic group. For example, this partly explains the trust grouping of the tiling and plastering trades that can be seen in Figure 6. They are usually both from group C and don't interact with the others. In the Ir Yamim projects the plasterers from group A and they do interact with the others.

Table 3: Ethnic groups of last planners per sub project

Occupation	Yavne 1-2-3	Yavne 6-7	Yavne 20-21	Dan 2	Dan 3	Ir Yanim 1	Ir Yamim 2	Ir Yamim 3
Builder (masonry walls)	B	B	B	A	B	B	B	B
Electrician	A	A	A	B	B	A	A	A
Plumber	B	B	B	B	B	A	A	A
Air-conditioning installer	D	D	D	D	D	A	A	A
Tiling crew	C	C	C	C	C	B	C	C
Plastering crew	C	C	C	C	C	A	A	A
Drywalls crew	B	B	B	A	B	A	A	A
Client changes coordinator	D	D	D	D	D	D	D	D
Site superintendent	A	B	D	D	B	D	B	A
Project Manager	D	D	D	D	D	B	B	B

This appeared at first to be an obstacle to comparison of the depth of the social networks, because, thanks to the nature of the action research, it became clear that communication within ethnic groups was naturally more common than across the groups due to cultural and language barriers. However, this feature in fact provides a unique opportunity for measurement: inter-ethnic communication is a key indicator of the strength and depth of the social network.

Figure 7 shows how many of the essential communication channels cross ethnic boundaries for each project, how many of those are active, and the percentage that are active.

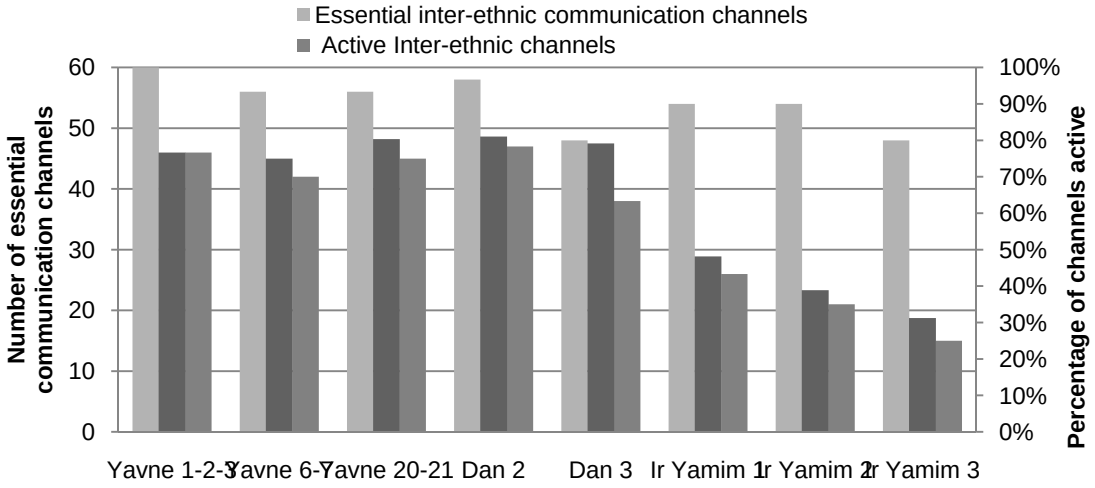


Figure 7: Essential inter-ethnic communication channels

LPS IMPLEMENTATION AND SOCIAL NETWORK FORMATION

Finally, we consider the relationship between LPS implementation and the depth and strength of social network formation. Figure 8 plots a set of social network strength measures against the PBP index. Possibly the most significant result is the relationship between the percentage of active inter-ethnic communication channels and the LPS implementation, because those communication relationships do not form spontaneously. The percentage of active inter-ethnic channels is much higher on sites with LPS than those without it.

Furthermore, the network depth appears to be independent of the extent of LPS implementation. Detailed investigation of the scores for the items within the PBP index for those projects where LPS is practiced reveals that two specific practices of the 15 are common to all the projects sites with LPS implementation. We therefore hypothesize that they are the primary cause of social network formation. They are: 1) Standardization of short-term planning meetings, and 2) Participation of crew representatives in decision making in short-term planning meetings.

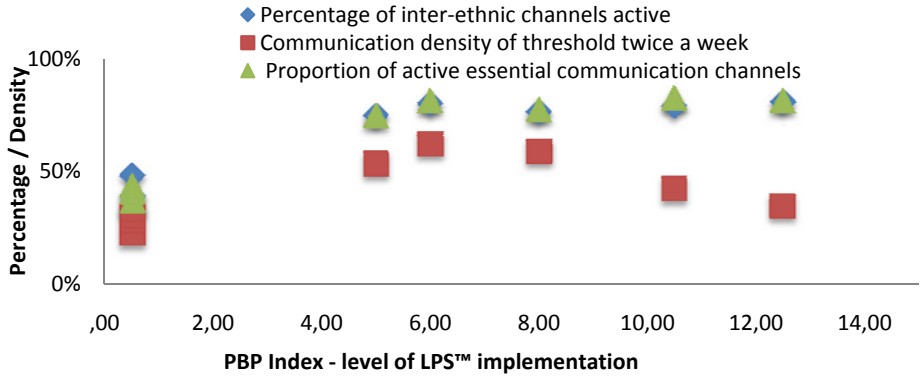


Figure 8: Relationships between the level of LPS implementation and measures of the strength of the social network.

CONCLUSIONS

Although the number of projects studied was relatively small, they were studied in depth and over a number of months. The projects were directly comparable in terms of their size, type, production stage, work content, contracting arrangements and subcontracting crews. The following conclusions can thus be drawn with some confidence:

- Implementation of the LPS appears to play a strong role in engendering development of a social network among the project participants. The basic hypothesis is valid.
- Partial implementation of LPS is sufficient to strengthen the social network, especially as measured by intensity of communication. The weekly work planning meeting appears to be the key element in this regard.
- Crews on sites where LPS is implemented have a different understanding of the concept of reliability compared with sites where it is not implemented. We surmise that actors on sites with no formal production planning have a different perspective because no detailed weekly work plan exists for them to evaluate others against. Where there are no relationships and no commitments, one does not necessarily perceive others as unreliable. The way reliability is measured for social network analysis must take this into account in all future research.
- Cultural and language barriers associated with ethnic groupings of trade crews strongly influence the levels of communication on the construction site. Communication across ethnic group lines is therefore a strong measure of social network strength. The LPS results in the formation of social network connections across ethnic group lines, where very weak or no connections would have existed without it.

No conclusions can be drawn at this stage concerning the relationships between social network strength, coordination of work, and workflow outcomes. The research reported is on-going. In the next steps, interventions to improve the strength of the social networks will be undertaken, without the use of LPS™. Also, the workflow results for each site will be measured. These steps are designed to allow analysis of the relationships between each of the independent variables – social network strength and degree of LPS implementation – and the resulting workflows.

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Appendix I: Questionnaire for communication, reliability and trust.

- How many times in the past week did you talk with each of the other members of the team? In a formal meeting, OR in an informal face-to-face meeting OR on the phone?
- For each crew on whose work you depend: if they commit to complete work on a given day, how confident are you that they will really finish on the day promised? How reliable is the crew? Answers were given as a simple percentage.
- For each other crew: would you be willing to loan your private tools or equipment to that crew?

Appendix II: Questionnaire for establishing essential communication channels.

- **For superintendents:** At minimum, how many times within a week should each team member talk to the other members in the team to establish efficient coordination between project actors in order to achieve smooth workflows? In a formal meeting, OR in an informal face-to-face meeting OR on the phone?
- **For each subcontractor:** At minimum, how many times within a week should you talk to the other members in the team to establish efficient coordination between project actors in order to achieve smooth workflows? In a formal meeting, OR in an informal face-to-face meeting OR on the phone?

	BLD	ELE	PLM	AC	TLN	PLS	DRY	CCC	SI	PM
BLD										
ELE										
PLM										
AC										
TLN										
PLS										
DRY										
CCC										
SI										
PM										

Figure 9: Standard blank for filling each of the answers of both questionnaires