Developing a Framework of Common Information Space (CIS): Grounded Theory Analysis of Airport CIS

Nallini Selvaraj , Bob Fields

Interaction Design Centre, School of Engineering and Information Sciences, Middlesex University, London, UK
{N.Selvaraj, B.Fields}@mdx.ac.uk

Abstract. The notion of Common Information Space (CIS) has been proposed in the field of Computer Supported Cooperative Work (CSCW) as a conceptual framework for analyzing cooperative work processes. The area is still in its formative years and requires more research to contribute to its development. This paper presents findings from an investigation undertaken for such an endeavor. Three perceptions of CIS are presented, which are, CIS as a socio-technical arrangement, dynamic arrangement, and dependency management arrangement. These have been derived from review of existing research contributing to CIS notion development and Grounded Theory analysis of collaborative work process in air traffic control setting. The findings presented in this paper provide a comprehensive and consolidated view of the notion development. The paper contributes to the ongoing discussion of CIS notion development by making theoretical as well as methodological contribution.

Keywords: Computer Supported Cooperative Work, Articulation Work, Common Information Space, Workplace Studies, Air Traffic Control

1 Introduction

Modern work settings are collaborative ensembles that entail complex work processes and diverse social activities. Work is distributed among multiple personnel with dependencies between their undertakings. In order to manage the dependencies, personnel involved in the work process have to cooperate with each other by what is known in the field of Computer Supported Cooperative Work (CSCW) as "articulation work". Articulation work is the work undertaken to manage dependencies in the work process by *coordinating, scheduling, aligning, meshing*, etc. of distributed individual activities [1-3].

In the past few years research has been undertaken in the field of CSCW to provide support for articulation work through the construction of information spaces which are viewed as communication spaces or interaction spaces [4]. These spaces support collaborative work activities by facilitating communication through information exchange and information sharing. A number of terms have been formulated to represent them such as media spaces, shared workspace, shared information spaces, shared and common communication spaces, and more recently common information

spaces [5]. These concepts are still evolving and are needed because of their significance in the discussion of features of cooperative work.

One of the first discussion about the significant position of such information spaces in the articulation of cooperative work was under the label of "shared information space" by Bannon and Schmidt [5]. In a subsequent paper [4] they extended this concept under the label of "Common Information Space" (CIS). The difference between the two is in the perception towards the role of such information spaces in cooperative work process. In the case of shared information space, focus is on articulating cooperative work by using artefacts to mediate communication. However, in the case of common information space, the focus is not just on interaction through information sharing but also on establishing common understanding of the information held and propagated in such spaces. According to Bannon, one of the reasons for the shift in terminology is *to lessen the connotations associated with the word 'sharing' and to indicate the transient and instrumental aspects of people having information in 'common* [6].

Development of the notion of CIS is still in the formative years especially with respect to CIS for collaborative work across heterogeneous work communities. The focus of this research is to contribute to the notion development. In this paper, we first present a review of existing research contributing to CIS conceptualization through a simple framework. Our contribution to the development of the notion is then depicted by extending the framework through an empirical study conducted in the air traffic control work environment and Grounded Theory analysis of the collaborative work process of this setting.

2 Notion of Common Information Space (CIS)

There is a growing realisation lately that the complexities involved in a collaborative work ensemble such as dynamic interaction, distributed decision making, heterogeneous worker/group collaboration, etc. cannot be handled by just supporting information sharing or pooling information from multiple sources. Rather, there is also a need to incorporate an interpretive element to this process. Common Information Space (CIS) is a notion germinating in this evolution where the focus is on placing information in common as well as establishing common interpretation or at least "common enough interpretation" to achieve efficient task performance [4].

In the field of CSCW, CIS has been proposed as a concept for analysing cooperative work. Schmidt and Bannon introduced the concept of CIS to point out that information has to be "placed in common" explicitly involving creation in one context and usage in a different context by reformulating and re-contextualizing it to be relevant in latter [4]. Therefore, CIS does not represent just a repository of information to which people have common access but also how they incorporate it in daily usage and integrate it into the work practice.

In general, the notion of CIS focuses on the interrelationship between actors, artefacts, information, and cooperative work. Review of literature in this area reveals that researchers from various disciplines have discussed different aspects of CIS. Because the concept is still in its early stages of development there exists diverse

perception towards the notion. The next section presents a framework constructed from a review of research leading to these varied conceptualizations of CIS. The framework is intended to help understand the concept development by synthesizing and organizing these diverse perceptions of CIS along two main attributes, which are, CIS as a socio-technical arrangement and CIS as a dynamic arrangement.

3 Framework of CIS Conception from Existing Research

Studies undertaken for developing the notion of CIS have focused on specialised cooperative work settings such as; air traffic control tower and software company [7], bank, football competition, and museum [6], hospital ward [8-10], airport [11], and oil and gas company [12]. While reviewing these studies two fundamental questions were addressed: What are the pertinent questions being addressed in the research, and How are the findings conceptualized? Some of the questions driving research in this area were found to be: How should CIS be conceived? What are the characteristics of CIS? and How can the notion of CIS be applied to the analysis and design of cooperative work arrangements?

Two main perceptions of CIS transpire from these studies and their findings. They are CIS as *a socio-technical arrangement* and as *a dynamic arrangement*. Conceptualizations from various research undertakings have been classified to formulate these two perceptions of CIS, as depicted in Fig.1. The three conceptualizations of 'Artefact as CIS', 'Workspace as CIS', and 'Achieved in Practice' contribute to the socio-technical arrangement perception and 'Malleable', 'Situated' and 'Temporal' contribute to the dynamic perception of CIS.

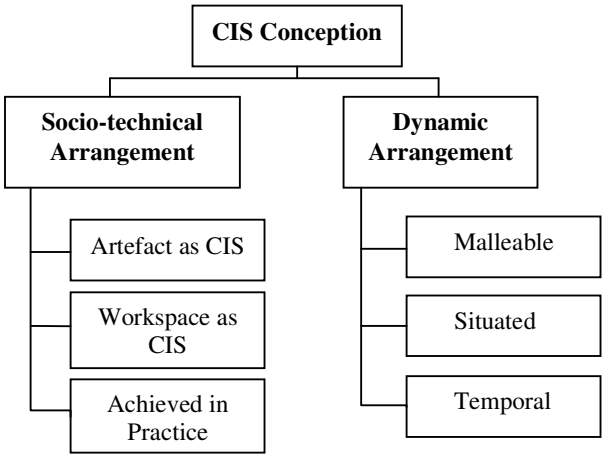

Fig. 1. Framework of CIS Conception

The framework is illustrated next through discussion of conceptualizations evoking the two perceptions of CIS. Table 1. presents conceptualization of CIS from various

research undertakings informing the two perceptions of CIS depicted in the framework.

Table 1. Studies contributing to the perception of CIS as a socio-technical and dynamic arrangement

	Socio-Technical Arrangement			Dynamic		
Concepts / *Studies*	**Artefact as CIS**	**Workspace as CIS**	**Achieved in Practice**	**Malleable**	**Situated**	**Temporal**
Schmidt & Bannon '92[4]	▨		▨		▨	
Clement & Wagner '95[13]			▨	▨		
Bannon & Bodker '97[7]		▨	▨	▨	▨	
Randall '00[14]	▨		▨			
Bertelsen & Bodker '01[15]		▨	▨		▨	
Reddy et al. '01[8]	▨		▨	▨		▨
Bossen '02[9]		▨				
Fields et al. '04[11]		▨	▨		▨	
Rolland et al '06[12]	▨	▨	▨	▨	▨	▨
Munkvold et. al. '07[10]		▨	▨		▨	▨

3.1 Socio-technical Arrangement

The technological arrangement of the work setting along with the social practices of personnel functioning in the setting plays a significant role in the construction and maintenance of CIS. This section presents how different researchers have conceptualized such an arrangement of CIS.

Artifact as CIS. Schmidt and Bannon [4] conceptualize information artefacts as CIS by illustrating how these artefacts maintain a central archive of organizational information as well as disseminate information to cooperating actors. To function as a common information system artefacts need to be not only robust but also easily and quickly accessible to users from different background [14]. Reddy and her colleagues [8] explore how information propagated by a computerized patient record is incorporated into the work practices of a hospital intensive care unit where different representations of the same underlying information are provided to different work groups depending on their needs. However, additional work is required to synchronise interpretations. The role of common database as a CIS to share knowledge across different heterogeneous context has been explored by Rolland and other researchers [12] in a large oil and gas company. Although the database performs this function to some extent there are inherent limitations and barriers of such a system for achieving CIS across heterogeneous settings, for example, problems in interpretation due to lack of contextual knowledge and creation of new forms of fragmentation.

Workspace as CIS. The depiction of workspace as CIS varies with the work setting, i.e. when the collaborating actors are collocated and when they are distributed. Bannon and Bodker [7] present the workspace as CIS when actors are physically co-present. For example, the workspace of air traffic control room in an airport is a CIS constituted by the amalgamation of information artefacts, physical behaviour such as speaking aloud and gestures, visual observation, and openness of actions. Such a setting facilitates establishing common understanding of the field of work because of the physical co-presence of those working together. Rolland et. al. [12] provide a different take on CIS for collocated actors by presenting 'collaboration rooms' as a socio-technical arrangement where the arrangement of collaboration technologies in the room needs to be constantly re-negotiated to render a CIS unlike that of the airport control room which consists of stable arrangement of collaboration technologies.

In the case of distributed work setting, Bertelsen and Bodker [15] have challenged the notion that CIS is about access to everything everywhere by depicting the wastewater plant setting as a common artefact. They conceptualize the workspace as having several centres and peripheries and composed of overlapping regions, where establishing commonness of information is attributed to mobility within the workspace. Akin to this perception, Bossen [9] takes a broader perspective on CIS by portraying a hospital ward as massively distributed CIS and a common artefact like the wastewater plant. He has developed a framework of seven parameters to analyse the workspace as CIS. He attributes establishment of shared interpretations to not just the physical proximity of those involved but also to the number and means of communication available to people. In a similar setting, Munkvold et. al. [10] explore the infrastructural arrangement such as the electronic nursing module, inter and intra disciplinary discussions, conference room arrangement, and human mediators contributing to the establishment of CIS of a hospital ward. Taking the perception of overlapping regions in CIS further, Fields et. al. [11] depict the work environment of an airport as a constellation of overlapping CISs that are articulated through boundary objects.

Achieved in Practice. One perception common to all research undertakings in this area is the view that CIS is achieved in the daily practices of actors in the work process. Randall [14] does not consider technology to be the defining feature of CIS. Rather, it is the coalescence of pre-existing habits and practices of varying groups and individuals that establishes the commonness of information. CIS is jointly constructed and maintained by actors of the cooperating ensemble in a manner not necessarily constrained by prescribed procedures and conventions [4]. Besides sharing information additional work by actors such as incorporating contextual knowledge is required to establish common interpretation of shared information. Clement and Wagner [13] consider providing communication spaces to establish and maintain CIS. These electronic communication facilities allow actors to perform necessary negotiations by allowing them to rearrange the communication spaces according to changing needs. Bannon and Bodker [7] perceive CIS to be negotiated and established by actors involved where physical co-presence has an edge over spatially distributed

actors and also mutual intelligibility of actions plays a significant role. They provide a different take by prescribing the use of human mediators to facilitate common interpretation of information by both producers and consumers of the information.

By shifting the focus from co-located control room like settings to cooperation in geographically dispersed settings of waste water treatment plant, Bertelsen and Bodker [15] present how CIS is established through the movement of people around the wastewater plant and through learning, participation, and experimentation. In a hospital setting even though people are not as dispersed as in the wastewater plant, Reddy et al. [8] illustrate that the benefits of collocation is lost due to the diverse work practices of different groups. In order to establish sufficiently common understanding of shared information to carry out individuals tasks, people have to discuss, exchange, and compare different representations of the same information. Negotiations of information interpretation are carried out informally during the course of work. It takes place during groups meetings by exchanging information about local work practices, thereby helping to gain better understanding of how changes made to information representation will affect other's work. Fields et. al. [11] emphasize the fact that commonness of information is achieved not by just having the information present and available but also in being able to build a 'common picture' by coordinating it with other elements in the setting. CIS is performed through the practices of those involved by switching between different alternatives and types of information representing the same phenomenon as well as by negotiating meanings held by the different representations [12].

The three conceptualizations presented above reveal how different researchers perceive the socio-technical arrangement of CIS. The perceptions vary depending on the work setting with varying focus on the technology, people, and work practice.

3.2 Dynamic Arrangement

Malleable. Researchers argue that mutable objects play a significant role in establishing CIS across heterogeneous context. For example, the technological arrangement of the collaboration room can be improvised according to the needs of the collocated and virtual participants involved in the discussion [12, 13]. Clement and Wagner [13] put forth the idea of integrating flexible regionalization into technical facilities by allowing actors to *erect, shift, blur, harden, dissolve, and strengthen boundaries of communication spaces*. Bannon and Bodker [7] have conceptualized CIS to be of open and malleable nature that allows translation and portability of information across boundaries where local contexts are re-established. In a similar light, Reddy et al. [8] have illustrated the importance of information malleability in a work setting by presenting how different representations of same underlying information help different work groups to coordinate their activities by de-contextualizing and re-contextualizing information as needed.

Situated. The notion of CIS is founded on the premise that emphasizes the importance of establishing common interpretation and not just sharing information to facilitate articulation work [4]. Interpretation of information however, takes place locally and on specific occasions of use. Bannon and Bodker [7] illustrate the situated nature of CIS by describing the degrees of openness and closure required with varying settings of CIS – i.e. when CIS is constituted for physically co-present actors or for those cooperating at "arms length". The situated nature of CIS is depicted for collocated settings by Rolland et. al. [12] who illustrate how by being present in the collaboration room during discussions provides additional context for interpreting information represented on various artefacts in the room. Someone walking into the room after the discussion ends might not be able to make complete sense of the representations. Emphasis is placed by Randall [14] on the need for understanding organizational context in which CIS has to operate because common information would be required by different actors with multiple work practices. In a geographically dispersed setting such as the wastewater plant, *overview, predictability and peripheral awareness are all related to how people move about in the plant, and not to a particular location* [15]. Fields et. al. [11] place importance on contextualizing information to form common understanding through various means such as visual, verbal, and physical conduct, coordinating information from a number of sources and representations, and pre-existing common ground.

Temporal. Reddy et. al.[8] depict the temporal nature of CIS by presenting the *retrospective* and *prospective* attributes of a common information artefact and emphasize the importance of mediation between the two perspectives in order to render it into a CIS for different groups. Also, in case of CIS for heterogeneous groups, sharing and negotiation of common understanding is temporary and fluid where momentary understandings are achieved on specific occasions and is short-lived [12]. Rolland et. al illustrate this through the way a 'collaboration room' is a temporary arrangement that exists only for a short period of time as a CIS for the duration of discussions taking place in the setting. Munkvold et. al. [10] illustrate the temporal dimension of CIS through the temporality involved in the multiple trajectories of patients, doctors, nurses, and technologies. For example, the medical record evolves over time during a patient's illness trajectory that refers to past, present, and future. These are disconnected trajectories that briefly intersect where people from different work practices coordinate their activities.

From the above review of the work conducted in this area, we can infer that there exist quite varied and dispersed views on the characterization of CIS. The investigation being currently undertaken is an attempt to contribute to the development and clarification of the notion of CIS. This is done by studying how personnel from different work communities collaborate to manage various dependencies arising in the course of accomplishing tasks leading to a common goal. Also, from the review it was observed that most of the conceptualization of CIS was based on ethnographic studies. We feel that a more rigorous process of investigation is required to develop the notion of common information space, which is being addressed in this paper. In the next section we present the empirical investigation informing our contribution to CIS conception.

3 Data Collection and Analysis

The underlying principle of this research is that it is important to understand collaborative work process in its natural setting to inform the development of Common Information Space (CIS). In a collaborative work process there are many interacting elements. To explore such work processes the researcher has to obtain a practitioner's perspective of the system by situating oneself within everyday work activities. Various researchers [17, 4, 7, 16] have been advocating the importance of understanding phenomenon in a work process as it occurs in the real work setting in order to provide appropriate support for it. This research takes the qualitative approach because the study requires a methodological approach that would facilitate comprehending human behavior in a socio-technical context involving the three elements of human being(s), technical artifact(s) and context of use.

3.2 Study Site

The domain of interest for this research is the work process of Air Traffic Control (ATC) and in particular work taking place in an airport. The study has been conducted at a medium-sized single runway airport in the UK. The focus has been on collaboration between different work communities in and around the airport especially between personnel in the control tower, approach control, operations centre, and pilots. The focus was on these work communities because they have to collaborate with each other and share technological information systems to manage traffic movement in and around the airport. The control tower and operations centre setting was the direct field of this study while working of the other two work communities, pilots and approach control, was perceived from these two work settings.

3.3 Data Collection

Data for the research was collected through field studies. A series of studies have been undertaken at the airport over the last three years. Data was collected through ethnographic techniques of interviews, observation, field notes, collecting organizational and technical documents as well as literature on the field site. Formal and informal observational studies were undertaken in the study site. This involved taking notes of observed phenomenon and informal discussions with personnel about the observations made. Field notes contained information on environmental setting, behaviour of people, work practices, and questions arising from observations made. Data was also collected by conducting semi-structured interviews with personnel in the work communities of control tower and operations centre. Concurrent protocol was employed where participants were asked to talk through what they were doing while they were working. All the interviews and verbal protocols were recorded and later transcribed into text for analysis. Besides getting first hand data from the site, several secondary sources of data were obtained. This included organization and

technical documents, studies conducted by others in the area of ATC, and literature on the field site.

3.4 Grounded Theory Analysis

This research employs the Glaserian [18] approach to Grounded Theory methodology application. Data is conceptualized through coding which is the foundation of Grounded Theory development. Glaser prescribes coding through the phases of: Substantive Coding, Theoretical Coding and Selective Coding [19] all of which is employed in this research. These phases are not entirely linear and work in conjunction with each other. The Grounded Theory process is both inductive and deductive. Inductive, as instead of starting with a hypothesis or theory, relevant theoretical concepts are allowed to emerge from the data during the coding and categorization process. *Deductive work in grounded theory is used to derive from initial codes as to where to go next in order to sample for more data to generate the theory* [19]. This is a cyclic process where the researcher goes back and forth between induction and deduction. A more detailed illustration of Grounded Theory methodology implementation in this research can be found in another paper [20] by the authors .

4 CIS Framework Extension

The notion of CIS focuses on the relationship between actors, artifacts, information, and cooperative work. The relationship between these elements have been portrayed in various research undertakings mainly by how information is represented and propagated through information artifacts and how it has been integrated into the daily work practices of personnel functioning in cooperative work settings, as depicted in the framework presented in section 3. We extend this framework through Grounded Theory analysis of the collaborative work process involved in the functioning of an airport setting.

In this research, we analyze the relationship between the four constituting elements of CIS in the course of managing interdependencies in the work process. There are two contributing factors for incorporating this perception in developing the notion of CIS. One is that the Grounded Theory analysis brings forth the centrality of the interdependency concept in the analysis of collaborative work. The other is that the notion of interdependence is at the core of cooperative work [4] and therefore it should form the crux of CIS which is aimed at supporting cooperative work.

The airport setting shares features of cooperative work settings investigated previously in studies contributing to CIS notion such as collocated actors, geographically distributed workspaces, arrangement of collaboration technologies, and the need for establishing and maintaining sufficiently common understanding of the field of work. The concepts generated during the Grounded Theory analysis are used here to extend the framework, which is presented in Fig. 2.

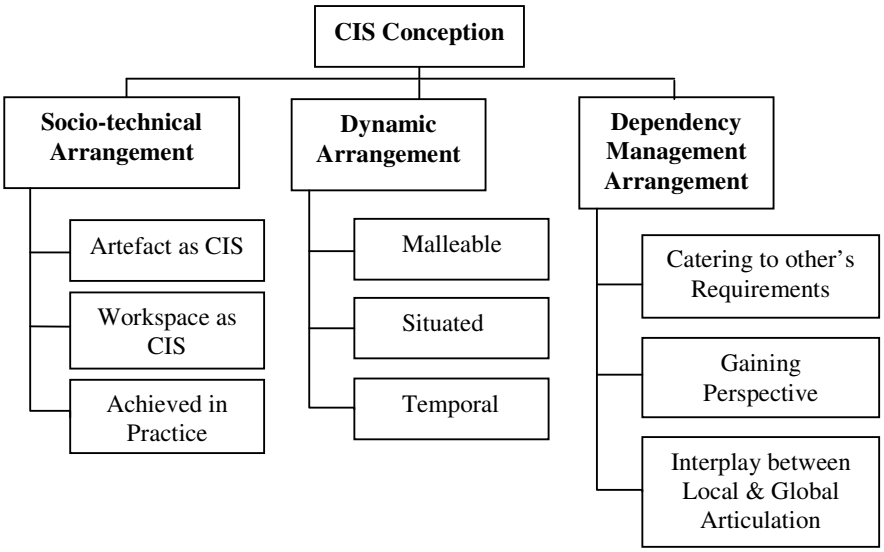

Fig. 2. Extended Framework of CIS Conception

In the following sections, two perceptions of CIS – as a socio-technical arrangement and dependency management arrangement - are described. The dynamic arrangement perspective is not described in detail here due to want of space. However, from the data analysis all the three concepts of malleability, situatedness, and temporality have been concurred. The descriptions are illustrated through interview transcripts from fieldwork data and the categories and properties generated during the Grounded Theory analysis.

5.1 Socio-technical Arrangement

Based on the Grounded Theory analysis, the workspace of work communities in the airport setting is perceived as CIS. It was found that the technological artifacts employed in these workspaces perform various mediation roles based on the practices by which information presented by them was put to use by those sharing it. Hence, the socio-technical arrangement entails the workspace and the practices by which CIS is established and maintained, which is illustrated in the ensuing sections.

Workspace as CIS. In the airport four work communities were studied, which are, the control tower, operations centre, approach control and pilots. The work communities are geographically distributed with the control tower, operations centre, and pilots located in the airport and the approach control outside the airport. The airport consists of multiple CISs where each work community's workspace setting is a CIS. This is because creating a CIS is not attributed just to the technology populating the setting but requires an amalgamation of various information resources

of the workspace, procedural knowledge, responsibilities attributed to the roles of the personnel within the work community, benefits of collocation for observation, discussions, negotiations, and work practices established within the work community. The CIS of the airport then is a constellation of these overlapping CISs. This is because the work communities do not function independently. They are highly dependent on each other to manage the traffic movement in and around the airport. For example, the following transcript illustrates the dependency between the ground controller in the control tower and the departing aircraft pilot

"The first thing that you have to give is the Departure Route, which is his (aircraft pilot) clearance to move. No aircraft can go anywhere without a clearance. They need to know where to go basically and if you don't give them a point where to go and where to go from and where to go to and a route, they are in limbo. Basically that's what it is. You have to tell him (aircraft pilot) where to go. Otherwise he is going to come up to you and say 'what do I do? What stand am I? Which way do you want me to go?' So clearance is the main part of what we do when we are issuing instructions and this clearance is his permission to travel from here to his destination."

Here an overlap of information space is created between the CIS of the control tower and that of the aircraft pilot. Both the ground controller and the pilot need to establish common understanding of appropriate action in this context. By giving the pilot permission and direction to move around the airport the ground controller creates a brief overlap in the common information spaces until the aircraft has departed from the airport and control of the aircraft has been handed over to the approach control.

Achieved in Practice. The coding process revealed four main types of interdependencies between the different work communities: procedural dependency, information dependency, situation dependency and time dependency. This is elaborated in another paper by the authors [20]. The dependencies are managed through various social acts of coordination and cognitive acts of coordination. These acts of coordination are the categories in the grounded theory analysis, the properties of which reveal the practices by which CIS is established between work communities. The following table (Table 2) presents the categories and their properties. The codes within double quotes are in-vivo codes where the actual words of the interviewees are used to label the codes.

Table 2. Categories and Properties of Social and Cognitive Acts of Coordination

Category	Properties
Social Acts of Coordination	"Watching what's going on", Keeping People in the Loop, Requesting, Verbal Announcement, Exercising Authority, Helping Others, Sharing information, Sharing Responsibility, Act in Response, "Providing Required Information at right time", Verbally Concurring Course of Action
Cognitive Acts of Coordination	Expectation about Other's Behavior, Deciding Priority of Action, "Changing the plan quickly", "Making Informed Decisions", Planning

It is beyond the scope of this paper to illustrate and describe the properties of the categories. The following transcript provides an illustration of the two properties – Sharing Information and "Providing Information at the Right Time" - of the social acts of coordination category.

"When I give an aircraft pushback or annotate it with an active sign, the Assistant at the approach control will put the strip (flight progress strip) in front of the Coordinator. When it (aircraft) taxis out to the holding point, our Assistant in the control tower will then put a hold and again take-off on the screen (on her Departure Status Information screen)"

Information is shared by making changes to the common information system which allows it to act as a device for intermediating coordination of actions required for the task performance both within their respective work communities as well across communities. The information representation also depicts various aspects of work performance such as contextual information (status of aircraft departure), decisions made by the controller in the control tower (give permission for aircraft pushback), and task performance status (aircraft pushback, aircraft taxiing). By incorporating contextual aspects in information representation the system allows personnel in both work communities to gain common perspective of work being undertaken, thereby acting as a device for articulating interpretation. It also acts as a device for organizing coordination because when information is changed in the system by the controller in the controller tower it acts as an indicator or trigger for the Assistant in the approach control to take action.

5.1 Dependency Management Arrangement

Three main categories were identified in the grounded theory analysis that illustrates how CIS acts as a space for managing dependencies. Hence, the CIS of the airport is perceived as an arrangement for managing various dependencies arising in the work process. The three categories are:

Catering to other's Requirement. One of the main consequences of the two acts of coordination (presented in section 5.1.2) is catering to other requirements in terms of information, procedural compliance, or just helping each other out in performing tasks. An example illustration of this aspect of CIS is presented in the following transcript.

"……He (helicopter pilot) talks to me (Ground Controller)to start with to turn the engines on. I'll give him permission to lift, I don't clear him to take-off over there because you have to be very careful about that...because if something does go wrong. To be honest I can't give clearance to anything there. So I will just get him off the ground and transfer him to the tower and the tower once they know taxiway delta is clear will give him clearance to take off."

This is an example of a situation where a police helicopter has to take-off from the airport. The police helicopters do not have to file a flight plan in advance. They can take-off whenever they are required to and as soon as possible. So when the pilot of the helicopter decides to leave the airport he calls the Ground Controller (GC) on his radio telephone frequency, and requests permission to start engine and move to taxiway. The GC will grant him permission to start his engine, lift and move to

taxiway delta after ensuring that there are no movements on that area of the airport. Then he transfers control of helicopter to the Tower Controller (TC). After that, the TC will decide if he can grant the helicopter pilot permission to take-off from taxiway delta. This will depend on the traffic situation on the runway. As far as possible the TC will try and suspend traffic that might get in the way of the helicopter taking off. Also, under normal circumstances taxiway delta is under the control of the GC whereas in this situation the TC will take charge of movement on the taxiway. In this case the helicopter is not taking-off from the runway but from the taxiway. It is a crucial position to take-off from because there might be aircraft that have to move towards the runway from their stand in the Apron area or there might be those that are coming into the taxiway from the runway. Also, in the airport there are 'free range' vehicles that are allowed to move freely under the aerodrome authority's permission. The conversation taking place between the helicopter pilot and the controllers is broadcasted on the radio frequency which is available to these 'free rangers'. Once they know that the helicopter is planning to take-off from taxiway delta they are expected to keep away from that taxiway and the runway. If they need to go on or near the runway they have to get permission from the TC.

So if anything goes wrong with the helicopter taking off, according to the organizational norm the tower controller would be held responsible for the situation. Under normal circumstances however, the ground controller and tower controller coordinate their actions and make decisions about how and when it is appropriate to allow the helicopter to take-off. Therefore, the responsibility for resulting actions is now shared between the two controllers, at least under social conventions. This shared accountability now creates a context where those involved help each other by catering to other's requirements.

Gaining Perspective. Another aspect of CIS that enables it to act as an arrangement for managing dependencies is by facilitating those involved to gain common enough perspective on state of the work environment. Table 3 presents the properties of the category 'Gaining Perspective' generated in the Grounded Theory analysis.

Table 3. Categories and Properties of Category - 'Gaining Perspective'

Gaining Perspective	Synthesizing Multiple Information Sources, Mutual Intelligibility of Action, "Get tuned to each other", Common Practice, Identifying Information Availability, Notifying Information Availability, Anticipation, "play by the rules", "being proactive", Justifying One's Action, Updating, Verbally Concurring Course of Action, Determining Prospective Environmental Conditions, Determining Task Performance Status, Determining Temporality

The following interview transcript illustrates various properties of this category.

"Ground Controller - *(pointing outside to an aircraft in its stand) ….you see the guy (ground staff) walking over there now unplugging the leather flaps while he talks to the pilots and then we will be expecting him to taxi any minute now…any second now"*

This transcript was coded for the following properties "Get tuned to each other", "being proactive", Mutual Intelligibility of Action, Determining Task Performance Status, and Determining Temporality. The transcript illustrates the point that even

though the two communities of control tower and aircraft pilots are geographically distributed they are still within visual range. The ground controller in the control tower is able to establish a sufficiently common understanding of events taking place in the work environment by proactively looking for information in the workspace to determine other's task performance status. He is able to infer the consequence of the ground personnel's actions in relation to the tasks performed by ground controller. He is able to do so because of Mutual Intelligibility of Action enabled by procedural knowledge.

Interplay between Local and Global Articulation. The overlapping CISs interweave local and global articulation required to collaborate across heterogeneous work communities. Local articulation is the work taking place within each work community to manage traffic movement and global articulation is the activities taking place between the dispersed work communities to manage interdependencies in the work process. The data analysis reveals that both local and global articulation needs to be addressed together. The perception of overlapping interdependent CISs in the airport addresses this local-global association. This is illustrated in the following scenario:

"We (Ground Controller (GC)) may have an aircraft that goes out to the hold and wants to get back to the stand, we may go to them and quickly and say 'can you go back to stand five'…..most of the time coordination with the Apron (in the operations centre) would be done through the Assistant"

In this case, a departing aircraft was waiting to take off near the runway but could not due to technical problems and wanted to go back to the stand in the parking lot. To perform this task, the ground controller in the control tower needs to articulate activities both locally within the control tower and globally across the work communities of pilots and operations centre. The actions taken to manage this situation are depicted below.

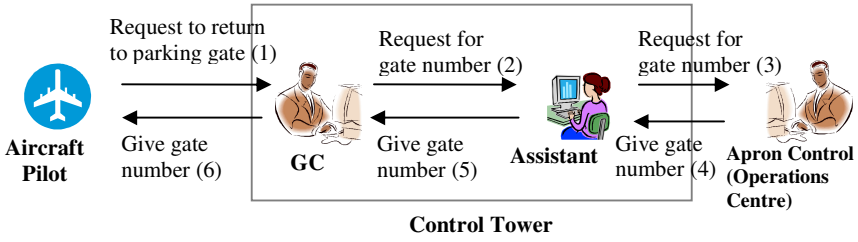

Fig. 3. Interplay between Local and Global Articulation Work

6 Conclusion

In this research we are endeavoring to contribute to the development of the notion of Common Information Space (CIS) through a Grounded Theory driven investigation.

We have does this by placing the findings of the empirical investigation against conceptions from previous research. The notion of CIS is still in its formative stages and diverse conceptions of this notion have been developed by researchers. Considering these varied conceptualizations contributes to the notion development in various ways, such as

- It suggests that none of these present a coherent story
- Provides different starting points for analyzing the CIS notion
- Presents different insights into how CIS can be conceptualized

We have developed a framework to consolidate the different conceptions of CIS to provide an integrate representation of this notion. This helps to analyze conceptions in relation to others and provides a comprehensive insight into the development of this notion. We have extended this notion by incorporating another perception of CIS, which is CIS as Dependency Management Arrangement. This has been illustrated by describing how the overlapping interdependent CISs in an airport help cater to the requirements arising out the various dependencies in the work process, gain sufficiently common perspective of the work setting to perform interdependent tasks, and carry out the interplay between local and global articulation required to collaborate across work communities. Research informing the development of CIS notion hitherto has been undertaken primarily through ethnographic studies based on which inferences are drawn. In order to develop the notion of CIS there needs to be a systematic and rigorous methodology steering the theory development process. This is addressed in the investigation by employing Grounded Theory methodology to provide a systematic approach to conceptualizing CIS. This research makes theoretical as well as methodological contribution to the development of the notion of CIS.

Acknowledgements. We would like to thank NATS, U.K. for granting permission to conduct the field studies in the airport. We would also like to thank the reviewers of the conference for their valuable feedback and suggestions.

References

1. Gerson, E. M., Star, L. S.: Analyzing Due Process in the Workplace. ACM Transactions on Office Information Systems. 4, 257-270 (1986)
2. Strauss, A.: The Articulation of Project Work: An Organizational Process. The Sociological Quarterly. 29, 163-178 (1988)
3. Schmidt, K.: Cooperative Work and its Articulation: Requirements for Computer Support. Travail Humain. 57(4), 345-366 (1993)
4. Schmidt, K., Bannon, L.: Taking CSCW Seriously: Supporting Articulation Work. Computer Supported Cooperative Work (CSCW): An International Journal. 1, 7-40 (1992)
5. Bannon, L. J., Schmidt, K.: CSCW: Four Characters in Search of a Context. Studies in Computer Supported Cooperative Work: Theory, Practice and Design. 3-16 (1991)
6. Bannon, L. J.: Understanding Common Information Spaces in CSCW. In: Proceedings of the Workshop on Common Information Spaces, Copenhagen (2000)

7. Bannon, L. J., Bødker, S.: Constructing Common Information Spaces. In: Proceedings of the Fifth European Conference on Computer-Supported Cooperative Work (ECSCW'97), Lancaster, England, pp. 81-96. Kluwer Academic Publishers, Dordrecht (1997)
8 Reddy, M.., Dourish, P., Pratt, W.: Coordinating Heterogeneous Work: Information and Representation in Medical Care. In: Proceedings of the Seventh European Conference on Computer Supported Cooperative Work (ECSCW'01), Bonn, Germany, pp. 239-258. Kluwer Academic Publishers, Netherlands (2001)
9. Bossen, C.: The Parameters of Common Information Spaces: the Heterogeneity of Cooperative Work at a Hospital Ward. In: Proceedings of the Conference on Computer Supported Cooperative Work, pp. 176-185. ACM, New Orleans (2002)
10. Munkvold, G., Ellingsen, G.: Common Information Spaces along the illness trajectories of chronic patients. In: Proceedings of the Tenth European Conference on Computer Supported Cooperative Work (ECSCW'07), Limerick, Ireland, pp. 291-310. Springer (2007)
11. Fields, B., Amaldi, P., Tassi, A.: Representing Collaborative Work: The Airport as Common Information Space. Cognition, Technology and Work. 7(2), 119-133. Springer, London (2005)
12. Rolland, H. K., Hepso, V., Monteiro, E.: Conceptualizing Common Information Spaces Across Heterogeneous Contexts: Mutable Mobiles and Side-effects of Integration. In: Proceedings of the Conference on Computer Supported Cooperative Work, Banff, Alberta, Canada. pp. 493-500. ACM Press (2006)
13. Clement, A., Wagner, I.: Fragmentation Exchange: Disarticulation and the Need for Regionalized Communication Spaces. In: Proceedings of the Fourth European Conference on Computer-Supported Cooperative Work (ECSCW'95), Stockholm, Sweden, pp. 33-49. Kluwer Academic Publishers, Dordrecht (1995)
14. Randall, D.: What's Common about Common Information Spaces? In: Proceedings of the Workshop on Cooperative Organization of Common Information Spaces, Technical University of Denmark, (2000)
15. Bertelsen, W. O., Bodker, S.: Cooperation in massively distributed information spaces. In: Proceedings of the Seventh European Conference on Computer Supported Cooperative Work (ECSCW'01), Bonn, Germany, pp. 1-17. Kluwer Academic Publishers, (2001)
16 Crabtree, A.: Designing Collaborative Systems. A Practical Guide to Ethnography. Springer-Verlag, London (2003)
17. Poole, M. S., DeSanctis, G.: Use of group decision support systems as an appropriation process. In: Proceedings of the 22nd Annual Hawaii International Conference on Systems Sciences, pp. 149-157. ACM, New York (1989)
18. Glaser, B. G., Strauss, A.: The Discovery of Grounded Theory: Strategies for Qualitative Research. Aldine, New York (1967)
19. Glaser, B. G.: Theoretical Sensitivity. Advances in the Methodology of Grounded Theory. The Sociology Press, Mill Valley, California (1978)
20. Selvaraj, N., Fields, B.: A Grounded Theory Approach towards Conceptualizing CIS for Heterogeneous Work Communities. In: Proceedings of the 23rd BCS Conference on Human Computer Interaction (HCI 2009), Cambridge, UK, pp. 471-479. British Computer Society, Swinton (2009)