4. **Coordination and physical vicinity**

The aim of this chapter is to explore the importance of physical proximity between schedulers and operators within manufacturing firms. In literature, a small distance between interdependent employees is assumed to be a prerequisite for a high level of coordination. This study investigates this assumption empirically for the relationship between scheduling and manufacturing and shows effects of proximity that are only partly in line with literature. Consequences of relocating the scheduling department within a production firm are studied using a longitudinal case study approach. Data has been collected within three phases: before, shortly after and one year after the relocation. Findings show that schedulers and operators perceived positive changes in ease of coordination and performance due to the relocation. However, coordination behavior did not significantly change despite the shorter distance between the departments. Apparently, physical proximity between scheduling and manufacturing influences performance mainly through social and behavioral variables rather than via increased frequencies of task-related communication. The results indicate that operations management theory may be enriched with studies on factors affecting human coordination and their behavioral consequences. The chapter demonstrates the need to carefully design, manage, and facilitate the interface and critical task interdependencies between scheduling and manufacturing departments.

4.1 **Introduction**

Physical proximity is a classical design variable in operations management. However, there is hardly empirical research on the effect of physical proximity on the coordination behavior of schedulers in manufacturing firms. Therefore, our research team grasped the opportunity to perform a longitudinal case study within a manufacturing firm when the management of this firm announced the physical relocation of the scheduling department. Considering the large amount of communication between schedulers and shop floor operators, especially during rescheduling, the management searched for instruments to enhance the level of coordination between these departments. Before the relocation, the schedulers were located in an office outside the factory; they would move to an office in the middle of the shop floor. This situation provided the research team with an exclusive opportunity to investigate effects of proximity between schedulers and operators in an empirical setting.

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8 A revised version of this chapter has been submitted for publication: De Snoo, Van Wezel, and Wortmann (2011d). Does location matter for a scheduling department? A longitudinal case study on the effects of relocating the schedulers. Resubmitted after a review to the International Journal of Operations & Production Management. An earlier, shorter version of this chapter has been published as a case study in the book ‘Behavioral Operations in Planning and Scheduling’ (De Snoo and Van Wezel 2011c).
In literature, proximity is seen as an important enabler for efficient coordination. For example, Galbraith (2002) states: “Proximity of employees is an important factor in fostering productive relationships. There is good evidence that reducing distance and physical barriers between people increases the amount of communication between them” (p. 50). Within a variety of domains, physical proximity has been put forward as a determinant of coordination behavior and performance of employees working in different departments (Pinto et al. 1993; Van den Bulte and Moenaert 1998; Sosa et al. 2002; Sharifi and Pawar 2002; Vandevelde and Van Dierdonk 2003; Pagell 2004). However, no study has addressed the specific relationship between planners or schedulers and manufacturing or shop floor operators. In their recent essay on Behavioral Operations Management, Loch and Wu (2007) recommend the study of consequences of proximity for coordination performance. Contributing to this new stream within operations management theory, this chapter discusses proximity between schedulers and operators.

Planning and scheduling are concerned with allocating a firm’s resources to customers’ demands in terms of volume and timing; manufacturing is the process of realizing these demands by the creation of products. Regularly, one scheduler is involved in the development and updating of the schedules of multiple operators, actively sustaining the coherence between their activities. Often, schedulers and operators are confronted with a variety of events requiring adaptation of the schedules (Koh et al. 2002; Aytug et al. 2005). Consequently, timely and appropriate coordination between the scheduling and the manufacturing departments is essential. McKay and Wiers (2006) stress that in “any factory situation where there are tight constraints (either in time or physical reality), the scheduler has to make sure that he is actually involved (and not confronted with the results afterwards), by having a good relationship with the shop floor and by taking a cooperative attitude in solving problems” (p. 194). They continue by stating: “if this relationship does not exist, the classic results of local, myopic optimization at the cost of global sub-optimization will be seen” (McKay and Wiers: 194). However, whereas the notion of efficient information flows between planning/scheduling and manufacturing/control is emphasized in most textbooks (e.g., Hopp and Spearman 2001; Vollmann et al. 2005; Slack et al. 2007; Heizer and Render 2008), organizational aspects of this coordination have received only scarce attention (Ruffini et al. 2000; MacCarthy 2006). In a sense, it is assumed that schedulers and operators will communicate with each other in an efficient way. Empirical studies demonstrating the large amount of communication between schedulers and operators indicate the need to investigate
enablers and inhibitors for this coordination, such as the physical location of the scheduling department (McKay et al. 1995a; Jackson et al. 2004; Berglund and Karlton 2007).

Given the importance of efficient coordination between scheduling and shop floor, and given the lack of empirical studies specifically investigating the influence of physical proximity on this coordination, we investigate in this chapter how proximity between schedulers and shop floor operators affects their coordination behavior and performance. The study aims to answer this question by a longitudinal case study within one manufacturing firm. The single-case study approach allows an in-depth investigation including carefully repeated measurements and considering the specific context of the studied phenomena (Voss et al. 2002; Yin 2003; Siggelkow 2007). Rich data are collected within three measurement phases before and after the movement of the scheduling department.

The remainder of the chapter is structured as follows. Section 4.2 discusses the theoretical background of the study. Section 4.3 explains the research methodology adopted and introduces the case company. Section 4.4 presents the research findings. Section 4.5 discusses the main results, considers limitations, and provides avenues for further research. Section 4.6 concludes the chapter.

4.2 Theoretical background

4.2.1 Proximity within scheduling research

Within operations management, the variable physical proximity has been primarily studied within the field of facility layout design. This field is mainly focused on positioning machines and work cells, using mathematical techniques that calculate the best location for these (for a recent overview, see Drira et al. 2007). Within this field, the need for physical proximity between work units and people is determined by the frequency of interactions (for material handling) and the distance between the work units. The few studies discussing the location of the schedulers within a firm provide insights into the broader effects of physical proximity. Schedulers provide operators with schedules, that is, they act like superiors stating what has to be done. However, these schedulers are not the formal managers or supervisors of these operators nor do they possess the technical skills to assist the operators during schedule execution. Because of this position, schedulers do not have the authority to prescribe operators’ behavior strictly. Instead, schedulers communicate, negotiate, and persuade to get things done (Jackson et al. 2004). The influence of their physical location is illustrated by McKay and Wiers (2006): “If the scheduler is part of the production department, it might be
easier to have the schedule executed as it is, without local changes. However, if the scheduler is in a logistical department situated between production and sales, and the production department focuses on efficiency, and sales focuses on service, then the situation might be different. When removed from the immediate department, the scheduler might have a hard job in convincing production to reduce the quantity on one job to help a job in next week’s schedule, or to use an alternative process, or to use different material” (p. 182). A multiple case study by Berglund and Karlton (2007) has also demonstrated the importance of the schedulers’ location: “Their physical proximity to others enabled them to more easily obtain information from production and other employees, and, therefore, to efficiently solve scheduling problems. This central physical location thus strongly contributed to their role as an information node and problem solver” (p. 172). These studies suggest that a smaller physical distance between scheduling and manufacturing would positively influence the effectiveness of information sharing and the level of insight into each other’s processes. Further, these higher levels of information sharing and mutual understanding would lead to higher performance.

4.2.2 Proximity within R&D-team research

Consequences of physical proximity on communication behavior and performance have been studied more thoroughly within the field of new product development (Schmidt et al. 2001; Sharifi and Pawar 2002). Thomas Allen started with investigating the consequences of collocating employees involved in research and development tasks, and developed the ‘law of propinquity’ stating that communication frequency decreases steeply with the physical distance between people (Allen 1977). He also found that various types of communication were affected by physical proximity in different ways (Allen 2007). Extending Allen’s studies, Van den Bulte and Moenaert (1998) found that the collocation of R&D teams enhanced communication between them, but that communication frequency did not fall due to an increasing distance. One of the suggested explanations for this lies in the communication medium used, which shifted from face-to-face to telephone. Similar findings have been reported by Sharifi and Pawar (2002) who found that collocation of R&D-teams is related to, amongst others, improved communication, time savings, and reduced conflicting personal goals.

Inspired by Allen’s ‘law of propinquity’, Loch and Wu (2007) have recently proposed to investigate the effects of physical proximity in studying coordination in operations
management. Extending the stream of Behavioral Operations Management literature (Wu and Katok 2006; Croson and Donohue 2006; Bendoly et al. 2006a; Gino and Pisano 2008), they advocate that information exchange and coordination between people do not only have a ‘rational side’, i.e., they are needed to handle task interdependencies, but they also have an ‘emotional side’. Coordination between people is not limited to the exchange of goods and information, but it results also in expectations and acts of reciprocity (Loch and Wu 2007). For example, within the context of our study this means that an operator feels gratitude because the scheduler has done something for him, and he tends to like the scheduler. As a result, he even feels an obligation to do something in return. If he fails to reciprocate, he feels guilty, and the scheduler feels indignation. This ‘reciprocity algorithm’ of coordination (Loch and Wu 2007) implies that interactions transform the way people look at each other.

4.2.3 Proximity and organizational communication research

Finally, to determine possible effects of proximity between scheduling and manufacturing, we shortly discuss organizational communication literature that includes a variety of studies on factors influencing communication behavior. Daft and Lengel (1986) have argued that information processing and communication within firms are driven by two forces: uncertainty and equivocality. Uncertainty relates to the absence of information (Galbraith 2002), whereas equivocality relates to ambiguity, the presence of multiple interpretations about a particular situation. As discussed, communication between schedulers and operators is also driven by uncertainty and equivocality. Schedulers need information from operators to maintain feasible schedules, and operators need information about schedule changes due to rescheduling events (Stoop and Wiers 1996; McKay and Wiers 2006). Similarly, when solving such events, schedulers are dealing with equivocality: operators, managers, and other stakeholders may have different and even conflicting views regarding the causes and possible solutions of a problem. Jonsson and Mattsson (2006) have shown that the number of companies with replanning capability in their ERP systems has increased, but that only a minor portion of the companies use automatic replanning. Therefore, human involvement and communication are required to treat uncertainty and equivocality during scheduling and rescheduling.

According to Daft and Lengel (1986), organizational design “can provide information of suitable richness to reduce equivocality as well as provide sufficient data to reduce uncertainty” (p. 559). Information richness is the ability of information to change people’s understanding within a certain time interval; interactions that can change understanding in a
timely manner are considered rich. Communication media differ in the capacity to process rich information; for example, face-to-face is the richest medium because it provides immediate feedback so that interpretation can be checked, it provides multiple cues (body languages, tone of voice), and it supports personalization. This so-called Media Richness Theory suggests that communication is more effective and more efficient when richer media are used if equivocality is high (Webster and Treviño 1995; Kahai and Cooper 2003; Ambrose et al. 2008). A study by Treviño et al. (2000) has shown that the use of media is associated with physical distance between the employees, perceived medium richness, and level of equivocality. Moreover, Kahai and Cooper (2003) found that richer media resulted in more socio-emotional communication and in an increase of the participant’s ability to identify the others’ expertise. Finally, in a study about the interface between design and manufacturing, Vandevelde and Van Dierdonk (2003) have noticed the importance of empathy in interdepartmental communication, that is, the ability of employees to recognize differences between the others’ and their own world having an eye for the needs, goals, work approach, and motivators of the other.

4.2.4 Research model

Based on these theories, several hypotheses about the effects of physical proximity between schedulers and operators can be postulated. First, a decrease of physical distance between the scheduling and manufacturing departments will lead to changes in coordination behavior between schedulers and operators, such as a higher number of interactions and a preference for face-to-face over phone communication. Second, physical proximity will influence the type of interactions, such as the proportion of socio-emotional communication. Third, the level of mutual insight between schedulers and operators will be positively influenced by a decrease in physical distance. Moreover, the extent of congruence in views and interests (i.e., equivocality) will be influenced by changing proximity. Finally, theory suggests that proximity between departments has a positive influence on performance because of the positive changes in these intermediate variables. Within our study, this performance is related to the feasibility, or workability, of the schedules, the effectiveness of the scheduling and the manufacturing departments, and the level of coordination satisfaction. Figure 4.1 shows the variables being investigated in this research; the variables and their operationalization are further explained in the following sections.
4.3 Methodology and case introduction

4.3.1 Research approach

Given the state of research on coordination between scheduling and manufacturing, the
single-case study approach seemed fitting, because this approach is especially appropriate to
investigate phenomena that are barely studied and that require an open, exploratory design
(Voss et al. 2002; Yin 2003; Eisenhardt and Graebner 2007; Siggelkow 2007). Further, the
approach is useful if repeated measurements are performed; then, a longitudinal approach is
followed (Pettigrew 1990). Moreover, the empirical analysis of a departmental relocation is
an opportunity rarely possible. Therefore, our case can be typified as a ‘revelatory case’
providing further support for using the single-case study approach (Yin 2003). The research
design builds upon and extends Van den Bulte and Moenart’s (1998) quasi-experiment
regarding relocation of R&D-team members. These authors measured communication
patterns twice: before and after the relocation. To get a more in-depth understanding of
change over time due to the relocation, we decided to measure the consequences of the
scheduling department’s relocation within three phases: before, shortly after, and one year
after the relocation.

As said, the case involves a firm with a typical planning and control situation in which the
researchers were doing a project. During that project, the researchers were informed about the
management’s plan to relocate the scheduling department and considered the opportunity to
investigate this relocation change. Fortunately, the management approved the research design
that required active participation of the staff.
4.3.2 Case introduction

Before describing the research methods employed, the case situation is introduced briefly. The make-to-order manufacturer processes about 150 client-specific orders each day. Twenty-five sales agents are responsible for order procurement. Around 30,000 product parts are purchased from a large group of suppliers and used in the three manufacturing departments: metalworking, painting, and assembly. The standard lead-time of work-in-progress is five days (Fig. 4.2): one day for each of the manufacturing departments, one day for testing, and one day for loading and transport. The sixth day is used for delivery.

![Production process diagram](image)

**Figure 4.2** Production process.

Over 200 operators are working in the manufacturing departments in multiple shifts. Each department is managed by a production manager and several foremen. The production manager is not involved in the daily operations, but responsible for implementing the long- and mid-term strategy and the development of staff schedules. The foremen act as information hubs between the schedulers and the operators; they work as operators at the various workstations, but have an extra responsibility in communicating information from and to the schedulers.

Metalworking consists of 40 workstations in which steel operations are performed. Production orders have different routings; orders are produced both lot-for-lot and in batches, depending on available capacity. Within painting, the products from the metalworking department are painted and powder coated. Two powder-coating lines are available, one that is highly flexible but not highly efficient, and one that requests long cleaning and setup times but is suitable for large batches. The assembly department consists of seven assembly lines. Both self-produced products and products purchased from suppliers are assembled and packaged for delivery to the end-customers.

Each manufacturing department has its own scheduler. Figure 4.3 shows the basic structure of the scheduling and manufacturing activities. The main task for the schedulers is to cluster orders on certain dates and to assign them to work cells or production lines. The resulting schedules are released to the shop floor daily. Alongside this task of creating schedules, the schedulers are confronted with many requests to change existing schedules because of all
kinds of events like rush orders, order changes, material supply problems, and machine failures. Based on new information from salesmen, product developers, suppliers, foremen, and others, the schedulers adapt the schedules and communicate changes to the operators.

Figure 4.3 Relation between scheduling and manufacturing.

Delivery reliability is the most important performance objective according to the management. A special job function has been created, the so-called ‘troubleshooter’, fulfilling the role of ‘order chaser’, to urge schedulers to schedule and operators to produce products that have to be delivered soon. The firm realizes, on average, a delivery reliability rate of more than 95%. Finally, the fifth person in the scheduling department is the inventory controller involved in inventory control activities, both for the raw material inventories as well as the pipeline inventory, i.e., the work-in-progress.

Before the relocation, the scheduling department was located in an office above the distribution docks for the trucks. The physical distance to the shop floor departments varied between around fifty meters (assembly) to a few hundred meters (painting and metalworking). For face-to-face interactions, schedulers regularly took a bicycle to meet the operators. Most operators and foremen never visited the schedulers; what was happening at the scheduling department was a ‘black box’ for them. The plant layout did not force the schedulers and operators to meet each other; for example, the routes used to the parking and smoking areas differed and most employees used their meals at their workstation instead of going to the canteen.
4.3.3 **Research methods**

It was decided to collect data on three points in time: two weeks before the physical movement of the scheduling department (Phase 1), three months after this relocation (Phase 2), and one year after the relocation (Phase 3). Within each phase, different research methods have been employed. Compared to earlier studies measuring communication between employees from different departments, our study is the first in combining both data about single communication incidents (Van den Bulte and Moenaert 1998) as well as aggregated data about coordination behavior (Sosa et al. 2002; Sosa et al. 2004; Watson-Manheim and Belanger 2007). First, open interviews were used to build a general understanding of the firm’s structure and culture, and the relationship between scheduling and manufacturing. Second, two types of questionnaires were employed to gather specific information about interactions between schedulers and shop floor operators, and about expectations and experiences related to the relocation, as explained in the sub-sections below. Third, semi-structured interviews were used to verify the findings from the questionnaires, and to collect additional explanations. In this way, these interviews enabled triangulation of the findings from the questionnaires (Voss et al. 2002; Yin 2003).

Various other tactics were employed to establish the validity and reliability of the study, as recommended by Yin (2003) and others. First, as many steps of the research as possible were documented in a case study database. Second, one of the researchers was the interviewer, enabling this activity to be consistently performed. Third, each phase was followed with a detailed report for the company containing all findings; this report was discussed with the management to check the correctness of interpretation and to get additional insights.

4.3.3.1 **Questionnaire to measure expectations and experiences**

The questionnaire about expectations and experiences related to the relocation was filled out by schedulers and foremen. Alongside several general questions (department, function, etc.), the participants were asked to respond to statements about the effects of the relocation. Variables were based on the studies regarding proximity effects discussed in Section 2, such as the level and treatment of uncertainty and equivocality. Accordingly, topics in the statements included the extent of changed insight into what happens at the scheduling and manufacturing departments, change in scheduling and manufacturing effectiveness, and change in feasibility of the schedules. The full questionnaire is included in Appendix 4A.

Each statement was clearly linked to the relocation and phrased as an improvement. For instance, the first statement was formulated: “Because of the relocation of the scheduling
department, I will get a better overview of what happens at the scheduling department.” A seven-point Likert scale was used with 1 = totally disagree and 7 = totally agree. This scale was interpreted as follows: value 1 indicates that no improvement was expected; values above 1 indicate improvement in increasing order, with value 7 indicating very strong improvement. The same questionnaire was used during all three phases.

4.3.3.2 Questionnaire to measure actual interactions

Alongside filling out this questionnaire on expectations and experiences, the schedulers were asked to report all task-related interactions during one day by means of a so-called interaction questionnaire. The respondents were asked to select the best description for the interaction from a list. This list was based on communication purposes and types mentioned in communication studies within other research fields (Sosa et al. 2002; Watson-Manheim and Belanger 2007; Allen 2007), and was adapted with types of communication mentioned in empirical scheduling studies (Jackson et al. 2004; McKay and Wiers 2006; Van Wezel et al. 2006a). In addition, the schedulers were asked to indicate the medium used, the level of insight in information of the other, the degree of similarity in view and interests between the interaction partners on the situation at hand, the importance of the interaction for both the respondent and the interaction partner, and the level of satisfaction about process and outcome of the interaction. The interaction questionnaire is included in Appendix 4B.

This instrument was used both shortly before and shortly after the relocation to be able to compare changing communication patterns. To exclude factors potentially influencing these interactions, two similar days in a week (Wednesday) were selected in close cooperation with the management. The same group of schedulers was working on these days having similar jobs to perform. Because of the high requirements on involvement of the schedulers (responding to 16 questions after each interaction), the management asked us to abstain from this instrument during Phase 3.

4.4 Results

The longitudinal research design enabled the collection of a large amount of data. Because of shifting working-time schedules and reallocation of tasks, some respondents participated in two phases or one phase. To ensure a reliable dataset, a few questionnaires had to be withdrawn because of inconsistencies in the given answers or a high number of missing values. Table 4.1 shows the number of questionnaires collected per phase.
Table 4.1 Number of questionnaires expectations and experiences per phase and department

<table>
<thead>
<tr>
<th>Department</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheduling</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>11</td>
<td>14</td>
<td>12</td>
<td>37</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>19</td>
<td>17</td>
<td>51</td>
</tr>
</tbody>
</table>

The interaction questionnaire was filled out by four schedulers on two Wednesdays within Phases 1 and 2. In total, 280 interactions were reported. Although the respondents had to report interactions by means of face-to-face contact or by phone, several participants had filled out the questionnaire for a regular meeting or an interaction by email as well. These forms were first removed from the data set. For this chapter, only interactions between the schedulers and operators (including the foremen) within metalworking, painting, and assembly are relevant. For instance, 59 interactions with somebody from scheduling were reported, thus communication within the scheduling department. All interactions with other departments than the manufacturing departments were removed. Finally, to ensure that we should analyze only work-related and relevant interactions, we had asked how important the interaction was for the scheduler and for the interaction partner. Only interactions that were important for at least one of both would be included in the further analyses. As a result, one interaction had to be removed from the dataset of Phase 1. The final dataset consists of 115 interactions. Table 4.2 shows the number of interactions per phase and per type of person who started the interaction: either a scheduler or an operator.

Table 4.2 Number of analyzed interactions per phase and initiator

<table>
<thead>
<tr>
<th>Initiator</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheduler</td>
<td>23</td>
<td>30</td>
<td>53</td>
</tr>
<tr>
<td>Shop floor operator</td>
<td>35</td>
<td>27</td>
<td>62</td>
</tr>
<tr>
<td>Total</td>
<td>58</td>
<td>57</td>
<td>115</td>
</tr>
</tbody>
</table>

In the remainder of this section, research findings are presented for each of the three phases in separate sub-sections. Within each sub-section, the results from the interviews, the interaction questionnaires and from the questionnaire regarding expectations and experiences are discussed and compared with the findings in the other phases. Figure 4.4 and Table 4.3 show results from the statement questionnaire, Table 4.4 provides results from the interaction questionnaire. Further, Table 4.4 shows the outcomes from application of the non-parametric
Mann Whitney U test to assess statistical differences in the outcomes between the phases. This method is suitable to test pair-wise comparisons (Siegel 1956) and has been used in several recent studies investigating behavioral issues in operations management (Wu and Katok 2006; Croson and Donohue 2006; Cantor and Macdonald 2009). The data within the figure and tables are explained in the various sub-sections. Results are discussed in Section 4.5.

![Insight in other department](image1)

![Schedule feasibility](image2)

![Manufacturing effectiveness](image3)

![Scheduling effectiveness](image4)

**Figure 4.4** Mean scores on statements per department per phase (see Appendix 4A).

**Table 4.3** Mean scores on statements per department per phase (see Appendix 4A)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Scheduling</th>
<th>Metalworking</th>
<th>Painting</th>
<th>Assembly</th>
<th>Manufacturing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P1</td>
<td>P2</td>
<td>P3</td>
<td>P1</td>
<td>P2</td>
<td>P3</td>
</tr>
<tr>
<td>Insight in scheduling</td>
<td></td>
<td></td>
<td></td>
<td>2.8</td>
<td>5.3</td>
<td>5.0</td>
</tr>
<tr>
<td>Insight in manufacturing</td>
<td>6.3</td>
<td>6.4</td>
<td>6.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schedule feasibility</td>
<td>3.8</td>
<td>4.8</td>
<td>4.6</td>
<td>4.0</td>
<td>5.3</td>
<td>4.5</td>
</tr>
<tr>
<td>Effectiveness manufacturing</td>
<td>4.5</td>
<td>5.0</td>
<td>5.2</td>
<td>4.5</td>
<td>4.7</td>
<td>5.0</td>
</tr>
<tr>
<td>Effectiveness scheduling</td>
<td>5.0</td>
<td>5.8</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Values show the average scores on the statements per department during each phase. The column ‘manufacturing’ presents averages over the three manufacturing departments. The final column shows the average score per statement from all respondents. Columns ‘manufacturing’ and ‘total’ are not represented in Figure 4.4.
Table 4.4 Statistics interaction questionnaire (for scales, see Appendix 4B)

<table>
<thead>
<tr>
<th></th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Mann Whitney U test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>MR</td>
<td>N</td>
</tr>
<tr>
<td>Insight in the partner’s information</td>
<td>57</td>
<td>63.91</td>
<td>57</td>
</tr>
<tr>
<td>Insight in the partner’s systems</td>
<td>50</td>
<td>61.11</td>
<td>57</td>
</tr>
<tr>
<td>Similarity of problem view</td>
<td>57</td>
<td>56.00</td>
<td>57</td>
</tr>
<tr>
<td>Similarity of interests</td>
<td>58</td>
<td>69.54</td>
<td>57</td>
</tr>
<tr>
<td>Satisfaction about process of interaction</td>
<td>58</td>
<td>51.22</td>
<td>57</td>
</tr>
<tr>
<td>Satisfaction about outcome of interaction</td>
<td>58</td>
<td>58.61</td>
<td>56</td>
</tr>
</tbody>
</table>

N = sample size; MR = mean rank.

4.4.1 Phase 1 – before the relocation

In the interviews, all schedulers indicate that communication and coordination with the shop floor are ‘very important’. They all communicate mostly by phone; the painting scheduler, assembly scheduler, and troubleshooter also go to the shop floor for face-to-face communication. One of the reasons for this is the multitude of nationalities within the workforce causing language problems, as indicated by the painting scheduler: “Much rescheduling and communication is caused by quality problems: painted products are often rejected and have to be repainted. (…) In the painting department, many nationalities are working; you cannot explain everything well by phone. Moreover, many temporary workers are employed. Therefore, I regularly visit the shop floor to explain things to them; that is easier than by phone. (…) During some periods of the day, it is less busy, then, I can visit them.”

During the interviews, schedulers and operators express strong opinions about each other’s behavior and competences. Several operators complain about the ‘incompetence’ of the schedulers, because they do not sufficiently take into account the actual manufacturing situation and the (im)possibilities of the shop floor. On the other hand, schedulers show frustration about self-willed operators not following the schedules, or ‘lazy’ operators not communicating events quickly. The metalworking scheduler: “Recently, a machine in metalworking was defect; only after several hours, I was informed. Therefore, I could not respond quickly and problems spread through painting; tardy delivery could not be prevented anymore.”

The results from the statement questionnaire (Figure 4.4 and Table 4.3) show that the assembly foremen have the lowest expectations that the relocation of the scheduling department will lead to more insights into what happens at the scheduling department. The metalworking foremen have also low expectations, only the painting foremen are more
positive. However, whereas these operators expect to get only somewhat more insight in what occurs at the scheduling department, the schedulers expect to get much more insight into the shop floor. Regarding improvements in schedule feasibility, the respondents expect some improvements, but again the assembly foremen’s expectations are the lowest. Finally, schedulers and metalworking foremen expect that the effectiveness of manufacturing will certainly improve; the painting and assembly foremen have lower expectations of effectiveness improvements.

The measurement of interactions provides further insight into the situation of coordination between scheduling and manufacturing before the relocation. Ninety percent of the reported interactions occurred by phone, only ten percent by a face-to-face interaction. Regarding the type of interaction, over fifty percent was reported as ‘question and answer’, followed by ‘collaboration’ (19%) and ‘announcement / command’ (17%). Table 4.4 (column Phase 1) shows that, on average, schedulers had insight in the information and computer systems of the shop floor to a large degree. Further, schedulers had a similar view and fairly similar interests as their shop floor interaction partners regarding the situation at hand. Schedulers were satisfied with both the process and the outcome of the interactions.

4.4.2 Phase 2 – three months after the relocation

After the relocation, the scheduling department is located in the middle of the factory; all manufacturing departments are located within walking distance. To go to the scheduling department, several shop floor departments have to be crossed. The smoking area and toilets are shared, but meal breaks are still used separately. In the perception of most respondents, the frequency of communication has increased, as indicated, for instance, by the inventory controller: “I communicate more with the foremen because they are nearby.”

The data from the statement questionnaire provide additional insights into the changes in perceptions shortly after the relocation (Figure 4.4 and Table 4.3). The foremen highly agree with the statement that the relocation has resulted into a higher level of insight into what is happening at the scheduling department, whereas their expectations were rather low. Thus, the relocation has brought more than they had expected. This is illustrated by a quote from a foreman from the painting department: “Because you can walk to the scheduling department easy, you get an answer to your question more easily and more quickly.” Reversely, according to the schedulers, the level of insight into the shop floor has largely improved due to the relocation; their expectation has become true in this respect. Interestingly, the increased level
of insight also leads to a better understanding of the operators’ actual behavior, as illustrated by the painting scheduling: “After the relocation, I even more realize that production operators should follow the schedule as prescribed.” According to all respondents, schedule feasibility has improved: all respondents report higher values during Phase 2 compared with Phase 1. Largest changes between experience and expectation are mentioned by the assembly foremen and metalworking foremen. Finally, the effectiveness of manufacturing and the effectiveness of scheduling have improved as a result of the relocation. Possibly, effectiveness and feasibility are improved because of the new opportunities to explain problems and solutions to each other, as suggested by the troubleshooter: “I have more face-to-face interactions than phone interactions. Explaining things to operators and supporting them has improved.” Overall, the respondents appear to be positive about the relocation.

Similar as in Phase 1, the schedulers were asked to report all work-related interactions during one day. Comparing the findings from both measurements provides a number of interesting results. The columns headed Phase 2 in Table 4.4 show the results from the interaction measurement during Phase 2. The final three columns show the results of application of the Mann Whitney U test that is used to test statistical differences between the phases. First, the number of reported interactions has not changed (58 in Phase 1, 57 in Phase 2), whereas an increase in interactions was expected due to the shorter distance between the departments and considering Allen’s law of propinquity (Section 4.2.2). Moreover, such an increase in the frequency of communication was also the perception of the respondents during the interviews. A second remarkable finding is that, after the relocation, the level of insight in the information of the interaction partner and the level of insight in the computer systems the other was using, have decreased. The Mann Whitney U test shows a significant difference regarding both variables. Thus, despite the shorter distance, the level of information insight seems not to be improved. Again, this finding does not match with the interviewees’ perceptions and the other questionnaire results reported above. Third, the level of similarity in problem view has not significantly changed between both phases; it remains high. However, the level of similarity in interests regarding the problem situation differs significantly: after the relocation, less similarity in interests has been reported than before the relocation. Finally, Table 4.4 shows that the level of satisfaction about the interaction process has significantly increased; this satisfaction was high already, but it has increased even more. Mean satisfaction about the outcome of an interaction has not changed significantly, but has remained high.

Figure 4.5 shows changes in the medium used for the interactions in both phases. Despite an increase in the number of face-to-face interactions from 5 to 9, changes are rather small
whereas a large increase in the proportion of face-to-face interactions was expected. A Chi-square test for the actual values (Phase 1: 5 face-to-face interactions; 53 using the phone; Phase 2: 9 face-to-face, 48 phone), shows that the difference is not significant ($\chi^2(df = 1, N = 115) = 3.672, p = .06)$.

![Figure 4.5](image1.png)

**Figure 4.5** Frequency of communication medium use.

![Figure 4.6](image2.png)

**Figure 4.6** Frequency of selected interaction descriptions.

Finally, Figure 4.6 shows percentages of ‘interaction descriptions’ that could be selected by the respondents. The frequencies are distributed significantly differently between Phase 1 and Phase 2 ($\chi^2(df = 5, N = 111) = 19.284, p = .002$). The description ‘collaboration’ has been
selected more often after the relocation at the expense of the description ‘question and answer’. Thus, it seems that the relocation has resulted into a different view of the schedulers on the type of interactions with the shop floor.

**4.4.3 Phase 3 – one year after the relocation**

Thirteen months after the relocation, schedulers and foremen were interviewed again. As said, because of the high workload to register all interactions during a working day, that data collection method could not be used again. Instead, the questionnaire with statements had been extended with a few open questions.

Figure 4.4 (and Table 4.3; columns headed P3) shows that due to the decreased physical distance between scheduling and manufacturing, mutual insight into what happens at the departments has increased according to respondents from all departments. The number of interactions has increased in the perception of the respondents, as illustrated by the troubleshooter: “Operators visit the scheduling department more often. Now, they do so without knocking on the door.” During the interviews, the foremen confirm that the decrease in the distance between scheduling and manufacturing has resulted into a better understanding of the shop floor by the schedulers. However, the shorter distance has also led to some kind of undesirable interfering behavior by the schedulers, as explained by a foreman from the assembly department: “Some schedulers started interfering with the shop floor, for instance about the minimum quality of products, whereas the foreman has the responsibility for quality decisions”. The largest change in experience is observed by the painting foremen: during Phase 2, they perceived some improvements in the level of insight in scheduling, whereas during Phase 3, they notice strong improvements. Possibly this is because it has become easier to discuss things, as explained by a foreman: “Now, I always go the scheduling department; it is much better than calling. Discussing problems has become easier.”

With regard to the feasibility of the schedules, expectations of the relocation were not high during Phase 1. However, the data from Phase 2 and Phase 3 indicate that the respondents experienced a positive link between the relocation and schedule feasibility. Between Phase 2 and 3, a slight decrease in feasibility improvement is reported by the metalworking and painting foremen.

In line with their expectations, the schedulers experience a higher effectiveness of manufacturing due to the relocation. Expectations and initial experiences were a bit lower in manufacturing itself, but after a year, the foremen admit that the relocation has resulted in a
higher effectiveness of their departments. Further, scheduling effectiveness has strongly improved due to the relocation according to both the schedulers and the foremen. Explaining some reasons for this higher effectiveness, the troubleshooter said: “Coordination has improved, because it is more direct; now, it is possible to join the operator if necessary. There is more information and it is available earlier; you can respond more quickly.”

Finally, the respondents express different opinions about the use of communication media during Phase 3. The inventory controller: “Operators still call, but if there is an urgent problem, they pass by”. The assembly scheduler indicates that there is still more communication by phone than face-to-face, although he goes to the shop floor more quickly now. A metalworking foreman: “I always call first, sometimes I go to the scheduler, especially in special situations. I also a chat have with the scheduler more regularly when I am close by.” The advantage of face-to-face interactions above phone interactions in urgent situations is illustrated by another foreman from the assembly department: “If you visit the scheduler, immediate action is taken, whereas if you call, you have to wait if and when action is taken.”

4.5 Discussion

This study has explored the importance of physical proximity between scheduling and manufacturing, and the consequences of relocating the scheduling department. All in all, our results show that the location of the scheduling department determining the extent of proximity between scheduling and manufacturing matters. In this way, the statement within literature that the physical layout design of a manufacturing company makes a difference (Galbraith 2002; Allen 2007; Heizer and Render 2008) is corroborated. However, several findings are in conflict with literature assumptions regarding proximity. The main findings from our study are briefly discussed now.

4.5.1 Discussion of findings

First, we found notable effects of the relocation on actual coordination behavior, such as communication frequency and medium use. The number of interactions reported during a working day within Phase 1 and Phase 2 did not change, whereas an increase of the number of interactions was expected based on Allen’s law of propinquity (Loch and Wu 2007; Allen 2007). However, Allen has remarked that physical proximity has especially an effect on not-directly task-related communication, such as sharing of knowledge and creativity. When we
discussed our findings with the firm, we concluded that the interactions we had measured dealt with problems to be solved immediately. In line with this, a possible explanation for the media-use finding is also related to the content and the urgency of the interactions. Saunders and Jones (1990) suggested that a number of contextual factors, such as the number of simultaneous decisions to make, the presence of time pressure, and the perceived importance of a decision all influence media use. Possibly, the measured interactions dealt with events that required an immediate response and with schedule adaptations that required immediate implementation. For such urgent interactions, use of the phone is preferred because face-to-face interactions require at least some walking time and the phone contains sufficient media richness for such interactions. Yet, it should be realized that the second measurement took place only three months after the relocation; probably, more time would be needed for building relationships between the schedulers and operators, resulting in an increase in the amount of interactions and in the proportion of face-to-face communication.

Second, the results indicate that the decrease of the distance between schedule developers and schedule executors has resulted in a higher level of insight into what happens at the other’s department. This higher level of mutual understanding could be associated with the higher level of schedule feasibility, and with the higher levels of effectiveness within manufacturing and scheduling. In this way, the proposed relationship between proximity, the level of mutual insight and performance (Figure 4.1) has been confirmed. However, the findings from the interaction questionnaire indicate a decrease in the level of insight in the information and the computer systems of the interaction partner. A possible explanation is that the questions in the interaction questionnaire were specifically focused on the information and systems used for the problem at hand, whereas the statement questionnaire and interviews dealt with the general level of mutual insight.

Third, the shorter distance between schedulers and operators has not led to more congruence in interests. Instead, on average, a lower level of similarity of interests, i.e., higher equivocality (Daft and Lengel 1986), was found. Probably, the shorter distance had led to a better understanding of each other, including objectives and interests, and, consequently, differences in interests have become clearer. In other words, the relocation could have led to more awareness regarding equivocality resulting into a higher level of interest incongruence during Phase 2.

Fourth, schedulers have reported, on average, higher values of expectations and experiences compared to the operators. Possibly, this is caused by the simple fact that the location of the schedulers has changed, whereas the operators were not relocated. This can
also explain the lower levels of operators’ expectations compared to their experiences: it was just after the relocation that the operators actively realized the possible consequences of the schedulers’ movement.

Finally, the data provide some support for Loch and Wu’s (2007) statement that coordination within operations management indeed does not only have a rational, but also an emotional side. Their reciprocity algorithm stating that humans expect positive returns from helping behavior became exemplary clear when the schedulers complained about operators not following the schedules whereas they were busy with finding solutions for all kinds of shop floor problems. The shorter distance between the schedulers and operators seemed to have influenced these feelings, as demonstrated by the high level of improvements reported in the questionnaires and the quotes about the increasing levels of mutual understanding. The influence of proximity on the reciprocity algorithm is also illustrated by the results from the interaction measurement that shows a change in the types of interactions before and after the relocation (Figure 4.5). A significantly higher number of interactions were typified as ‘collaboration’ during Phase 2 at the expense of the description ‘question and answer’. As such, this finding illustrates that for higher levels of coordination both interaction and collaboration are needed, as stated by Kahn and Mentzer (1998).

### 4.5.2 Main contributions

The study contributes to theory in several ways. First, the study shows the multi-faceted influence of proximity between schedulers and operators and discusses several reasons for collocation scheduling and manufacturing. Because of the specific interdependencies between scheduling and shop floor, the primary research implication, therefore, concerns the need to investigate appropriate instruments to facilitate coordination between schedulers and operators. Understanding and facilitating the communication process between scheduling and manufacturing employees is a key element to improve (re)scheduling and production performance. Therefore, scheduling and manufacturing control theory may be enriched with studies investigating factors enabling or inhibiting coordination between scheduling and shop floor. Further, our findings provide support for several recent proposals to investigate behavioral consequences of such factors within the domain of operations management (Wu and Katok 2006; Bendoly et al. 2006a; Loch and Wu 2007; Gino and Pisano 2008). Finally, this study has contributed to the small number of studies on factors enabling the achievement of integration between departments (Vandevelde and Van Dierdonk 2003; Danese and
Romano 2004; Pagell 2004; Wijngaard et al. 2006). As such, it provides a more in-depth understanding of the positive relationship between the level of integration and firm performance, as addressed in the majority of operations management research on internal integration (Kahn and Mentzer 1998; Narasimhan and Das 2001; O'Leary-Kelly and Flores 2002; Gimenez and Ventura 2005).

For practitioners, our study shows that physical proximity between scheduling and manufacturing influences coordination behavior and performance. Therefore, by decreasing the physical distance between scheduling and shop floor, firms can improve the level of mutual understanding between schedulers and operators resulting into higher levels of effectiveness in these departments. Managers are recommended to identify the critical task interdependencies between schedulers and operators in order to facilitate communication among them.

4.5.3 Limitations and further research

Several limitations of the study have to be mentioned, also indicating opportunities for future research. First, although the precise repetition of the measurement methods enabled the collection of much data in a way rarely done before, the measurement is potentially influenced by the specific circumstances of the measurement days, such as the actual order portfolio and machine failures. Second, the research has been based on one particular manufacturing firm and, thus, its results might not be generalizable to other firms directly. For instance, the level of uncertainty and complexity will have affected the need for coordination between scheduling and manufacturing. Thus, there is an opportunity for replicating this study across different firms and industries. In such research, the research model (Figure 4.1) can be used as a starting point for the selection of variables to be investigated. Third, because of the sample characteristics, statistical investigation of causal relationships between the studied variables over time was disregarded, but it remains a challenging opportunity for further research. Further, physical proximity is just one factor influencing information exchange and coordination between departments. Although this study has provided much insight into the role of this variable, further empirical studies are necessary to get a more complete understanding of factors influencing coordination between scheduling and manufacturing.
4.6 Conclusion

This study has investigated consequences of changing the physical distance between scheduling and manufacturing. The systematic, repeated measurement of perceptions regarding the effects of the relocation and of actual interaction behavior enabled an extensive analysis of the influence of proximity. Our results show that the physical location of the scheduling department matters. Physical vicinity between schedulers and operators appears to have positive effects on perceptions of schedule feasibility and effectiveness, while actual changes in coordination behavior remain limited. Accordingly, the main effect of decreasing the physical distance between scheduling and manufacturing may be in improving the level of mutual understanding, that is, in decreasing the perceived distance between schedulers and operators. This subsequently results into performance improvements.

Appendix 4A – Questionnaire on expectations and experiences

Respondents were asked to indicate their level of agreement with several statements. A seven-point Likert scale was used, with 1 = totally disagree and 7 = totally agree. The descriptions in brackets represent the variables as used in Table 4.3.

1. Since the relocation of the scheduling department, I have a better overview of what happens at the scheduling department. [Insight in scheduling]
2. Since the relocation of the scheduling department, I have a better overview of what happens at the manufacturing departments. [Insight in manufacturing]
3. Since the relocation of the scheduling department, the feasibility of the schedules has improved. [Schedule feasibility]
4. Since the relocation of the scheduling department, the manufacturing departments perform more effectively. [Effectiveness manufacturing]
5. Since the relocation of the scheduling department, the scheduling department performs more effectively. [Effectiveness scheduling]

During Phase 1, the statements were phrased as expectations, during Phase 2 and Phase 3 as experiences. For example, statement 1 was formulated during Phase 1: “Because of the relocation of the scheduling department, I will get a better overview of what happens at the scheduling department.”

Statement 1 has been presented to the manufacturing foremen only, statement 2 has been presented to the schedulers only. Statement 5 has been added during Phase 2; based on the results from Phase 1 the researchers concluded that a sole focus on determining performance differences in manufacturing would not be appropriate.
Appendix 4B: Questions and answer options in the interaction questionnaire.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Question or statement</th>
<th>Answer options / Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiator</td>
<td>1. Who did start the interaction?</td>
<td>1. You&lt;br&gt;2. The other</td>
</tr>
<tr>
<td>Medium</td>
<td>3. How did you interact?</td>
<td>1. By phone&lt;br&gt;2. Face-to-face</td>
</tr>
<tr>
<td>Insight in the partner’s information</td>
<td>4. Did you have insight in the information the other was using?</td>
<td>1. No, totally not&lt;br&gt;2. To some extent&lt;br&gt;3. To a large extent&lt;br&gt;4. Yes, completely</td>
</tr>
<tr>
<td>Insight in the partner’s systems</td>
<td>5. Did you have insight in the computer systems the other was using?</td>
<td>1. No, totally not&lt;br&gt;2. To some extent&lt;br&gt;3. To a large extent&lt;br&gt;4. Yes, completely</td>
</tr>
<tr>
<td>Similarity of problem view</td>
<td>6. Do you think you and your interaction partner had a similar view on the situation you were dealing with (when the interaction started)?</td>
<td>1. No&lt;br&gt;2. Yes</td>
</tr>
<tr>
<td>Similarity of interests</td>
<td>7. Do you think you and your interaction partner had similar interests regarding the situation you were dealing with?</td>
<td>1. No, opposing interests&lt;br&gt;2. To some extent similar interests&lt;br&gt;3. To a large extent similar interests&lt;br&gt;4. Yes, similar interests</td>
</tr>
<tr>
<td>Importance for respondent</td>
<td>8. To what extent was the interaction necessary for you to fulfill your tasks properly?</td>
<td>1. Very unimportant&lt;br&gt;2. Unimportant&lt;br&gt;3. Important&lt;br&gt;4. Very important</td>
</tr>
<tr>
<td>Importance for interaction partner</td>
<td>9. To what extent was the interaction necessary for the other to fulfill his/her tasks properly?</td>
<td>1. Very unimportant&lt;br&gt;2. Unimportant&lt;br&gt;3. Important&lt;br&gt;4. Very important</td>
</tr>
</tbody>
</table>