# Business Process Modeling in the 1920s and 1930s as reflected in Fritz Nordsieck's PhD Thesis

Jan Mendling[*,a]

[a] Humboldt-Universität zu Berlin

Abstract. *The PhD thesis by Fritz Nordsieck submitted in 1931 was one of the first scientific works in Germany that focused explicitly on business process models. Although the general contributions of Nordsieck to the study of business processes is often acknowledged, there is hardly any reflection on his specific findings on process modeling in any of the works after World War II. This is problematic since research on process modeling often assumes that later works on Petri nets and IDEF in the 1960s defined the starting point of process modeling. In this article, we discuss the contributions of Nordsieck's thesis. We find that the practice of workflow modeling was already richly developed in the 1920s. Even though some present-day concepts were still missing, the thesis still has the potential to inform contemporary research. Most important is the discussion of different categories of diagrams on a spectrum from spatio-temporal to conceptual, which demonstrates the need of re-integrating ideas from information visualization and conceptual modeling, two fields that have been artificially separated and researched by different communities over the last 40 years.*

Keywords. Business Process Modeling • Organizational Routines • Workflow Charts • Fritz Nordsieck

Communicated by Ralf Laue. Received 2021-03-06. Accepted on 2021-06-22.

## 1 Introduction

Fritz Nordsieck (1906–1984) was one of the first to explicitly study how business analysts make use of business process models. His PhD thesis from 1931 with the title *Die Schaubildliche Erfassung und Untersuchung der Betriebsorganisation* (English: The diagrammatic description and analysis of business organization) was published by C. E. Poeschel Verlag as Nordsieck (1932). His thesis builds on a collection of 117 diagrams from 105 publications, organized in three categories.

The importance of Nordsieck's thesis for the organization sciences and business process modeling, at least in the German-speaking countries, is emphasized by Staehle (1969), Grochla (1977), Franken and Frese (1981), Keller and Detering (1996), Kieser (1999), zur Muehlen (2004), Dorow and Blazejewski (2006), and Mendling (2008). His thesis is cited more than 100 times according

*Figure 1: Photo of the young Fritz Nordsieck published in Archiv für Molluskenkunde (Janssen 1987)*

* Corresponding author.
E-mail. jan.mendling@hu-berlin.de
I thank Schäffer-Poeschel Verlag für Wirtschaft-Steuern-Recht GmbH for the permission to reprint figures from Nordsieck's PhD thesis and Schweizerbart for permission to reprint Nordsieck's portrait photo. I also thank Hartmut Nordsieck for comments on an earlier version of this article.

to Google Scholar, his opus magnum Nordsieck (1934): *Organisationslehre* (English: organization study) more than 300 times, and his late Nordsieck (1972): *Betriebsorganisation* (English: business organization) around 250 times.

Franken and Frese (1981) reflect upon the significance of his works for modern business and management research, and stress that

> "Classical organization studies begin with Nordsieck [...]. Only Nordsieck laid the conceptual foundation upon which a new branch of business administration, namely organization studies, could develop."

Franken and Frese (1981) highlight that his work already recognizes the salience of *tasks* as the starting point for any understanding of organizations. Remarkable is also the fact that Nordsieck (1934) already emphasized the duality of *organization* as a system of rules and structures that support the overall goal of the business and *organizing* as the practice of planning and defining organizational rules. Also the distinction between structural and procedural organization is credited to him by Grochla (1977).

zur Muehlen (2004) praises that his visionary thinking already anticipated the process-oriented design of information systems. Indeed, much of the more recent citations to Nordsieck stem from publications on business process modeling. zur Muehlen (2004) translates a statement in Nordsieck (1972) as follows:

> "Think about [a] modern data processing [system]. This, too, represents a significant process that is even connected with the business process and accompanies - or even controls - this process across different segments."

After Nordsieck completed his PhD at the University of Cologne, he continued in 1934 as a scientific assistant to *Deutscher Gemeindetag* (English: association of German municipalities) and served as the editor-in-chief of the *Zeitschrift für öffentliche Wirtschaft* (English: journal of public management). He aimed for a habilitation, which was apparently not granted for political reasons (Janssen 1987). After serving in World War II as an officer, he held various senior administrative positions on the municipality and district level in the Lower Rhine region.

At a later stage of his career, he observed an increasing gap between his values and the demands of his political and administrative duties (Janssen 1987). As a response, he turned more and more to his hobbies of painting and malacology (the study of animals such as snails, slugs, clams, octopuses and squid). For the latter subject, he developed a scientific interest and approached it in a somewhat comparable way as already shown process models in his PhD works (Franken and Frese 1981): He collected instances and tried to capture the commonalities of their outer appearance. The difference was that now, it was not diagrams created by others, but he created sketches and paintings of molluscs himself (Janssen 1987). This led to various publications of articles and books on describing and taxonomizing different groups of molluscs. His research in this area inspired him to actively contribute to nature conservation, an engagement for which he received a medal of honor from the nature conservation association in North Rhine-Westphalia. Furthermore, he was active as a philosopher and chess player.

The historic roots of process modeling techniques are often closely related to the advent business-oriented computers in the 1960s (Couger 1973) and office automation in the 1980s (zur Muehlen 2004), but their concepts can be traced back already to scientific management (Taylor 1911) and motion studies (Gilbreth and Gilbreth 1917) in the 1920s. Nordsieck's PhD thesis offers unique insights into the spectrum of models, diagrams and representations that were used at those times. While his work is often mentioned as a rich source of inspiration, such words of praise have hardly been substantiated by more than cursory examples and definitions. For that reason, it is unclear how much of modern process modeling concepts are already included in his work, or if he might have even identified concepts that would contribute to research on business process modeling still today.

This paper addressed this research gap. More specifically, we reconstruct the contributions of Nordsieck's PhD thesis by the help of concepts that are established in recent research on process models, but which had not yet existed when his thesis was submitted. Even though we study his thesis as a historical document, we do not make use of research methods that are established in the field of economic history. Instead, we follow an approach similar to Burton-Jones (2014). In essence, this approach takes as input the informal description of a theory (in his case the book on the age of the smart machine by Zuboff (1988)) and constructs a more precise description by the help of conceptual models. The difference is that we use reconstruct modeling concepts, and not theoretical constructs. Our findings reveal a rich spectrum of process models and representations, which exhibits a diversity that is unknown to present day standardization efforts.

The paper is structured as follows. Section 2 discusses the translation of German technical terms to English. It also provides an overview of Nordsieck's PhD thesis. Section 3 describes the method of our analysis and presents the findings of our analysis. Section 4 discusses these results in the light of recent debates on business process modeling. Section 5 concludes the paper with a summary and an outline of future research directions.

## 2 Nordsieck's PhD Thesis

The ambition of his thesis is defined by Nordsieck (1932) in its preface: *"This work tries to provide an overview of techniques for diagrammatic representation and analysis of business organization in an as comprehensive as possible way."* To this end, *"the question has to be answered: which relationships, events and effects in businesses are accessible for organization-technical description?"* Tab. 1 summarizes the structure of the thesis. He subdivides his work into a general part and a specific part. The general part discusses foundations of diagrammatic representation in the context of business analysis. The specific part identifies three different categories of diagrams. He distinguishes structure diagrams with eight sub-categories, basic flow diagrams with four sub-categories, and timelines with three sub-categories.

Next, we discuss terminological challenges for interpreting the thesis and the references upon which it builds.

### 2.1 Terminological Challenges

One difficulty of reflecting Nordsieck's thesis stems from the fact that he uses terminology that is disconnected both from present day process modeling concepts and from present day German terms for these concepts. For this reason, it is important to define translations in a way that is systematic and traceable.

Tab. 2 shows some of the frequent terms used in Nordsieck's thesis. Note that there are alternative terms that can be used as a translation. The most important concept is Schaubild *(English: diagram)*. This concept is defined as a "graphical representation of a real or imaginary relational structure or event sequence" (Nordsieck 1932, p. 3). The term Schaubild is difficult to be explicitly distinguished from Plan *(English: chart)*, at least in a general sense. Among others, Verkehrspläne *(English: traffic charts)* are discussed as specific types of diagrams. The term *Harmonogramm* (English: harmonogram) has fallen out of use both in German and in English. For that reason, we use the more common, but less specific term *timeline*.

All diagrams and charts described by Nordsieck are models in a modern sense (Mendling 2008): their syntax, semantics, and notation are predefined or preconceived, constituting at least implicitly a modeling language. It is Nordsieck's ambition to understand these largely implicit modeling languages behind the diagrams he collects from practice and prior research.

*Table 1: Table of Contents of Nordsieck's PhD Thesis with page numbers (own translation)*



| German | English |
|---|---|
| Aufbau | composition |
| Aufgabe | task |
| Betrieb | business |
| Betriebsfaktoren | operating factors |
| Darstellung | representation |
| Erfassung | description |
| Gliederung | structure |
| Harmonogramm | timeline |
| Instanz | instance |
| Instanzenbau | instance composition |
| Instanzenweg | reporting line |
| Leitung | management |
| Plan | chart |
| Schaubild | diagram |
| Untersuchung | analysis |
| Verfahren | technique |
| Verrichtung | activity |

*Table 2: Glossary of frequently used terms in Nordsieck's PhD Thesis*

## 2.2 References used in the Thesis

Nordsieck's PhD thesis builds on 105 references. The full reference list is reproduced in Appendix A, including an English translation of each reference. Most of the references are German, several are French or English, some are Dutch, and one reference mixes German and Polish.

Much of his references are from German business administration journals. Most prominent is Zeitschrift für Organisation *(English: Journal for Organization)*, which was established in 1927 as the flagship journal of the German Gesellschaft für Organisation *(English: Association for Organization)*, an association that still today fosters exchange between academia and practice. 28 of Nordsieck's references are published in Zeitschrift für Organisation. 11 articles are from Betrieb *(English: business)*. A few other references, namely four articles each, stem from Sparwirtschaft *(English: savings banking)*, Organisation *(English:*

*organization)*, and Industrial Management.[2] Also of some significance are the proceedings of the IVe Congrès International de L'Organisation Scientifique du Travail *(English: 4th International Congress on the Scientific Organization of Work)* with six papers being cited.

It is also remarkable that Nordsieck builds on ten own prior publications. These include his diploma thesis that he wrote at the Faculty of Management, Economics and Social Sciences of the University of Cologne in 1928. Four of his cited articles were published in Zeitschrift für Organisation, another three in Die Betriebswirtschaft *(English: business administration)* (collectively listed as Reference 94), one in Zeitschrift für Handelswissenschaftliche Forschung *(English: journal for trade economics)*, and one in Zahlungsverkehr und Bankbetrieb *(English: transaction banking and banking business)*.

The extensive reference to then recent articles is testimony to the fact that Nordsieck's thesis is embedded in a vivid discourse at his time. At a more general level, he refers to early proponents of scientific management. Frenchman Henri Fayol and his foundational book on General and Industrial Management (Fayol 1916) is discussed in the context of task distribution and a commentary by Henri Verney (1925) on Fayol regarding the purposes of using diagrams. Also referenced is the book on Applied Motion Study[3] by Gilbreth and Gilbreth (1917). Noteworthy is the fact that Taylor (1911) is not cited in his thesis; maybe the Gilbreth's had been more visible in Germany for their work at the Auergesellschaft (Price 1990), a major German corporation for electric light and gas mantel manufacturing in Berlin, and the publication of their motion study book in German (Nordsieck cites both the English original and the German translation). References to Frederick W. Taylor and Max Weber, as well as to the Primer to Scientific Management by Gilbreth (1912) are found only later in his general book on organization studies (Nordsieck 1934).

The more specific discourse, in which his thesis is embedded, is on the usage of diagrams in organizational studies. There is one author who he explicitly singles out as a source of inspiration: Ernst Hijmans, Dutch engineering, director of the Standardization Office of the Netherlands, and a pioneer of organization studies in his country.[4] Several of Hijmans' works deal with diagrams and their application for specific organization analysis tasks, such as form diagrams (Hijmans 1928) and transport diagrams (Hijmans 1930). Nordsieck emphasizes the importance of Hijmans' works for his thesis in the preface. In the category of *References that cover the complete subject matter discussed in the thesis*, he points only to 1. Porter and 6. Beaumont on *charts*; 2. Wlach, 3. Mildner and 5. Hijmans more specifically on the *diagrammatic representation of organization charts*; and one of his own prior publications, beyond two reference without authors. From this fact, it seems as if the academic discourse was only emerging and driven by practical relevance.

Indeed, Nordsieck's topic appears to be of very practical relevance in the 1920s as evidenced by the number of references from industry. The work of various associations and committees from different countries is visible in several publications. The mentioned Hijmans was closely associated with the Nederlandsch Instituut voor Efficiency (Nive), a practitioners' association established in 1925 that continues to exist as a professional platform for managers.[5] Several of Hijman's publications appeared in a series published by Nive. In France, the Comité National de l'Organisation

[2] The magazine *Industrial Management* was first published in 1891, then called *Engineering Magazine*. Its history is summarized in a Wikipedia article at https://en.wikipedia.org/wiki/Engineering_Magazine. Digital scans of the magazine are online available at https://catalog.hathitrust.org/Record/005337008.

[3] A scan of this book on motion study is available online at https://archive.org/details/appliedmotionstu00gilbrich.

[4] For more on the work and life of Ernst Hijmans, see https://nl.wikipedia.org/wiki/Ernst_Hijmans (Dutch only). Scans of the two booklets on diagrams are online at https://vu.contentdm.oclc.org/digital/collection/nib/id/648 and https://vu.contentdm.oclc.org/digital/collection/nib/id/733.

[5] See https://www.nive.org/over-nive.

Française (CNOF) was founded in 1926.[6] The CNOF organized the IVe Congrès International de L'Organisation Scientifique du Travail and published its proceedings, from which Nordsieck cited six papers (Comité National de l'Organisation Française 1929). In Germany, the Reichsausschuß für Arbeitszeitermittlung (Refa) was established as a professional association in 1924.[7] Among others, Refa published education material, from which Nordsieck cites two. Also cited is a guidebook published by the Reichsausschuß für wirtschaftliche Fertigung (AWF).[8] The Ausschuß für wirtschaftliche Verwaltung (AWV)[9] published a guideline on the organization-technical representation of workflows in bookkeeping, which Nordsieck extended. Further to mention is the Verband Deutscher Ingenieure (VDI), which published the translation of the Applied Motion Studies by the Gilbreths, the Verband Deutscher Elektrotechniker, the Deutscher Normenausschuß, the Fachausschuß Rechnungswesen bei RKW, and the Fachausschüsse des Vereins deutscher Eisenhüttenleute. Also of relevance is the Hauptverband der Industrie österreichs.[10] Its Ausschuß für wirtschaftliche Betriebsführung (AWB) and its österreichischer Normenausschuß für Industrie und Gewerbe (önig) published guidelines for organization diagrams. Nordsieck cites five publications that build on their guidelines.

From this we conclude that Nordsieck addressed a topic of high practical relevance with his thesis that was in need of a deeper academic analysis.

[6] See https://fr.wikipedia.org/wiki/Comit%C3%A9_national_de_l%27organisation_fran%C3%A7aise. The CNOF served as a professional association for work organization. In 1997, it was integrated into IFG Executive Education France.

[7] Refa continued to exist as REFA - Verband für Arbeitsgestaltung, Betriebsorganisation und Unternehmensentwicklung *(English: Association for Work Design, Business Organization and Business Development)*.

[8] See https://www.awf.de/ueber-uns/historie/.

[9] See https://www.awv-net.de/awv/daten-fakten/index.html.

[10] See https://de.wikipedia.org/wiki/Industriellenvereinigung.

## 3 Reconstruction of Nordsieck's Thesis using Present-Day Concepts

### 3.1 Research Method

The methodological approach used in this paper is loosely inspired by Burton-Jones (2014). His paper has the objective to surface and precisely articulate the theory of the *Smart Machine* described by Zuboff (1988). To that end, he builds on coding procedures of grounded theory and content analysis. Such measures are not required for Nordsieck's thesis that provides a concise, systematic and structured presentation on a limited number of 76 pages (in contrast to the 468 pages of Zuboff's book). What is relevant for our study is that Burton-Jones explicates and reconstructs Zuboff's theory using conceptual models. We will utilize this idea and reconstruct Nordsieck's conceptualizations in a precise manner. In this way, we aim to formalize Nordsieck's ideas by the help of contemporary concepts that were not yet available when he was conducting his doctoral research.

### 3.2 Benefits of Diagrams

Right in the beginning of his thesis, Nordsieck discusses various properties of diagrams (Part I, Sect. A). This section is not much longer than one page, but concise and sharp. Nordsieck defines the concept of a *diagram* as a graphical representation of a real-world or imagined complex of relationships or sequences of events. This definition is closer to contemporary notions of a diagrammatic representation (*how information is represented*) as, for instance, described by Larkin and Simon (1987), than definitions of a conceptual model as a mapping (*what information is represented*) as described by Thalheim (2018), which have a strong connection with metamodels or grammars (Burton-Jones et al. 2017).

In his discussion of properties of diagrams and associated benefits, Nordsieck emphasizes both the question of *how* and *what* to represent. Natural language is his benchmark, as for many later authors who look at diagrams from a cognitive angle including Larkin and Simon (1987), Vessey

(1991), Kelton et al. (2010) or most recently Ritchi et al. (2020) and Malinova and Mendling (2022). Nordsieck states that "the usage of symbols equips the diagram with properties that facilitate not only to replace other means of representation, especially language, but to reveal the true nature of a represented matter in a more pristine way than other means of representation could."

The *cognitive* benefits of using diagrams are summarized by Nordsieck as follows. First, diagrams are *compact*. They eliminate the verboseness of natural language and represent matters in a short, lucid, clear and pictorial way. Staehle (1969) highlights Nordsieck's merits in emphasizing the potential of diagrams to represent complex facts synoptically, to minimize text, and to take the shortest possible time to grasp. Second, diagrams are *spatial*. Text is sequential and forces the reader into a specific reading order, while diagrams can be inspected in any direction. This argument is more than 50 years later systematically analyzed by Larkin and Simon (1987).

Nordsieck also points to a *conceptual* benefit. Diagrams force the modeler to exert the utmost *precision* by operating with symbols. The idea of a metamodel is implicitly developing with this argument when he states that every symbol should be introduced with careful thought. Research into the quality of symbols in a sense of concepts as defined in schemas, metamodels (Sharman 1978), or modeling grammars (Wand and Weber 1990) only develops 50 years after Nordsieck.

### 3.3 Purposes and Functions of Organization Diagrams

Nordsieck describes the purpose of organization diagrams to support the documentation and analysis of organizations. The similarities with the present-day tasks of the business process management lifecycle, as for instance covered by Dumas et al. (2018), is striking. He describes how an *organization study* should be conducted, an endeavor that we would call a process improvement project today. Such a study is driven by an *organizer*, a person that we might refer to as a business analyst. Organizers should pay attention to both the organizational structure and behavior.

An organization study is supposed to be conducted as follows:

1. As a first step, the organizer should conduct a documentation of the *as-is* situation. In modern business process management (BPM), this is called process discovery. The organizer should focus on recurrent work processes. These can be captured using diagrams.
2. The step of process analysis, which receives substantial attention in modern approaches to BPM, Lean or Six Sigma (Alter 2013; Dumas et al. 2018; Schroeder et al. 2008), is described only shortly and as part of as-is documentation. Recurrent issues, disruptions and errors are mentioned.
3. Then, the organizer turns to the specification of a *to-be* design of the organization. This new design is meant to fix all the issues of the current situation. As much as Reijers and Mansar (2005) will criticize it 75 years later, there is no discussion of how this to-be design of the organization is actually derived.
4. Nordsieck also mentions that the to-be design should replace the current practice, and that this requires various measures, including the provision of check lists. In modern BPM, this step is called process implementation.
5. He also mentions briefly that ongoing controls should be conducted. Modern BPM speaks of process monitoring in this context.

It is interesting to note that Nordsieck not only discusses as-is and to-be models, but also reference models *(German: Einheitspläne)*. His description is consistent with the present-day usage of the term, e. g., by Fettke and Loos (2003). Nordsieck emphasizes the benefits of using diagrams as a means of comparison and benchmarking between different organizations. He formulates the vision that reference models could be created for organizational structure and processes, among others, for those functions that are similar in many companies. The same idea shows up 60 years later in research on reference models and enterprise software (Keller and Teufel 1998; Scheer 1994).

### 3.4 Representations of Organization Diagrams

Nordsieck discusses that types of diagrams can be distinguished according to how information is represented. He identified geometric arrangement and types of elements as criteria.

Diagrams can be designed according to different *geometric arrangements* in three groups.

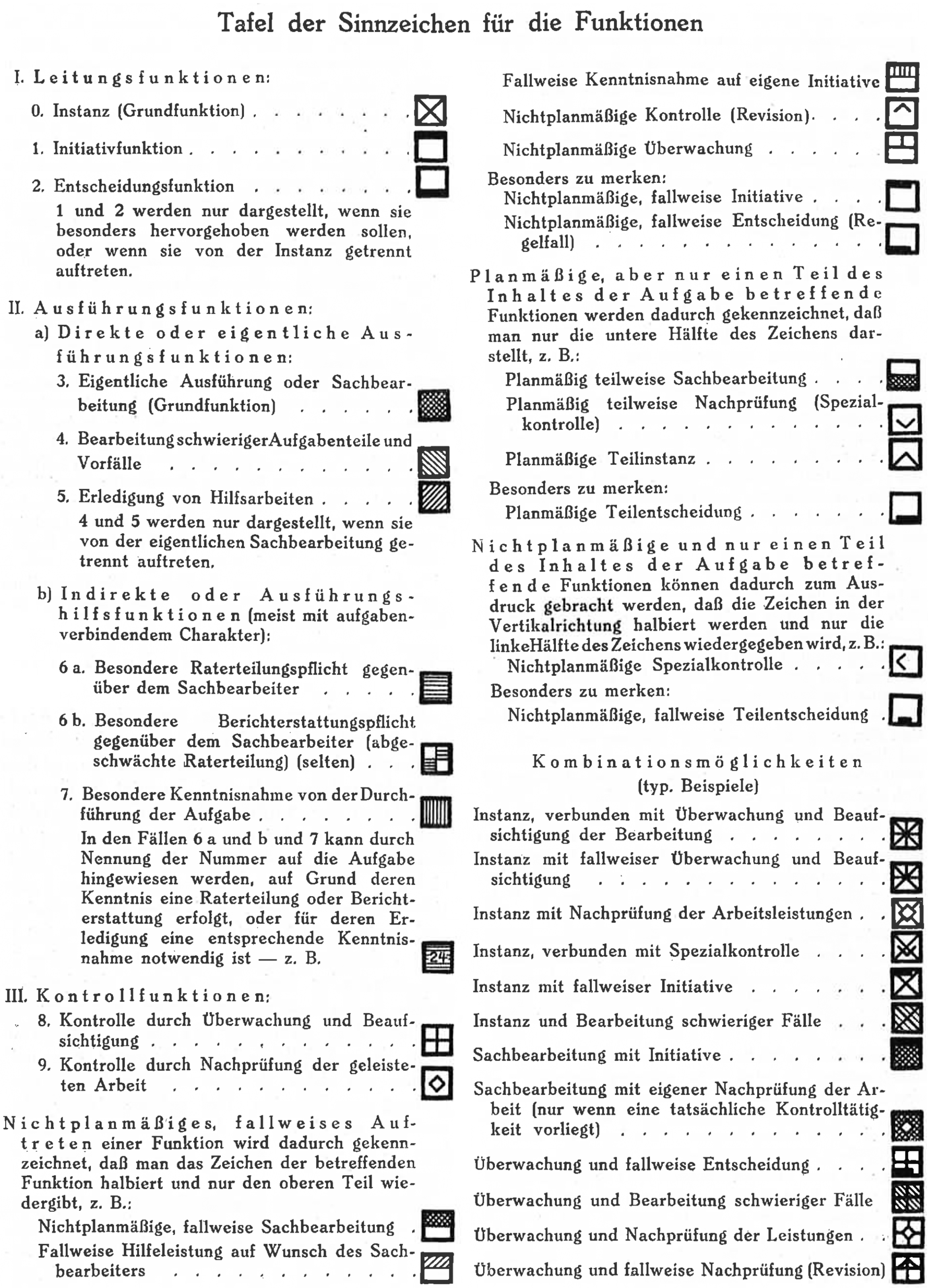
1. Free positioning: There are diagrams that use a *free positioning* of the elements. Modern graph-based diagrams such as UML class diagrams belong to this category.
2. Bound in one dimension: Diagrams can be *bound in one dimension*. Directed graphs such as BPMN business process diagrams or decision trees assume a dimension directed from left to right or top to bottom indicating temporal or logical order. A special case that Nordsieck mentions are diagrams that use a dimension that is scale-proportional. One modern example of a time-proportional diagram bound in one dimension are timeline charts.
3. Bound in two dimensions: Diagrams can be *bound in two dimensions*. Directed graphs such as BPMN business process diagrams can be extended with swimlanes for representing different actors orthogonal to temporal-logical order. A special case of a space-proportional diagram are planograms and factory layout plans.

It is striking that such a simple, yet powerful categorization of diagram types from the perspective of *how* information is represented is absent in modern research on process modeling. Related categorizations exist in the field of information visualization. Beyond, the classic by Bertin (1967), several fine-granular classifications have recently been proposed. Aigner et al. (2011) distinguish static versus dynamic and two- versus three-dimensional representations. Beck et al. (2017) describe force-directed, orthogonal, hierarchical and matrix layout of static graph as well as node-link, matrix and list layout of dynamic graphs. McNabb and Laramee (2017) distinguish data-centric, hierarchical, graph, and geospace-time representations. Research on graph drawing focuses on optimizing single aesthetics (Diaz et al. 2002), but less on organizing a diagram more generally. Hoffswell et al. (2018) distinguish layout types including tree, radial, Sugiyama-style, force-directed layouts.

Diagrams are composed of different elements. These elements can be represented in different ways. Nordsieck distinguishes three categories: symbols, color and shades, numbers and letters. First, symbols can be used to discriminate between different meanings. Symbols can be fully abstract or mnemonic. Fig. 2 shows an example of a list of task symbols with many abstract symbols from Nordsieck's thesis. Second, elements can be differentiated using color and shades. Interestingly, Nordsieck emphasizes that the use of color is at his time of writing largely restricted by technical challenges of color printing and reproduction (Nordsieck 1932, p. 8). Therefore, shading and hatching is often used in diagrams of the 1920s. Notably, these challenges have been overcome in the meantime. Color has become one of the most important and most effective means of discriminating elements (Green and Petre 1996; Moody 2009). Third, numbers and letters can be used as elements for referring to conceptual elements. This category is rather rare in modern diagrams. An example is the gateway element in BPMN models. The letter "X" indicates the type of the gateway as an exclusive gateway.

### 3.5 Domain of Organization Diagrams

Nordsieck describes the structure of a business as a network of personal, material, and geo-spatial relationships, which under observation reveals its true nature of continuous motion. This statement suggests some affinity with ideas found in structuration theoy (Giddens 1984) and sociomateriality (Leonardi 2013), but Nordsieck's understanding of motion is actually closely associated with the structure of pre-defined processes. Both



## Tafel der Sinnzeichen für die Funktionen

I. Leitungsfunktionen:

0. Instanz (Grundfunktion) . . . . . . . .

1. Initiativfunktion . . . . . . . . . . .

2. Entscheidungsfunktion . . . . . . . . .

1 und 2 werden nur dargestellt, wenn sie besonders hervorgehoben werden sollen, oder wenn sie von der Instanz getrennt auftreten.

II. Ausführungsfunktionen:

a) Direkte oder eigentliche Ausführungsfunktionen:

3. Eigentliche Ausführung oder Sachbearbeitung (Grundfunktion) . . . . . .

4. Bearbeitung schwieriger Aufgabenteile und Vorfälle . . . . . . . . . . . .

5. Erledigung von Hilfsarbeiten . . . . .

4 und 5 werden nur dargestellt, wenn sie von der eigentlichen Sachbearbeitung getrennt auftreten.

b) Indirekte oder Ausführungshilfsfunktionen (meist mit aufgabenverbindendem Charakter):

6 a. Besondere Raterteilungspflicht gegenüber dem Sachbearbeiter . . . . .

6 b. Besondere Berichterstattungspflicht gegenüber dem Sachbearbeiter (abgeschwächte Raterteilung) (selten) . . .

7. Besondere Kenntnisnahme von der Durchführung der Aufgabe . . . . . . . .

In den Fällen 6 a und b und 7 kann durch Nennung der Nummer auf die Aufgabe hingewiesen werden, auf Grund deren Kenntnis eine Raterteilung oder Berichterstattung erfolgt, oder für deren Erledigung eine entsprechende Kenntnisnahme notwendig ist — z. B.

III. Kontrollfunktionen:

8. Kontrolle durch Überwachung und Beaufsichtigung . . . . . . . . . . . . . .

9. Kontrolle durch Nachprüfung der geleisteten Arbeit . . . . . . . . . . . .

Nichtplanmäßiges, fallweises Auftreten einer Funktion wird dadurch gekennzeichnet, daß man das Zeichen der betreffenden Funktion halbiert und nur den oberen Teil wiedergibt, z. B.:

Nichtplanmäßige, fallweise Sachbearbeitung .

Fallweise Hilfeleistung auf Wunsch des Sachbearbeiters . . . . . . . . . . . .

Fallweise Kenntnisnahme auf eigene Initiative

Nichtplanmäßige Kontrolle (Revision). . . .

Nichtplanmäßige Überwachung . . . . .

Besonders zu merken:

Nichtplanmäßige, fallweise Initiative . . . .

Nichtplanmäßige, fallweise Entscheidung (Regelfall) . . . . . . . . . . . . . . .

Planmäßige, aber nur einen Teil des Inhaltes der Aufgabe betreffende Funktionen werden dadurch gekennzeichnet, daß man nur die untere Hälfte des Zeichens darstellt, z. B.:

Planmäßig teilweise Sachbearbeitung . . . .

Planmäßig teilweise Nachprüfung (Spezialkontrolle) . . . . . . . . . . . . .

Planmäßige Teilinstanz . . . . . . . . .

Besonders zu merken:

Planmäßige Teilentscheidung . . . . . . .

Nichtplanmäßige und nur einen Teil des Inhaltes der Aufgabe betreffende Funktionen können dadurch zum Ausdruck gebracht werden, daß die Zeichen in der Vertikalrichtung halbiert werden und nur die linke Hälfte des Zeichens wiedergegeben wird, z. B.:

Nichtplanmäßige Spezialkontrolle . . . . .

Besonders zu merken:

Nichtplanmäßige, fallweise Teilentscheidung .

Kombinationsmöglichkeiten
(typ. Beispiele)

Instanz, verbunden mit Überwachung und Beaufsichtigung der Bearbeitung . . . . . . . .

Instanz mit fallweiser Überwachung und Beaufsichtigung . . . . . . . . . . . . . . .

Instanz mit Nachprüfung der Arbeitsleistungen . .

Instanz, verbunden mit Spezialkontrolle . . . .

Instanz mit fallweiser Initiative . . . . . . .

Instanz und Bearbeitung schwieriger Fälle . . .

Sachbearbeitung mit Initiative . . . . . . . .

Sachbearbeitung mit eigener Nachprüfung der Arbeit (nur wenn eine tatsächliche Kontrolltätigkeit vorliegt) . . . . . . . . . . . . . .

Überwachung und fallweise Entscheidung . . . .

Überwachung und Bearbeitung schwieriger Fälle

Überwachung und Nachprüfung der Leistungen . .

Überwachung und fallweise Nachprüfung (Revision)

*Figure 2: Table of Symbols for Types of Tasks (Nordsieck 1932, p. 25)*

the structural and the behavior views of an organization are intertwined, because they jointly refer to several generic entities.

According to Nordsieck (1932), the structure of a business can be described with reference to the different actors, persons, means and objects. He distinguishes two types of actors *(German: Aufgabenträger)*: persons and means. The key difference between both is their degree of autonomy and agency. Persons are human actors who conduct work. Persons can be individuals and collectives. A collective can either be a group of persons with the *same* capabilities, these are called resource pools in operations management (Dumas et al. 2018), or a group of persons with *complementary* capabilities. These are often referred to as teams in resource management (Schönig et al. 2018). Means *(German: Hilfsmittel)* comprise tools, machines and geospatial means such as rooms and buildings. Means can partially be considered as non-human agents with the limitation that they at least to a certain extent depend upon human operation and control. All these different agents act on objects. Nordsieck (1932) distinguishes different categories of objects. The first category is defined by intellectual objects, for which he mentions the topic of a discussion as an example. The second category are persons as objects. These are, for instance, customers that are the target of services. The third category are material objects. Interestingly, Nordsieck (1932) counts both physical objects and informational objects to this category. The dividing line between physical and informational objects is indeed still a matter of recent debates on the ontology of the digital object (Faulkner and Runde 2019).

The dynamic aspect of a business according to Nordsieck (1932) is defined by tasks and work. He defines *task* as a conceptual entity and the actual fulfillment of a task as *work*. This means that work is constituted by the observation of sequences of action in relation to a task. Work and actors are connected via the notions of workload and work distribution. The distribution of work defines the assignment of units of work to specific actors while workload defines the number of work units that they can complete at a given time interval. Tasks are usually not isolated but they define more complex workflows *(German: Arbeitsabfolge)*. Furthermore, work is often bound to a specific work rhythm. Both workflow and work rhythm, as Nordsieck (1932) emphasizes, are often the concern of diagrammatic analysis of businesses.

If we compare the ontological view on business organizations by Nordsieck (1932), we can identify some interesting overlaps and differences with contemporary frameworks. We consider the Architecture for Integrated Information Systems (ARIS) by Scheer (2000) here. Actors are part of the organization view in ARIS, tasks are covered by the functional view. Objects are separated into the output view and the data view. The process view in ARIS ties together the dynamics of workflows that Nordsieck (1932) mentions. The major difference between Nordsieck (1932) and Scheer (2000) is the emphasis of informational objects: Scheer gives information primacy as a separate view while Nordsieck considers information as one specific category of objects. Even if given less emphasis, it is remarkable that information is explicitly discussed by Nordsieck.

The analysis of workflows is of particular importance for Nordsieck. It is associated with two categories of problems that he refers to as the time problem and the space problem. The *time problem* is concerned with the question how task elements can be arranged in sequences. This is the question of order that is addressed by many diagrams that Nordsieck (1932) discusses. It has to be distinguished from the question of temporal duration, which is faithful to the scale of time. These are captured by timeline diagrams. The *space problem* is concerned with the question of where work is performed and how workflows can be arranged across different locations. Specific diagrams focus on the corresponding concern of transportation.

In the following, we neglect structural diagrams *(German: Strukturschaubilder)*, to which Sect. A in Part II is dedicated, and focus on workflow diagrams *(German: Ablaufschaubilder)* (Sect. B) and timelines *(German: Harmonogramme)* (Sect. C).

### 3.6 Workflow Diagrams

Nordsieck (1932) describes different categories of workflow diagrams. Tab. 3 gives an overview. Key to his categories is a distinction between spatial-proportional diagrams and conceptual ones. Furthermore, diagrams can represent single or multiple paths. Mind that multiple paths are discussed with the suggestion of paths of different kinds like in railway schedules, which can highlight conflicts.

| **units** | **spatial** | **conceptual** |
|---|---|---|
| **single** | transport chart | flow chart |
| **multiple** | spatial traffic chart | conceptual traffic chart |

*Table 3: Categories of Workflow Charts*

For the category *transport chart* (single and spatial paths), he presents the example of an order and the path over several desks along the process (see Fig. 10 in the appendix). Diagrams with a spatial projection are largely missing in recent business process modeling research. De Leoni et al. (2012) is a rare application of projections of workflows on city maps. Diagrams like the one shown in Nordsieck (1932) are called planograms, which have been used for process projection by Solti et al. (2018). The introduction of information systems for office work has made them largely obsolete for informational processes.

For the category of *flow charts* (single and conceptual paths), he refers to the Refa guidelines. These guidelines define six levels of granularity for a workflow process. Fig. 11 from Nordsieck (1932) shows a corresponding example defining a decomposition tree from 1) production order, 2) production plan, 3) work sequence, 4) work steps, 5) grasp, and 6) grasp element. Nordsieck (1932) criticizes the bottom-up definition of Refa and its restricted application to production processes only. He introduces more general terms that are defined top-down making it 1) workflow, 2) work cycle, 3) work sequence, 4) work step, 5) partial work, and 6) work element. This top-down approach is remarkably similar to hierarchical task analysis (Stanton 2006) and consistent with later cognitive research on human problem solving (Newell and Simon 1972), goal decomposition (John and Kieras 1996a,b), and mental architectures (Anderson et al. 2004, 1997).

Nordsieck (1932) also pays some attention to work cycles. In particular, he distinguishes processes that are periodically triggered and event triggered. Differences in the rhythm of work naturally gives rise to different types of stocks. *Bulk stocks* are required for buffering different quantities (e. g. six screws are needed for a particular production piece, while screws can only be purchased in multiples of hundreds). *Variation stocks* buffer are needed to handle an unexpectedly large number of triggering events at any point in time. These matters are less a concern of modern business process modeling, but of system dynamics (Sterman 2000). Regarding work sequence, Nordsieck (1932) describes bundling and unbundling. This is an important concern, in particular for logistic processes, but hardly covered by modern business process modeling. It has been identified as a key challenge for object-centric process mining recently (Cabanillas et al. 2013; Gerke et al. 2009; Lu et al. 2015; van der Aalst 2019).

Nordsieck (1932) also describes a specific subcategory of workflow diagrams: workflows that capture parallelism and choices. These are faithful to temporal order of work, in contrast to the conceptual decomposition of work that was discussed just above. The diagram in Fig. 12 models choices while Fig. 13 shows parallelism. Subcategories of these workflow diagrams are restricted to capturing decomposition with choices, temporal order, with binding of the second coordinate.

Binding the second coordinate to actors or organizational units is a prominent subcategory. Examples of such diagrams are shown in Figures 17–21. Diagrams like Fig. 20 are conceptually similar to UML Activity diagrams and BPMN models with swimlanes. Nordsieck (1932) also describes workflow diagrams that do not use the temporal axis for layout. Fig. 22 shows an example that is similar to BPMN choreography diagrams. It is remarkable that he also identifies a category of data flow diagrams. These diagrams represent how forms and corresponding data is processed (see Fig. 24). Also a category for root causes and control mechanisms is proposed. Fig. 25 integrates risks and control tasks with the workflow representation.

There is a final special category of workflow diagrams. These are dedicated to staffing schedules as shown in Fig. 26. These indicate at which time intervals, different categories of personnel are available.

### 3.7 Timelines

Timelines defines the second category of diagrams that are concerned with dynamics in Nordsieck (1932). He uses the term harmonogram *(German: Harmonogramm)* to refer to timelines in an organizational context. The most prominent subcategory of timelines are Gantt charts, named after Henry Laurence Gantt (1919), an associate of Frederick Taylor.[11] Arguably, he was not the first one to design timelines. The first known publication of a timeline is in Joseph Priestley's book from 1765, showing a timeline chart of biographies (Aigner et al. 2011). Similar charts like the one by Gantt date to the late 19th century. Karol Adamiecki, a Polish engineer and organization scientist,[12] invented a diagram that he called *harmonogram* (Marsh 1975). This term also exists in English, German, and other Slavic languages, and must have been commonly used at the time of writing of Nordsieck (1932). He cites a talk in English by Adamiecki at the First International Management Congress in Prague in 1924.

The first subcategory of timelines that Nordsieck describes are *transport timelines*. These are diagrams that show where a vehicle like a railway train is at a given point in time, with time being fixed as one of the layout axes. The timelines are closely associated with railway schedules as they have been designed by railway companies since the 19th century. Fig. 27 shows an example of trains running back and forth between different stations of a production company.

The second subcategory of timelines are *workflow timelines*. These diagrams are meant to capture the rhythm of work. Fig. 28 shows the regular temporal pattern of work of a production process. Fig. 29 shows the specific pattern of batching of a molding production process. 90 years later, a similar chart called performance spectrum has been re-invented by Denisov et al. (2019) and Klijn and Fahland (2019) as a process mining technique.

The third subcategory covers timelines that are used for *staffing*. Fig. 32 shows an example that, in essence, informs about when which resources are bound for which type of work. These diagrams come close to Gantt charts. Mind that Nordsieck (1932) does not cite Gantt's article from 1919 in Industrial Management, so he might not have been aware of his work.

## 4 Discussion

Our reconstruction of the PhD thesis of Nordsieck (1932) has several implications for research. We highlight four major implications: the richness of early 20th century diagramming techniques for business processes and organizational routines, quality criteria explicitly discussed and implicitly used by diagrams, the close integration of different categories of workflow diagrams before the great shism between conceptual modeling and information visualization, and the affordances and constraints imposed by then contemporary production and reproduction techniques for diagrams.

The discussion in Nordsieck (1932) demonstrates the richness of the concepts covered by diagramming techniques in the 1920s and 1930s. These concepts are partially organized differently than for example in the ARIS framework by Scheer (2000), but cover most of its concepts. The concept

[11] A scan of his article is available on this website: https://babel.hathitrust.org/cgi/pt?id=mdp.35128001491289&view=1up&seq=101.
[12] See https://en.wikipedia.org/wiki/Karol_Adamiecki.

of a metamodel, modeling grammar, or modeling notations was not yet explicitly defined in the 1930s. Nordsieck (1932) already had a vague intuition of this concept when he states that "Brevity and clarity are enhanced in its effect by the force of exactness . . . Symbols must not be introduced without a process of reflection." His whole endeavor of identifying categories of diagrams lays the necessary foundations upon which follow-up work could have developed a notion of metamodel.

Nordsieck (1932) defines some quality criteria explicitly. Interestingly, these criteria have closer affinity with recent cognitive research on diagrams (Malinova and Mendling 2022) than with ontological research on diagrams (Burton-Jones et al. 2017; Wand and Weber 1990). He emphasizes brevity, clarity, and pictographic quality, which we know to be effective for visio-spatial search (Larkin and Simon 1987). He already discusses these benefits against weaknesses of textual representation of information when he states that "textual descriptions always stay linear and unidimensional." He also mentions exactness, which has an ontological dimension (Burton-Jones et al. 2017; Wand and Weber 1990). Though not explicitly discussed, the example diagrams in Nordsieck's thesis reveal that many common labeling styles had already been used back then. Many of the labeling guidelines described in (Leopold et al. 2013) seem to be considered in the examples.

It is important to note that Nordsieck (1932) uses a common framework to discuss diagrams that are today discussed in isolation by different research communities. The field of information visualization researches representations of dynamic phenomena such as event sequences by the help of binding at least one axis proportionally to time (Aigner et al. 2011), while the field of conceptual modeling has been mostly been concerned with conceptual structures (Wand and Weber 1990). The field of business process management (Dumas et al. 2018) has by and large developed its work in the tradition of conceptual system analysis and design. Only recently, steps are made to closer integrate research from both fields in the context of process mining (Yeshchenko et al. 2021).

The thesis also reveals some interesting insights into affordances and constraints (Norman 1999) of diagram production and reproduction techniques. It seems that the diagrams in the 1920s were mostly designed manually using pen, paper, and a ruler. Hand-written text is present in many diagrams in the thesis, but not in all. The usage of pen and paper imposed strict constraints on the flexible rescaling and repositioning of elements and text as we know it from contemporary software modeling tools. This might explain that many diagrams work with a strict binding of one or two axes, such that they often almost look like tables. For the sake of spatial economy, abstract and compact symbols are used to refer to, for instance, different types of activities (see Fig. 2). The set of visual representation was subject of debate at that time, as many of the articles published in Zeitschrift für Organisation cited by Nordsieck reveal. Also the usage of color seems to have been difficult at that time. Nordsieck (1932) laments that "Unfortunately, the usage of color coding is often limited by technical difficulties." He must have had an understanding of the effectiveness of color, as later demonstrated in various studies on business process models (Kummer and Mendling 2021; Reijers et al. 2011). The lack of better tools for modeling might be at least a partial explanation why conceptual modeling of business processes stagnated until the 1960s.

## 5 Conclusion

In this articles, we discussed the contributions of Fritz Nordsieck's PhD thesis with the title "The diagrammatic description and analysis of business organization", which was submitted in 1931 and published in 1932. The thesis is unique in the way how it approaches conceptual modeling in business in the 1920s and 1930s. It presents a rich collection of example diagrams and analyzes them according to a common framework. We find that the practice of workflow modeling was already richly developed at that time. His PhD thesis has the potential to inform contemporary research on business process modeling even 90 years after publication. Most important is his discussion of different categories of diagrams on a spectrum from spatio-temporal to conceptual. His work clearly shows the potential to re-integrate ideas from information visualization with conceptual modeling, both fields that have been artificially separated and researched by different communities over the last 40 years.

## References

Aigner W., Miksch S., Schumann H., Tominski C. (2011) Visualization of time-oriented data. Springer

Alter S. (2013) Work system theory: Overview of core concepts, extensions, and challenges for the future. In: Journal of the Association for Information Systems, p. 72

Anderson J. R., Bothell D., Byrne M. D., Douglass S., Lebiere C., Qin Y. (2004) An integrated theory of the mind.. In: Psychological review 111(4), p. 1036

Anderson J. R., Matessa M., Lebiere C. (1997) ACT-R: A theory of higher level cognition and its relation to visual attention. In: Human-Computer Interaction 12(4), pp. 439–462

Beck F., Burch M., Diehl S., Weiskopf D. (2017) A taxonomy and survey of dynamic graph visualization. In: Computer Graphics Forum 36(1), pp. 133–159

Bertin J. (1967) Semiologie graphique: diagrammes, reseaux, cartographie. Gauthier-Villars

Burton-Jones A. (2014) What have we learned from the Smart Machine? In: Information and Organization 24(2), pp. 71–105

Burton-Jones A., Recker J., Indulska M., Green P., Weber R. (2017) Assessing representation theory with a framework for pursuing success and failure. In: MIS Quarterly 41(4), pp. 1307–1333

Cabanillas C., Baumgrass A., Mendling J., Rogetzer P., Bellovoda B. (2013) Towards the enhancement of business process monitoring for complex logistics chains. In: International Conference on Business Process Management. Springer, pp. 305–317

Comité National de l'Organisation Française (1929) L'organisation scientifique du travail: IVème congrès international, Paris, 1929. Internat. Management Congress. Comité National de l'Organisation Française

Couger J. D. (1973) Evolution of business system analysis techniques. In: ACM Computing Surveys (CSUR) 5(3), pp. 167–198

De Leoni M., Adams M., Van Der Aalst W. M., Ter Hofstede A. H. (2012) Visual support for work assignment in process-aware information systems: Framework formalisation and implementation. In: Decision Support Systems 54(1), pp. 345–361

Denisov V., Fahland D., van der Aalst W. M. (2019) Predictive performance monitoring of material handling systems using the performance spectrum. In: 2019 International Conference on Process Mining (ICPM). IEEE, pp. 137–144

Diaz J., Petit J., Serna M. (2002) A survey of graph layout problems. In: ACM Computing Surveys (CSUR) 34(3), pp. 313–356

Dorow W., Blazejewski S. (2006) Entwicklung der Betriebswirtschaftslehre seit der Gründung der ersten Handelshochschulen: Rezension zweier fachhistorischer Sammelwerke. In: Archiv für Molluskenkunde 66(2), pp. 198–2018

Dumas M., Rosa M. L., Mendling J., Reijers H. A. (2018) Fundamentals of Business Process Management, Second Edition. Springer

Faulkner P., Runde J. (2019) Theorizing the Digital Object. In: MIS Quarterly 43(4)

Fayol H. (1916) Administration industrielle et générale. Prévoyance, Organisation, Commandement, Coordination, Control. Extrait du Bulletin de la Société de l'Industrie Minéeale. Dunod

Fettke P., Loos P. (2003) Classification of reference models: A methodology and its application. In: Information systems and e-business management 1(1), pp. 35–53

Franken R., Frese E. (1981) Fritz Nordsieck und die Entwicklung der Organisationslehre. In: Zeitschrift für Organisation 50, pp. 85–92

Gantt H. L. (1919) Organizing for Work: Machine Record Charts, Progress Charts and Man Record Charts Show What to Do to Get Production. In: Industrial Management 58(2), pp. 89–93

Gerke K., Claus A., Mendling J. (2009) Process mining of RFID-based supply chains. In: 2009 IEEE Conference on Commerce and Enterprise Computing. IEEE, pp. 285–292

Giddens A. (1984) The constitution of society: Outline of the theory of structuration. University of California Press

Gilbreth F. B. (1912) Primer of scientific management. D. Van Nostrand Company

Gilbreth F. B., Gilbreth L. M. (1917) Applied motion study: A collection of papers on the efficient method to industrial preparedness. Sturgis & Walton Company

Green T. R. G., Petre M. (1996) Usability analysis of visual programming environments: A 'cognitive dimensions' framework. In: Journal of Visual Languages & Computing 7(2), pp. 131–174

Grochla E. (1977) Organization Theory: Present State of the Science and Actual Challenges: An Analysis with Special Regard to the Development in the German-Speaking Countries. In: Management International Review, pp. 19–36

Hijmans E. (1928) Formulier-Diagramm en hunne Toepassing in de Industrie. J. Muusses, Purmerend

Hijmans E. (1930) Transport diagrammen voor massavervoer boven en onder den grond. J. Muusses, Purmerend

Hoffswell J., Borning A., Heer J. (2018) Setcola: High-level constraints for graph layout. In: Computer Graphics Forum 37(3), pp. 537–548

Janssen R. (1987) Fritz Nordsieck. In: Archiv für Molluskenkunde 118(4), pp. 105–128

John B. E., Kieras D. E. (1996a) The GOMS family of user interface analysis techniques: Comparison and contrast. In: ACM Transactions on Computer-Human Interaction (TOCHI) 3(4), pp. 320–351

John B. E., Kieras D. E. (1996b) Using GOMS for user interface design and evaluation: Which technique? In: ACM Transactions on Computer-Human Interaction (TOCHI) 3(4), pp. 287–319

Keller G., Detering S. (1996) Process-oriented modeling and analysis of business processes using the R/3 reference model. In: Modelling and methodologies for enterprise integration. Springer, pp. 69–87

Keller G., Teufel T. (1998) SAP R/3 process oriented implementation. Addison-Wesley

Kelton A. S., Pennington R. R., Tuttle B. M. (2010) The effects of information presentation format on judgment and decision making: A review of the information systems research. In: Journal of Information Systems 24(2), pp. 79–105

Kieser A. (1999) Geschichte der Organisationslehre. In: 100 Jahre Betriebswirtschaftslehre in Deutschland. Verlag Franz Vahlen, pp. 111–127

Klijn E. L., Fahland D. (2019) Performance mining for batch processing using the performance spectrum. In: International Conference on Business Process Management. Springer, pp. 172–185

Kummer T., Mendling J. (2021) The Effect of Risk Representation Using Colors and Symbols in Business Process Models on Operational Risk Management Performance. In: Journal of the Association of Information Systems

Larkin J. H., Simon H. A. (1987) Why a diagram is (sometimes) worth ten thousand words. In: Cognitive science 11(1), pp. 65–100

Leonardi P. M. (2013) Theoretical foundations for the study of sociomateriality. In: Information and organization 23(2), pp. 59–76

Leopold H., Eid-Sabbagh R., Mendling J., Azevedo L. G., Baião F. A. (2013) Detection of naming convention violations in process models for different languages. In: Decis. Support Syst. 56, pp. 310–325

Lu X., Nagelkerke M., van de Wiel D., Fahland D. (2015) Discovering interacting artifacts from ERP systems. In: IEEE Transactions on Services Computing 8(6), pp. 861–873

Malinova M., Mendling J. (2022) Cognitive Diagram Understanding and Task Performance in Systems Analysis and Design. In: MIS Quarterly

Marsh E. R. (1975) The Harmonogram of Karol Adamiecki. In: The Academy of Management Journal 18(2), pp. 358–364

McNabb L., Laramee R. S. (2017) Survey of surveys (SoS)-Mapping the landscape of survey papers in information visualization. In: Computer Graphics Forum 36(3), pp. 589–617

Mendling J. (2008) Metrics for Process Models: Empirical Foundations of Verification, Error Prediction, and Guidelines for Correctness

Moody D. (2009) The “physics” of notations: Toward a scientific basis for constructing visual notations in software engineering. In: IEEE Transactions on Software Engineering 35(6), pp. 756–779

Newell A., Simon H. A. (1972) Human problem solving. Prentice-Hall Englewood Cliffs

Nordsieck F. (1932) Die Schaubildliche Erfassung und Untersuchung der Betriebsorganisation.. Organisation - Eine Schriftenreihe. Poeschel

Nordsieck F. (1934) Grundlagen der Organisationslehre. Poeschel

Nordsieck F. (1972) Betriebsorganisation: Tafelband: Begriffe, Grundsätze, Formen u. Methoden d. Betriebsorganisation; Materialsammlung für Unterricht u. Praxis; mit 48 Schaubildern u. Tab. Poeschel

Norman D. A. (1999) Affordance, conventions, and design. In: Interactions 6(3), pp. 38–43

Price B. (1990) Frank and Lillian Gilbreth and the motion study controversy, 1907-1930. In: A mental revolution: Scientific management since Taylor

Reijers H. A., Freytag T., Mendling J., Eckleder A. (2011) Syntax highlighting in business process models. In: Decision Support Systems 51(3), pp. 339–349

Reijers H. A., Mansar S. L. (2005) Best practices in business process redesign: An overview and qualitative evaluation of successful redesign heuristics. In: Omega 33(4), pp. 283–306

Ritchi H., Jans M., Mendling J., Reijers H. A. (2020) The influence of business process representation on performance of different task types. In: Journal of Information Systems 34(1), pp. 167–194

Scheer A.-W. (1994) Business Process Engineering: Reference Models for Industrial Enterprises

Scheer A.-W. (2000) ARIS—business process modeling. Springer

Schönig S., Cabanillas C., Di Ciccio C., Jablonski S., Mendling J. (2018) Mining team compositions for collaborative work in business processes. In: Software & Systems Modeling 17(2), pp. 675–693

Schroeder R. G., Linderman K., Liedtke C., Choo A. S. (2008) Six Sigma: Definition and underlying theory. In: Journal of operations Management 26(4), pp. 536–554

Sharman G. (1978) What is a "Good" Semantic or Meta Model? In: Fourth International Conference on Very Large Data Bases, September 13-15, 1978, West Berlin, Germany. IEEE Computer Society, p. 138

Solti A., Raffel M., Romagnoli G., Mendling J. (2018) Misplaced product detection using sensor data without planograms. In: Decision Support Systems 112, pp. 76–87

Staehle W. H. (1969) Definition of Goals, Coordination and Control of Decentralized Organizational Units by Means of Ratio Systems. In: Management International Review, pp. 74–77

Stanton N. A. (2006) Hierarchical task analysis: Developments, applications, and extensions. In: Applied ergonomics 37(1), pp. 55–79

Sterman J. D. (2000) Business dynamics: systems thinking and modeling for a complex world. Irwin McGraw-Hill

Taylor F. W. (1911) The Principles of Scientific Management. Harper and Brothers

Thalheim B. (2018) Conceptual model notions–a matter of controversy: Conceptual modelling and its lacunas. In: Enterprise Modelling and Information Systems Architectures (EMISAJ) 13, pp. 9–27

van der Aalst W. M. (2019) Object-centric process mining: Dealing with divergence and convergence in event data. In: International Conference on Software Engineering and Formal Methods. Springer, pp. 3–25

Verney H. (1925) Le Fondateur de la Doctrine Administrative Henri Fayol. Discours Prononcés au Banquet du 7 Juin 1925. Résumé de la Doctrine Administrative. In: Dunod

Vessey I. (1991) Cognitive fit: A theory-based analysis of the graphs versus tables literature. In: Decision sciences 22(2), pp. 219–240

Wand Y., Weber R. (1990) An ontological model of an information system. In: IEEE transactions on software engineering 16(11), pp. 1282–1292

Yeshchenko A., Di Ciccio C., Mendling J., Polyvyanyy A. (2021) Visual Drift Detection for Sequence Data Analysis of Business Processes.. In: IEEE Transactions on Visualization and Computer Graphics

Zuboff S. (1988) In the age of the smart machine. Basic books

zur Muehlen M. (2004) Workflow-based Process Controlling. Foundation, Design, and Implementation of Workflow-driven Process Information Systems.. Advances in Information Systems and Management Science Vol. 6. Logos

## Appendix A: Reference List of Nordsieck's PhD Thesis

The reference list of Nordsieck's thesis is organized according to topics in four sections:
1. References that that cover the complete subject matter discussed in the thesis;
2. References that discuss specific representation formats, but do not provide a holistic perspective;
3. References that do not primarily focus on diagrams in general, but which provide explanations of individual diagrams that they include;
4. Other research areas that relate to the thesis.
For non-English publications, we provide a translation of the title in brackets.

### 1. References that cover the complete subject matter discussed in the thesis

**1.** Porter, David B. (1924) Charts. In: Management's Handbook. Third Print. Ronald, New York

**2.** Wlach, Fritz (1927) Organisationstechnische Darstellung. Ihre Aufgabe und ihre bisherige Entwicklung, *(English: Organization-technical representation. Its function and its development so far)*. Zeitschrift für Organisation. Vol. 1, pp. 229–241

**3.** Mildner (1928) Schaubildliche Darstellung von Organisationsplänen (Ausschuß für wirtschaftliche Betriebsführung, Wien), *(English: Diagrammatic representation of organization charts (Committee for efficient operational management))*. Sparwirtschaft. Vol. 5, pp. 509–515

**4.** without author (1929) Schaubildliche Darstellung von Organisationsplänen. Ausschuß für wirtschaftliche Betriebsführung, Wien, *(English: Diagrammatic representation of organization charts. Committee for efficient operational management)*. IVe Congrès International de L'Organisation Scientifique du Travail, Mémoire LXXVII. Section: Enseignement et Questions Générales

**5.** Hijmans, Ernst (1929) Une nouvelle Méthode d'organisation par les graphiques de liasions et

d'attributions, *(English: A new organization method based on charts of connections and attributions)*. Communication. Bulletin du Comité National de l'Organisation Française. Vol. 3(6), pp. 1–13

**6.** Beaumont, Jacques (1930) Quelques Mots sure les Graphiques, *(English: Some words on charts)*. Mon Bureau. Vol. 21, pp. 49–52

**7.** without author (1926/28) Graphique, *(English: Charts)*. Pages 41, 106, 107, 108, 109. In: Dictionnaire de l'Organisation et de la Science du Travail. Comité National de l'Organisation Française, Paris

**8.** Nordsieck, Fritz (1930) Erfassung der Betriebsorganisation durch Organisationsschaubilder, *(English: Description of business organization using organization diagrams)*. Zeitschrift für Organisation. Vol. 4, pp. 487–91

**2. References that discuss specific representation formats, but do not provide a holistic perspective**

**A 2** and **A 3**: Problems of Instance Structure and Task Relationships

**9.** Hijmans, Ernst (1926) De Organisatie der Directie, de Indeeling der Functies Grafisch Voorgesteld. De Tentoonstelling op het Gebied van de Openbare en Particuliere Bedrijfsadministratie, *(English: The organization of management, the division of tasks represented as charts. The illustration in the area of public and private business administration)*. J. Muusses, Purmerend, pp. 41–46

**A 6:** Composition of Facilities

**10.** without author (1928) Schaltzeichen und Schaltbilder, *(English: Switching symbols and circuit diagrams)*. 2. Auflage. Verband Deutscher Elektrotechniker E. V., Berlin, und dem Deutschen Normenausschuß E.V., Berlin. Beuth-Verlag, Berlin

**A 7:** Composition of Administrative Tools (Account Systems)

**11.** Schmalenbach, Eugen (1927) Der Kontenrahmen, *(English: The chart of accounts)*. Zeitschrift für handelswissenschaftliche Forschung. Vol. 21, pp. 431–475

**12.** Schmalenbach, Eugen (1929) Der Kontenrahmen, *(English: The chart of accounts)*. 2. Auflage. G. A. Gloeckner, Leipzig

**13.** Schriftenreihe "Einheitsbuchführungen". *(English: Publication series "Single-entry accounting")* Fachausschuß Rechnungswesen beim RKW, und zwar

1. Mittlere Maschinenfabriken, *(English: Mid-sized engineering works)*.
2. Braunkohlenbergbau, *(English: Brown coal mining)*.
3. Mittlere Eisengießereien, *(English: Mid-sized iron fondries)*.
4. Webereien unter besonderer Berücksichtigung der Buntwebereien, *(English: Weaving mills under consideration of color weaving)*.
6. Binnenschiffahrt unter besonderer Berücksichtung der Schleppschiffahrt, *(English: Inland navigation under consideration of towing)*.
7. Brauereien, *(English: Breweries)*.
8. Gesenkschmieden, *(English: Drop forges)*.
9. Ziegeleien, *(English: Brick factories)*.
10. Grundplan der Selbstkostenrechnung, *(English: Standard chart of cost accounting)*.

**14.** Weber, Arnold E. (1928) Das Kontenschaubild als Spiegel der Buchhaltung. Entwicklung und Grundlagen seiner Vereinheitlichung, *(English: The chart of accounts as a reflection of bookkeeping. Development and foundations of its harmonization)*. Zeitschrift für Organisation. Vol. 2, pp. 382–387

**15.** Stefanič-Allmayer, Karl (1929) Schaubildliche Darstellung von Kontenplänen und von Buchungszusammenhängen, *(English: Diagrammatic representation of charts of accounts and of bookkeeping relationships)*. Zeitschrift für Organisation. Vol. 3, pp. 341–346

**B 2:** Workflow

Group **B22**:

**16.** Nordsieck, Fritz (1928) Die organisationstechnische Darstellung von Arbeitsabläufen in der Buchhaltung. Eine Erweiterung der Richtlinien des AWV, *(English: Organization-technical representation of workflows in bookkeeping. An extension of guidelines of the AWV)*. Zeitschrift für Organisation. Vol. 2, pp. 440–442

**17.** Göhring, E. J. (1921/22) Arbeitsschaubilder und ihre Verwendung für die Lieferzeitbestimmung, *(English: Workflow diagrams and their application for delivery time determination)*. Betrieb. Vol. 4, pp. 359–366 (573–580)

Group **B24**:

**18.** Grull, Werner (1919/20) Beitrag zur Frage der betriebstechnischen Verkehrspläne, *(English: Contribution to the question of business-technical traffic charts)*. Betrieb. Vol. 3, p. 676

**19.** Göhring, E. J. (1921) Verkehrsplan mit Darstellung der Zeitfolge, *(English: Traffic charts with representation of temporal order)* Betrieb. Vol. 3, p.676

**20.** Hardung, Otto (1921/22) Die Schrift der Organisation, *(English: The script of organization)*. Betrieb. Vol. 4, p. 254

**21.** Hardung, Otto (1922) "Methoden der graphischen Darstellung von Organisationen und Arbeitsvorgängen" und die "Schrift der Organisation", *(English: "Methods of graphical representation of organizations and workflows" and the "script of organization")*. Organisation. Vol. 24, pp. 110–113

**22.** Oelbermann, H. E. (1929) Die Abrechnung von Instandsetzungsaufträgen in Eisenhütten und Walzwerken unter gleichzeitiger Darstellung des organisatorischen Ablaufes der Auftragsbearbeitung, *(English: The billing of maintenance orders in steel factories and rolling mills with simultaneous representation of the organizational flow of order processing)*. Inaug.-Diss. Köln, Wiso-Fakultät

**23.** Breiter, Jos. Rob. (1924) Die Schrift der Organisation, *(English: The script of organization)*. Organisation. Vol. 26, pp. 254–255

**24.** Stefanič-Allmayer, Karl (1926) Zur Frage der Organisationsschrift, *(English: On the question of organization script)*. Sparwirtschaft. Vol. 3, pp. 223–224

**25.** without author (1927) Richtlinie für die organisationstechnische Darstellung von Arbeitsabläufen. Vorentwurf vom 5. Dezember 1927, bearbeitet von der Hauptgeschäftsstelle der Gesellschaft für Organisation E. V. im Auftrage des AWV, *(English: Guideline for the organization-technical representation of workflows. Preliminary draft of 5 December 1927, edited by the head office of the Association for Organization, registered association, on behalf of the AWV)*. Zeitschrift für Organisation. Vol. 1, pp. 631–641

**26.** Niedlich, Walter (1930) Darstellung eines Einzelverkaufs nach dem GfürO.-Verfahren. Eine Gegenüberstellung zu der Darstellung von Professor Hennig in der ZfürO Heft 1/1930, *(English: Representation of a retail purchase according to the technique of the Association for Organization. A comparison with the representation of Professor Hennig in the Journal for Organization, No. 1, 1930)*. Zeitschrift für Organisation. Vol. 4, p. 69

**27.** without author (1930) Organisationsschaubilder (Normblatt des AWB, Ausschuß für Wirtschaftliche Betriebsführung, Wien), *(English: Organization diagrams (Standard specification sheet of AWB, Committee for Efficient Business Management, Vienna))*. Sparwirtschaft. Vol. 8, pp. 147–152

**28.** without author (1930) Organisationsschaubilder. Zwei Normblätter und ein Beiblatt (Prot.-Nr. 556/1 und 557/1) des österr. Normenausschuß für Industrie und Gewerbe (önig), Wien, *(English: Organization diagrams. Two* *standard specification sheets and an addendum (Protocol No. 556/1 and 557/1) of the Austrian Standards Committee for Industry and Trade (önig), Vienna)).* Zeitschrift für Organisation. Vol. 4(10), pp. 264–267

**29.** without author (1930) übungs- und Preisaufgabe: Entwurf einer organisationstechnischen Darstellung, *(English: Exercise and prize competition: Design of an organization-technical representation).* Zeitschrift für Organisation. Vol. 4(11), p. 286
without author (1930) Das Ergebnis unserer übungs- und Preisaufgabe: OtD-Entwurf, *(English: The result of our exercise and prize competition: OtD-Draft).* Zeitschrift für Organisation. Vol. 4(23/24), p. 618–619

**30.** without author (1930) Organisationsschaubilder. Stellungnahme zum önig-Entwurf, ausgearbeitet von der wissenschaftlichen Arbeitsstelle der Gesellschaft für Organisation, Berlin, *(English: Organization diagrams. Commentary on the önig-Draft, edited by the scientific department of the Association for Organization).* Zeitschrift für Organisation. Vol. 4(11), pp. 293–295

**31.** Müller, F. G. (1930) Ein Vermittlungsvorschlag zur organisationstechnischen Darstellung von Arbeitsabläufen, *(English: A mediation proposal for the organization-technical representation of workflows).* Zeitschrift für Organisation. Vol. 4(13), pp. 350–351

**32.** Czarnecki, Ew. (1929) Méthode de l'Organisation Scientifique Appliquée à l'Administration Publique, *(English: The method of scientific organization applied to public administration).* IVe Congrès International de L'Organisation Scientifique du Travail, Mémoire LXVII. Section: Administration

**33.** Louis (1928) Les Graphiques d'Organisation. Communication faite à la séance du 12 mars 1925. *(English: Organization charts. Talk at the session of 12 March 1925).* Bulletin du Comité National de l'Organisation Française. Vol. 2(8), pp. 6–9

**34.** Van Deventer, John H. (1920) Planning Department Systems. How to Visualize Methods by Mapping the Routine. Industrial Management. Vol. 60(2), pp. 373–376

**35.** without author (1928) Das rationalisierte Beschwerdebüro. Technika Uprawlenia, *(English: The rationalized complaints office. The technique of empowerment.)* Zeitschrift für Organisation. Vol. 2(8/9), p. 248

**36.** Volk, C. (1919) Betriebstechnische Verkehrspläne, *(English: Business-technical traffic charts).* Betrieb. Vol. 1, pp. 373–382

**37.** Volk, C., Grull, W., Göhring, E. J. (1919/20) Betriebstechnische Verkehrspläne, *(English: Business-technical traffic charts).* Betrieb. Vol. 2, pp. 332–336

**38.** Hijmans, Ernst[13] (1929) Formulier-Diagramm en hunne Toepassing in de Industrie[14] , *(English: Form diagrams and their application in industry).* Publication No. 11 of the Nederlandsch Instituut voor Efficiency, Amsterdam. Efficiency-Dagen, 18-19 December 1928. J. Muussess, Purmerend

**39.** Hijmans, Ernst (1929) Le contrôle de Progression des Commandes dans une Fonderie de Pièces diverses, *(English: The control of order progress in a various-parts foundry).* Talk held on 17 November 1928 at the Association Technique de Fonderie de Paris. Bulletin de l'Association Technique de Fonderie de Paris

**40.** Hennig, Karl W. (1930) Zur graphischen Darstellung organisatorischer Arbeitsabläufe. Vorschlag eines neuen Verfahrens, *(English: On the diagrammatic representation of organizational workflows. Proposal of a new technique).* Zeitschrift für Organisation. Vol. 4, pp. 12–17

[13] Nordsieck incorrectly represented this reference as "Jr. Ernst Hijman", potentially due to a wrong interpretation of "ir.", which is the Dutch abbreviation of the title "ingenieur".
[14] This booklet is available online as a scan at https://vu.contentdm.oclc.org/digital/collection/nib/id/648.

Group **B27**:

**41.** Goerlitz, Hans (1919/20) Darstellung der Vorgänge im Abrechnungswesen durch Leistungspläne, *(English: Representation of processes in accounting through performance charts).* Betrieb. Vol. 2, pp. 237–243

**42.** without author (1928) Einfache sinnvolle Darstellung organisatorischer Zusammenhänge im Budget amerikanischer Privatbetriebe, *(English: Simple reasonable representation of organizational relationships in budgeting of american private businesses).* Zeitschrift für Organisation. Vol. 2, p. 22; see also Stefanič-Allmayer, Reference 15.

**43.** Bober, W. C. (1920) Graphical Planning of Payroll Procedure. Industrial Management. Vol. 60(2), pp. 336–337

Group **B28**:

**44.** Nordsieck, Fritz (1928) Die Organisation der formalen Fehlerkontrollen und Fehlersicherungen in der Buchhaltung des neuzeitlichen Bankbetriebs, *(English: The organization of formal error controls and error protection in accounting of modern banking businesses).* Kölner Diplom-Arbeit, Wiso-Fakultät, July 1928

**45.** Nordsieck, Fritz (1929) Graphische Darstellung der formalen Fehlerkontrollen in der Bankbuchhaltung unter besonderer Berücksichtigung der Kontokorrentkontrollen, *(English: Diagrammatic representation of formal error control in bank accounting under the specific consideration of current account controls).* Zeitschrift für Handelswissenschaftliche Forschung. Vol. 23, pp. 145–169

**C 1:** Workflow Timelines

**46.** Adamiecki, Charles (1924) Scientific Organisation of Work. In: First International Management Congress, Prague. The Masaryk Academy-Institute for Industrial Management

**47.** Hijmans, Ernst (1929) Travail Continue Equilibré au Lieu de "Travail à la Chaine Artificiel". Application de fonderie, *(English: Continuous balanced work at the place of artificial assembly line work. The application to foundry).* IVe Congrès International de L'Organisation Scientifique du Travail, Mémoire CXXX. Section Industrie

**C 2:** Staffing Timelines

**48.** Poppelreuter, Walter (1929) Zeitstudie und Betriebsüberwachung im Arbeitsschaubild, *(English: Time study and business monitoring in work diagrams).* R. Oldenbourg, München und Berlin

**C 0–2:** Timelines in General

**49.** Nordsieck, Fritz (1931) Harmonogramme. Ein Beitrag zur schaubildlichen Untersuchung der Betriebsorganisation, *(English: Time tables. A contribution to diagrammatic analysis of business organization).* Zeitschrift für Organisation. Vol. 5, pp. 106–112

## 3. References that do not primarily focus on diagrams in general, but which provide explanations of individual diagrams that they include

**A 0:** Task Structure

**50.** Scott, Walter Dill, Clothier, Robert (1925) Personnel Management. Principles, Practices, and Point of View. A. W. Shaw Co, Chicago and New York

**A 1:** Task Distribution

**51.** Fayol, Henri (1925) Administration Industrielle et Générale. Prévoyance – Organisation – Commandement – Coordination – Contrôle, *(English: General and industrial management. Planning, organization, leadership, coordination, control).* Dunod, Paris

**52.** without author (1929) Wie ist Ihr Betrieb gegliedert? Wie sind die Zuständigkeiten geregelt? Rundfrage der Gesellschaft für Organisation, *(English: How is your business structured? How are responsibilities organized? Survey of the Association for Organization).* Zeitschrift für Organisation. Vol. 3(12), p.

111.
and publication of answers in Zeitschrift für Organisation. Vol. 4(4-5) in 1930

**A 2:** Problems of instance composition

see Scott-Clothier, Reference 50.

**A 3:** Task Relationships

see Hardung-Michel, Reference 66.

**A 4:** Problems of job charts

see Scott-Clothier, Reference 50 (promotion, level classification).

**53.** Hopf, H. A. (1926) Gehälter als Anspornmittel, *(English: Salaries as a means of incentive)*. Organisation. Vol. 27, pp. 372–375

**A 6:** Composition of facilities

**54.** Schubert, E. (1921) Die Sicherungswerke im Eisenbahnbetrieb, *(English: Safety infrastructure in railway operations)*. 5th Edition. Kreidl, Berlin and Wiesbaden

**A 7:** Composition of administrative tools (account system)

**55.** Bigelow, Carle M. (1920) Installing Management Methods in the Woodworking Industry. Industrial Management. Vol. 54, pp. 470–477

**56.** Marshall, Leon Carroll (1921) Business Administration. University Press, Chicago

**B 0:** Transport, flow, and traffic chart

**57.** Kampe, R. (1919/20) Das Transportwesen in Fabriken mit besonderer Berücksichtigung des Werkbahnbetriebs *(English: Transport organization in factories under specific consideration of factory railway operations)*. Betrieb. Vol. 2, pp. 405–407

**58.** Lansburgh, Richard H. (1923) Industrial Management. John Wiley & Sons, Inc., New York

**59.** Martin, Robert (1928) Die Schriftgutverwahrung muß dem Geschäftsbetrieb entsprechen. Dargestellt an einem Fall aus der Praxis, *(English: The document archiving must match the business operations. Illustrated based on a case from practice)*. Zeitschrift für Organisation. Vol. 2, pp. 429–432

**B 1:** Work structure

**60.** Hoffmeister, H. (1919/20) Arbeits- und Zeitstudien, *(English: Work and time studies)*. Betrieb. Vol. 2, pp. 57–73

**61.** without author (1926) Refa-Mappe für Gießereien, *(English: Refa folder for foundries)*. Edited by Reichsausschuß für Arbeitszeitermittlung. Beuth-Verlag, Berlin

**62.** without author (1928) Refa-Buch, Einführung in die Arbeitszeitermittlung, *(English: Refa-Book, Introduction to work time recording)*. Edited by Reichsausschuß für Arbeitszeitermittlung. Beuth-Verlag, Berlin

**63.** without author (1929) Grundlagen für Arbeitsvorbereitung, Zeitstudien, *(English: Foundations of production planning, time studies)*. Edited by Ausschuß für Handarbeit beim AWF (AWF 225). Beuth-Verlag, Berlin

**B 2:** Workflow charts

Group **B21**:

**64.** Rosencrantz, Walter (1926) Erfolge der Handdurchschreibebuchhaltung bei einer Sparkasse, *(English: Successes of manual duplication book accounting at a mutual savings bank)*. Organisation. Vol. 28, pp. 643–658

**65.** Witte, I. M. (1928) Neue amerikanische Verkaufs- und Lagerverfahren. Zweck und Ziel der Planabteilung im Einzelhandel. Mit Geleitwort von Russell W. Allen, *(English: New american sales and warehouse techniques. Purpose and objective of the planning department in retail business. With a preface by Russel W. Allen)*. Springer, Berlin

**66.** without author (1924) Fabrikorganisation, bearbeitet von O. Hardung und E. Michel. 10. Abschnitt der "Hütte", Taschenbuch für Betriebsingenieure, *(English: Factory organization, edited by O. Hardung and E. Michel. 10th section on "steelmaking")*. 2nd Edition. Wilh. Ernst & Sohn, Berlin, pp. 520–598

**67.** Troske (1924) Fabrikanlagen, aus "Hütte", Taschenbuch für Betriebsingenieure, *(English: Factory constructions, in "steelmaking", pocketbook for business engineerings)*. see Reference 66, pp. 354–473

**68.** Rosencrantz, Walter (1929) Durchführung der Organisationsarbeit. Vortrag auf der Tagung 1929 der Gesellschaft für Organisation, *(English: Conducting organization work. Talk at the 1929 Conference of the Association for Organization)*. Zeitschrift für Organisation. Vol. 3, pp. 288–292

Group **B22**:

**69.** Nordsieck, Fritz (1929) Die Gestaltung der innerbetrieblichen Organisation der amerikanischen Banken unter dem Einfluß des Zahlungsverkehrs, *(English: The design of business-internal organization of american banks under the influence of transaction banking)*. Zahlungsverkehr und Bankbetrieb. Vol. 11(10), p. 225–238

**70.** Hohenstein, H. (1925) Die Entwicklung eines Arbeitsbüros in einem Maschinenbaubetrieb mit Einzelfertigung, *(English: The development of the work office in a mechanical engineering company with job shop production)*. Maschinenbau. Vol. 4, pp. 626–634

**71.** Wagner, I. (1929) Rationalisation du Travail dans les Ateliers des Chemins de Fer de l'etat Polonais (P.K.P.), *(English: Rationalization of work in the workshops of the Polish State Railways)*. IVe Congrès International de L'Organisation Scientifique du Travail, Mémoire XXXIX. Section: Industrie

Group **B23**:

see Hardung, Reference 66.

Group **B24**:

**72.** Grull, Werner (1928) Die Organisation von Fabrikbetrieben, *(English: The organization of factory companies)*. 3rd Edition. Gloeckner, Leipzig

**73.** Hardung, Otto (1921) Fabrikbauten und Umstellungen, *(English: Factory buildings and change-overs)*. Betrieb. Vol. 3(23), pp. 751–759

**74.** Behlert, Karl (1928) Post-Eingang und Post-Verteilung, *(English: Incoming mail and mail distribution)*. Zeitschrift für Organisation. Vol. 2, pp. 240–243; according to the method of "Richtlinien", Reference 25.

Group **B25**:

**75.** Ludwig, H. (1926) Die Umstellung metallbearbeitender Betriebe mit Kleinserienfertigung, *(English: The change-over of metalworking companies with small-series production)*. Maschinenbau. Vol. 5, pp. 729–736

Group **B26**:

**76.** Hennig, Karl Wilhelm (1928) Betriebswirtschaftslehre der Industrie, *(English: Industrial Economics)*. Julius Springer, Berlin

Group **B27**:

**77.** Harrison, G. Charter (1918/19) Cost Accounting to Aid Production. Industrial Management. Vol. 56(2), pp. 273–282, 391–398, 456–63 and Vol. 57(1), pp. 49–55, 131–139, 218–224, 314–318, 400–404, 483–487

**78.** Nordsieck, Fritz (1929) Das Ausschreiben der monatlichen Prämienrechnungen. (Aus der Praxis der "Vaterländischen und Rhenania Versicherungs-Gesellschaft A.G.", vorgeführt auf der Ausstellung "Büro und Organisation", Köln), *(English: The editing of the monthly premium invoices. (Based on the practice of the National and Rhenania Insurance Corporation, inc., presented at the exhibition "Office and Organization", Cologne)*. Zeitschrift für Organisation. Vol. 3, pp. 572–575

Group **B28**:

**79.** Grull, Werner (1921) Die Kontrolle in gewerblichen Unternehmungen. Grundzüge der Kontrolltechnik, *(English: The control of trade corporations)*. Springer, Berlin

**80.** Schmandt, Heinrich (1926) Technik der Kontrolle im Bankbetrieb, *(English: Technique of control in the banking business)*. Spaeth & Linde, Berlin und Wien. (Betriebs- und finanzwirtschaftliche Forschungen, 2. Serie, Heft 23); also Nordsieck, Reference 69.

**B 3:** Staffing Schedule

see Work and Time Study, References 82/83.

**C 0:** Traffic Timelines

**81.** without author (1923) Das Deutsche Eisenbahnwesen der Gegenwart. I. und II. Band, *(English: The contemporary German railway industry. First and second volume)*. Reimar Hobbing, Berlin; also Kampe, Reference 57.

**82.** without author (1928) Richtlinien für Arbeits- und Zeitstudien im Eisenbahnbetriebsdienst. Innere Dienstvorschrift der Deutschen Reichsbahn-Gesellschaft vom 10. Februar 1928, *(English: Guidelines for work and time studies in the railway business service. Internal regulation of the German Imperial Railway from 10 February 1928)*.

**83.** without author (1928/29) Beispiele für Arbeits- und Zeitstudien im Eisenbahnbetriebsdienst. 2 Hefte. Innere Dienstvorschrift der Deutschen Reichsbahn-Gesellschaft. 1. Heft: 15. November 1928, 2. Heft: 24. Juni 1929 *(English: Examples of work and time studies in the railway business service. Two booklets. Internal regulation of the German Imperial Railway. Booklet 1 from 15 November 1928, Booklet 2 from 24 June 1929)*.

**84.** Tarwid, S. (1929) Introduction de l'Organisation Scientifique du Travail dans le Travail Technique des Gares de Triage, *(English: Introduction of scientific work organization for the technical works of railway yards)*. IVe Congrès International de L'Organisation Scientifique du Travail, Mémoire XLIV. Section: Industrie[15]

**C 1:** Workflow Timelines

**85.** Reichelt, A. (1928) Schmiedearbeit und ihre Zeiterfassung, *(English: Smithery and its time recording)*. Werkstatttechnik. Vol. 22, pp. 353–357

**86.** Lauke, H. L. (1928) Die Leistungsabstimmung bei Fließarbeit, *(English: The performance coordination of flow-oriented work)*. R. Oldenbourg, München-Berlin

**87.** Rummel, K. (1926) Erhöhung der Wirtschaftlichkeit in den technischen Betrieben der Großeisenindustrie. Sonderheft der Fachausschüsse des Vereins deutscher Eisenhüttenleute. Erweiterter Abdruck der Berichte 5–10 des Ausschusses für Betriebswirtschaft, *(English: Increase of efficiency in the technical production sights of the large iron industry. Special issue of the technical committee of the Association of German steel manufacturers. Extended offprint of reports 5–10 of the committee for business administration)*. Verlag Stahleisen m. b. H, Düsseldorf

**C 2:** Staffing Timelines

**88.** Baumann, A. (1927) Zur Bemessung der Gleiszahl in Einfahrgrupppen der Verschiebebahnhöfe, *(English: On the calculation of the amount of tracks for entry groups of railway yards)*. Verkehrstechnische Woche. Vol. 21(14), pp. 157–160; also Beispiele, Reference 83.

**89.** Gilbreth, Frank B. and Gilbreth, L. M. (1919) Applied Motion Study. A Collection of Papers on the Efficient Method to Industrial Preparedness. The Macmillan Co., New York

**90.** Gilbreth, Frank B. and Gilbreth, L. M. (1920) Angewandte Bewegungsstudien (Applied Motion Study). Neun Vorträge aus der Praxis der wissenschaftlichen Betriebsführung. Berechtigte übertragung ins Deutsche von I. M. Witte, *(English: Applied Motion Study. Nine Exhibits from the Practice of scientific management. Authorized translation to German by I. M. Witte)*. VDI-Verlag, Berlin

All Areas:

**91.** without author (1926) De Tentoonstelling op het Gebied van de Openbare en Particuliere

[15] Nordsieck uses the abbreviation "l'Organisation S. T." in the title, which likely means "l'Organisation scientifique du travail".

Bedrijfsadministratie, *(English: The organization of management, the division of tasks represented as charts. The illustration in the area of public and private business administration.)* T. O. P. A. Boek, J. Muusses, Purmerend. 3 Volumes[16]

## 4. Other research areas that relate to the thesis

Theoretical Part

**92.** Walb, Ernst (1927) Die Organisation der Unternehmung und des Betriebes, *(English: The organization of the corporation and the business)*. Rothschilds Taschenbuch für Kaufleute. Vol. 2, pp. 10-41. Gloeckner, Leipzig

**93.** Halberstaedter, H. (no year) Gegenstände der Einzelbetriebs-Organisationsuntersuchungen, *(English: Subjects of single business organization analyses)*. Unpublished Manuscript

**94.** Nordsieck, Fritz (1931) Grundprobleme und Grundprinzipien der Organisation des Betriebsaufbaus, *(English: Fundamental problems and principles of the organization of business structure)*. Die Betriebswirtschaft. Vol. 24(6), pp. 158–162; Vol. 24(7), pp. 204–210; Vol. 24(8), pp. 232–238

Purposes of Diagrams:

**95.** Verney, M. Henri (1925) Le Fondateur de la Doctrine Administrative Henri Fayol. Discours Prononcés au Banquet du 7 Juin 1925. Résumé de la Doctrine Administrative, *(English: The founding father of scientific management Henri Fayol. Talk given at the banquet of 7 June 1925. Taking stock of scientific management)*. Dunod, Paris

Symbols:

**96.** Wlach, Fritz (1928) Gliederung durch Sinnzeichen, *(English: Structure through symbols)*. Zeitschrift für Organisation. Vol. 2, p. 113

**97.** Stefanič-Allmayer, Karl (1928) Buchstaben-Symbole, *(English: Letter symbols)*. Zeitschrift für Organisation. Vol. 2, p. 114

**98.** Niedlich, Walter (1928) Ziffernsymbole, *(English: Numeric symbols)*. Zeitschrift für Organisation. Vol. 2, pp. 116–117

**99.** Victorius, Curt (1928) Buchstaben oder Ziffern? Buchstaben und Ziffern, *(English: Letters or numbers? Letters and numbers)*. Zeitschrift für Organisation. Vol. 2, p. 118

**100.** without author (1928) No. 13, published on 10 July 1928. Zeitschrift für Organisation. Vol. 2. Colored Issue

Technical Aids for Diagrammatic Representations:

**101.** Buratowsky, Franz (1929) Hilfsmittel zur Aufklärung von Verlustzeiten im Betriebe, *(English: Aids for resolving idle time in businesses)*. Sparwirtschaft. Vol. 7(4), pp. 173–177; Vol. 7(5), pp. 224–229; also Poppelreuter, Reference 48.

Standardization of Representation Forms:

**102.** without author (1928) Schritte zur internationalen Regelung der organisationstechnischen Darstellung, *(English: Steps towards the international regulation of organization-technical representation)*. Zeitschrift für Organisation. Vol. 2, p. 188

References from the Field of Planning:

**103.** Rosenberg (1921) Organisatorische Hilfsmittel für die Tagesarbeit des Betriebsleiters, *(English: Organizational aids for the daily work of the operations manager)*. Betrieb. Vol. 3(12), pp. 335–343

**104.** Tomaszewski, T. (1929) Méthode Graphique du Plan et du Contrôle des Travaux dans les Exploitations Agricoles, *(English: Diagrammtic method for planning and controlling work in farms)*. IVe Congrès International de L'Organisation Scientifique du Travail, Mémoire XLIII. Section: Agriculture

**105.** Bernert, Kurt (1930) Die Arbeitsdisposition in einer Lochkartenabteilung, *(English: Work disposition in the punched-cards department)*. Die Lochkarte und das Powers-System, February 1930, Issue 7, pp. 45–52

[16] A scan of these books is available via Delpher: http://resolver.kb.nl/resolve?urn=MMKB02:000119651:00009

Vol. 16, No. 6 (2021). DOI:10.18417/emisa.16.6


## Appendix B: Examples of Diagrams for each of Nordsieck's Categories

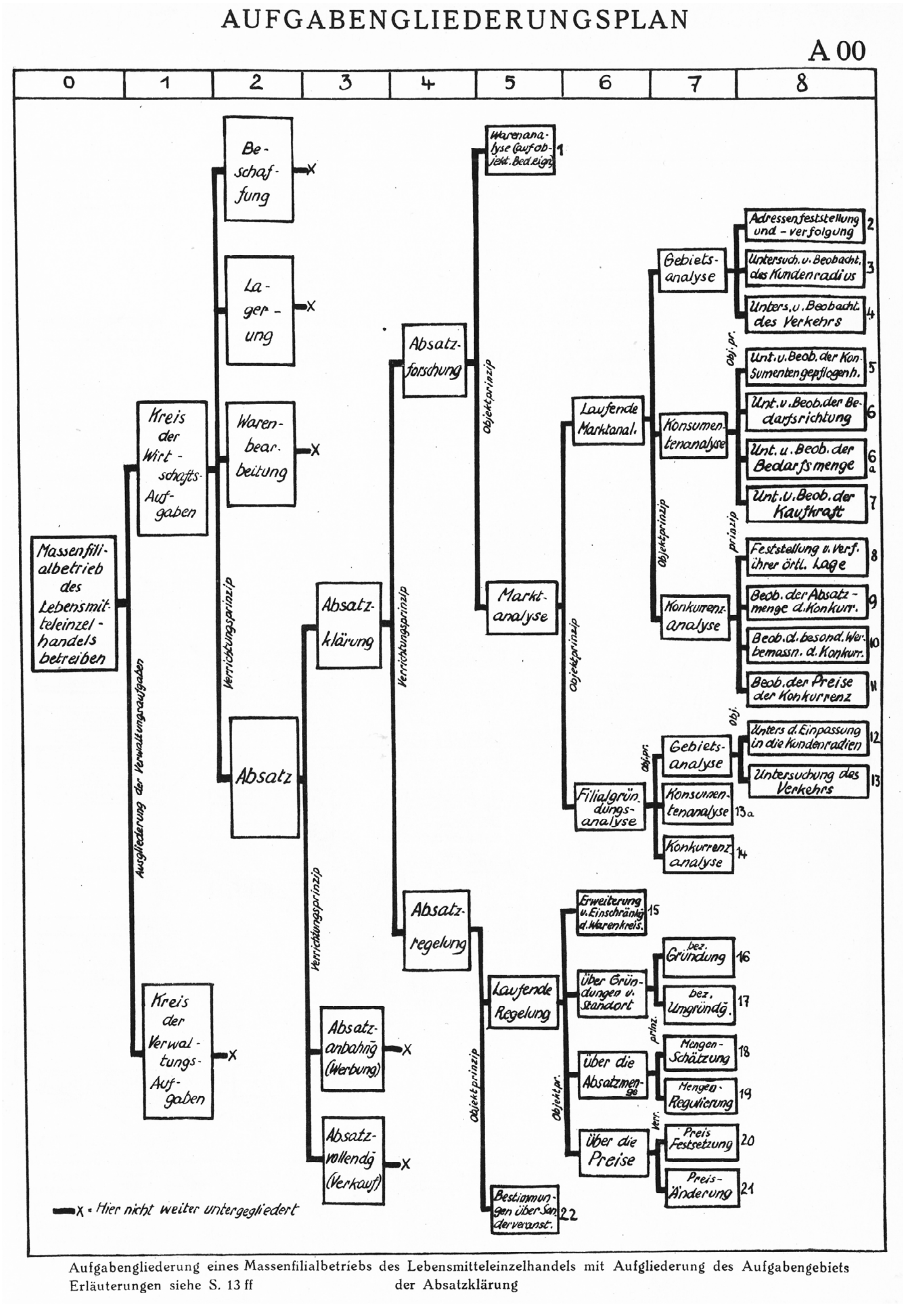
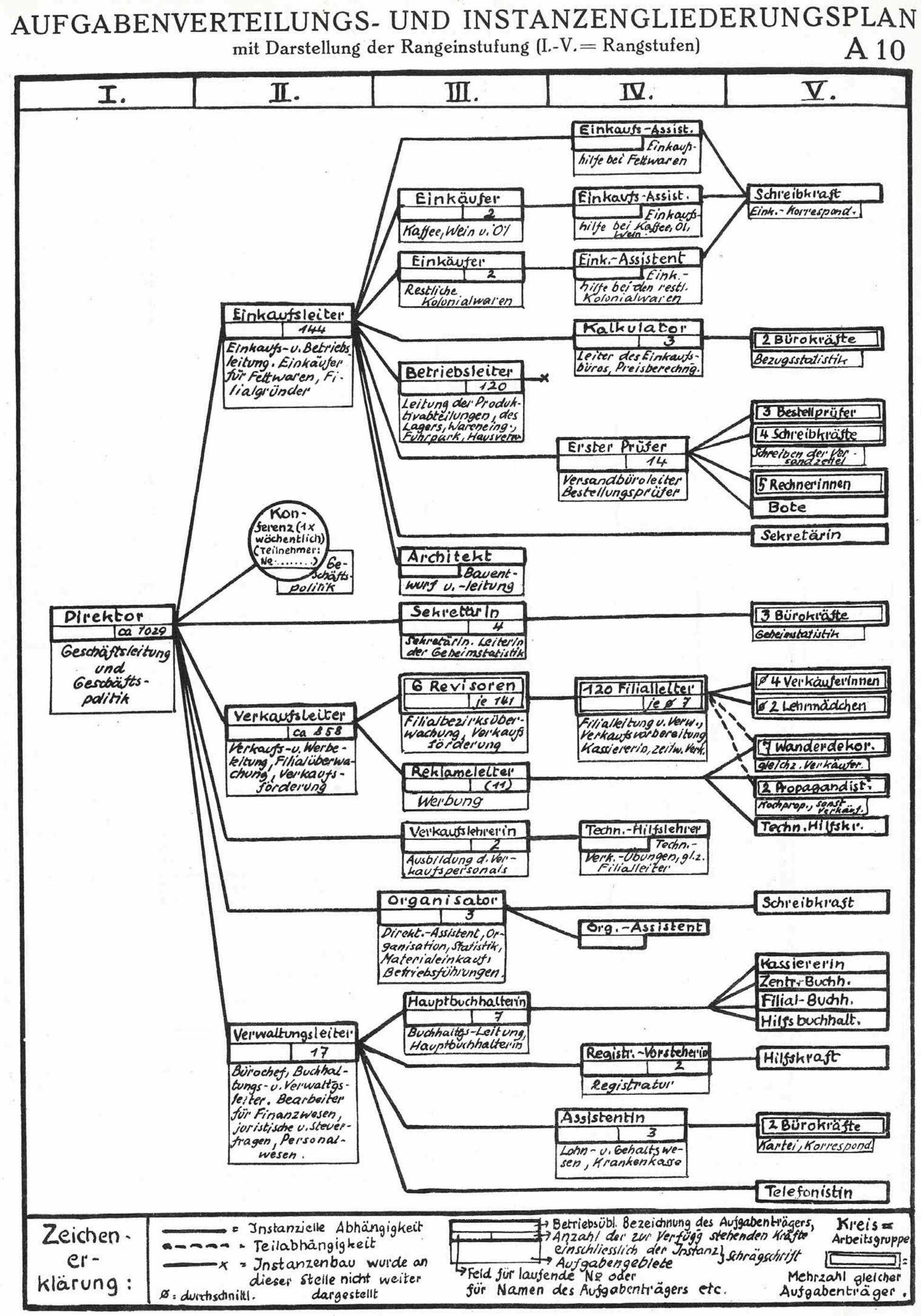


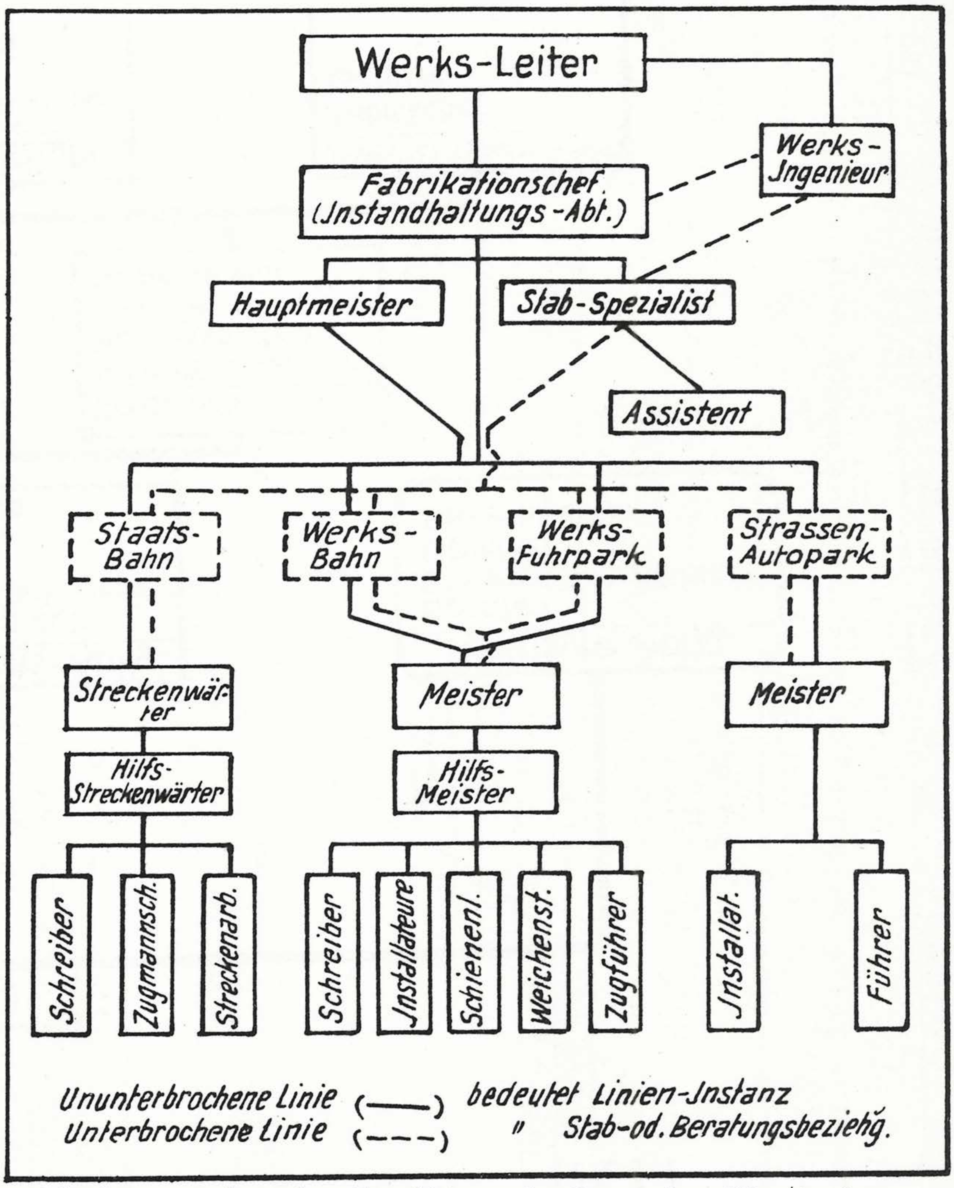

*Figure 3: Example A 00 belonging to the category A 0: Task structure (Nordsieck 1932, p. 79)*




Aufgabenverteilung und Instanzenbau eines Massenfilialbetriebs des Lebensmitteleinzelhandels (gekürzt)
Erläuterungen siehe S. 16ff.

*Figure 4: Example A 10 belonging to the category A 1: Task distribution (Nordsieck 1932, p. 80)*

A 24




Gliederungsplan der Speditionsabteilung der Westinghouse Electric & Mfg. Co.

Aus: Management's Handbook. New York 1924, S. 755. (Übersetzt)

Erläuterungen siehe S. 20

*Figure 5: Example A 24 belonging to the category A 2: Specific problems of instance composition (Nordsieck 1932, p. 82)*

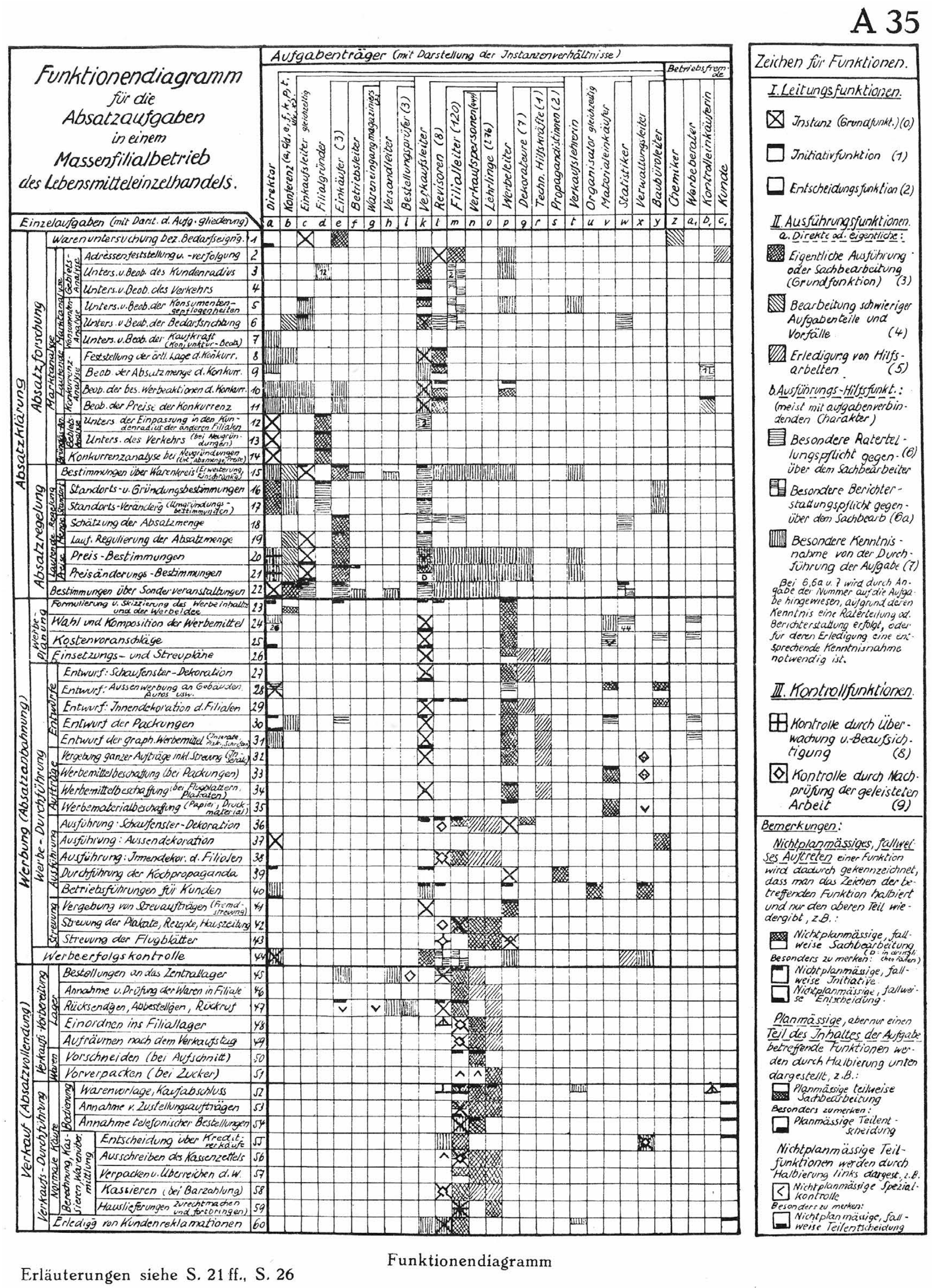



*Figure 6: Example A 35 belonging to the category A 3: Task distribution and task relationships (Nordsieck 1932, p. 89)*

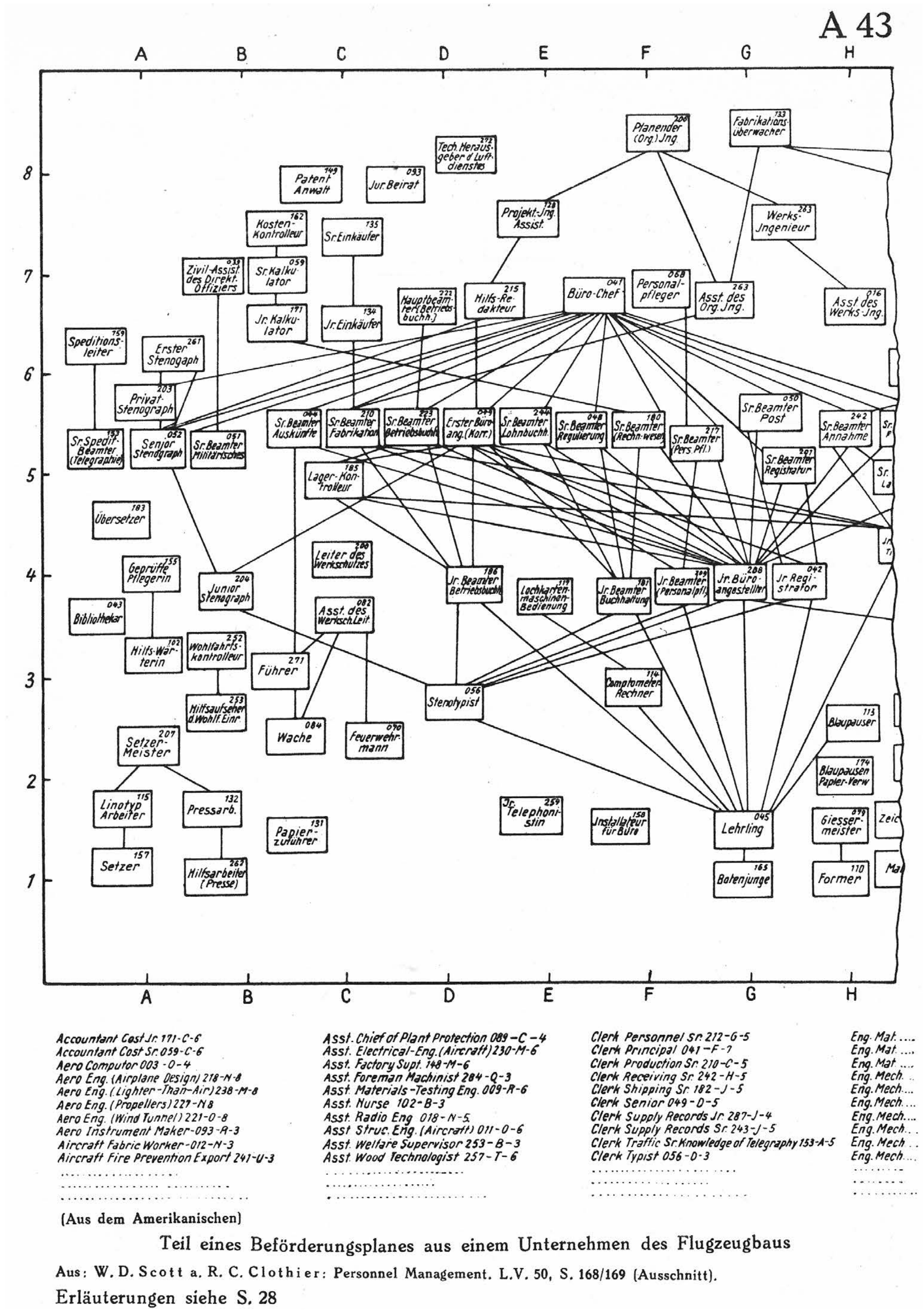
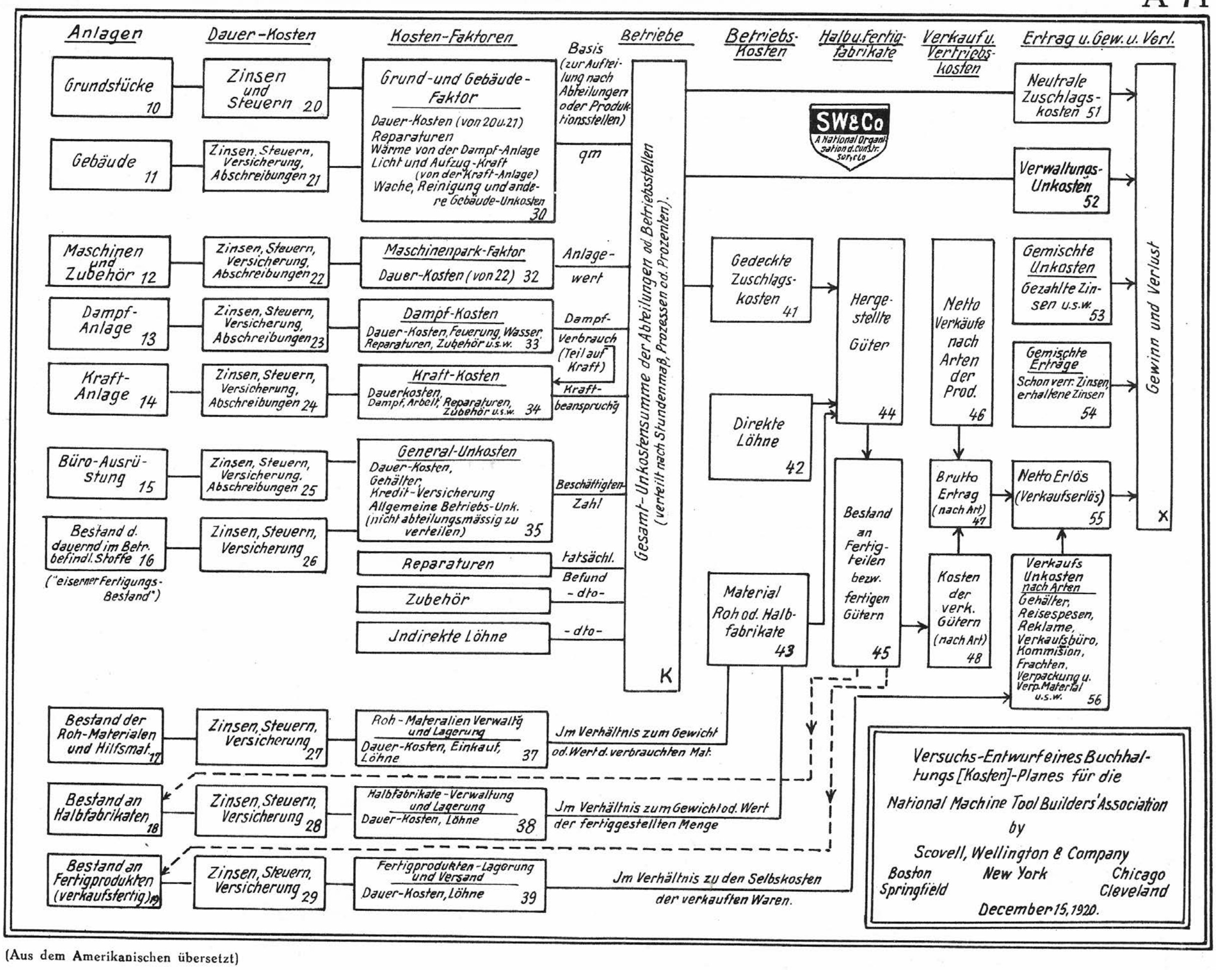



*Figure 7: Example A 43 belonging to the category A 4: Job creation, job description and job staffing (Nordsieck 1932, p. 91)*

A 71




(Aus dem Amerikanischen übersetzt)

Versuchs-Entwurf eines Buchhaltungs-Planes für die „National Machine Tool Builders' Association", von „Scovell, Wellington & Company", „a National Organization for Constructive Service". (Zeigt die amerikanische Art der Abteilungskalkulation nach der „Richtkosten"-Methode.)

Aus: Leon Caroll Marshall: L.V. 56, S. 485.

Erläuterungen siehe S. 30

*Figure 8: Example A 71 belonging to the category A 7: Composition of administrative tools (Nordsieck 1932, p. 93)*

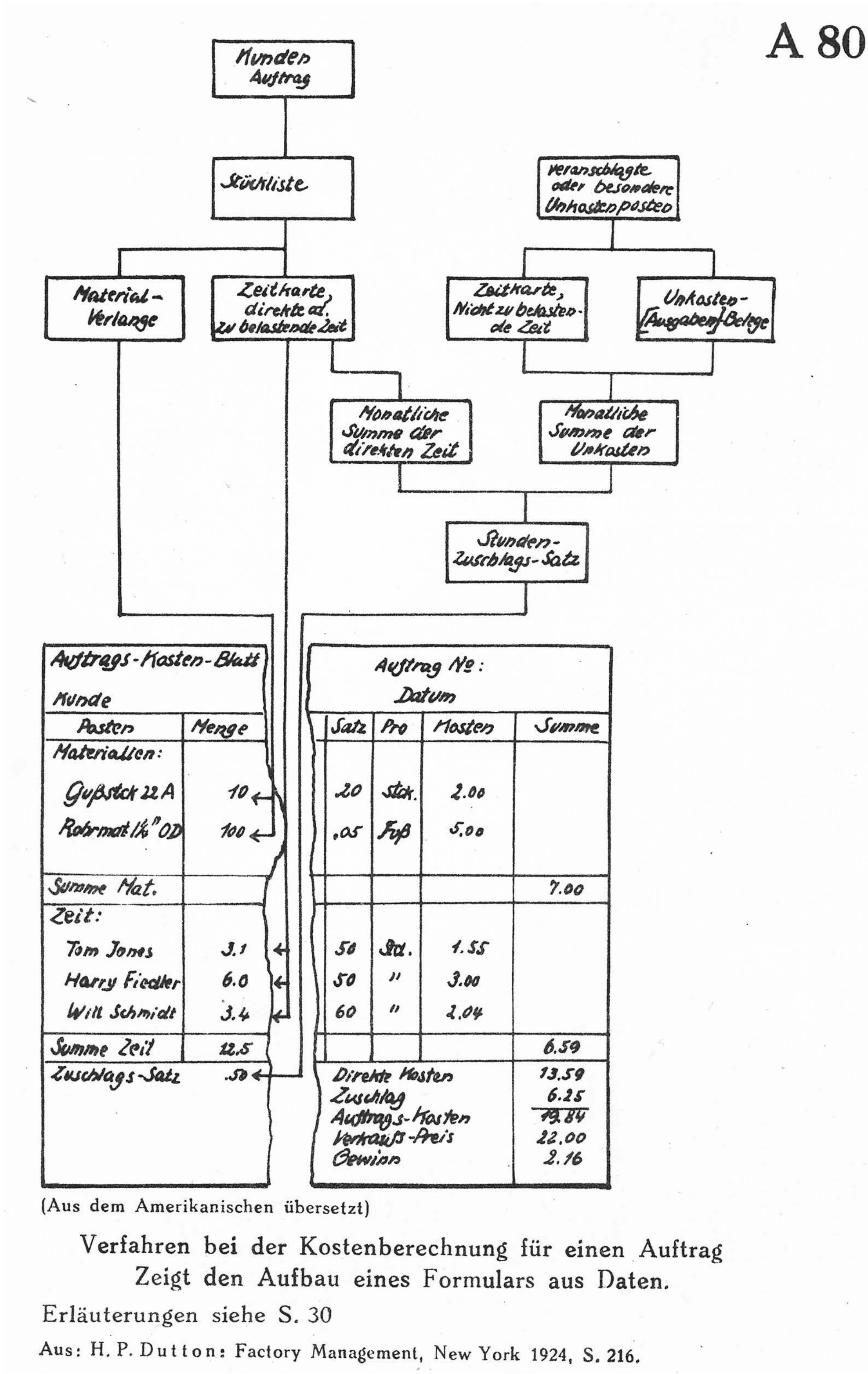



*Figure 9: Example A 80 belonging to the category A 8: Composition of larger work items (Nordsieck 1932, p. 92)*

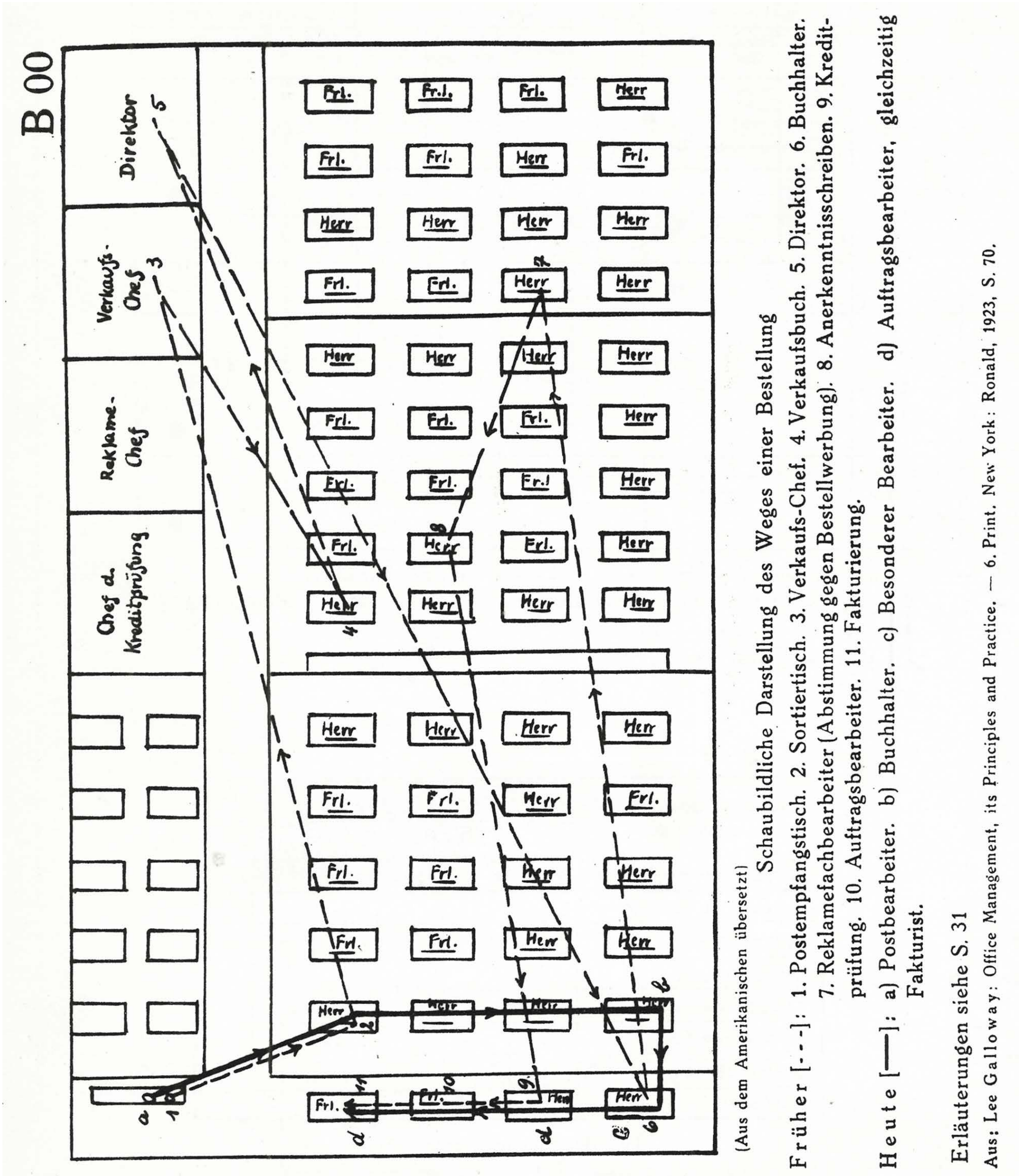



*Figure 10: Example B 00 belonging to the category B 0: Transport, flow, and traffic chart (Nordsieck 1932, p. 95)*

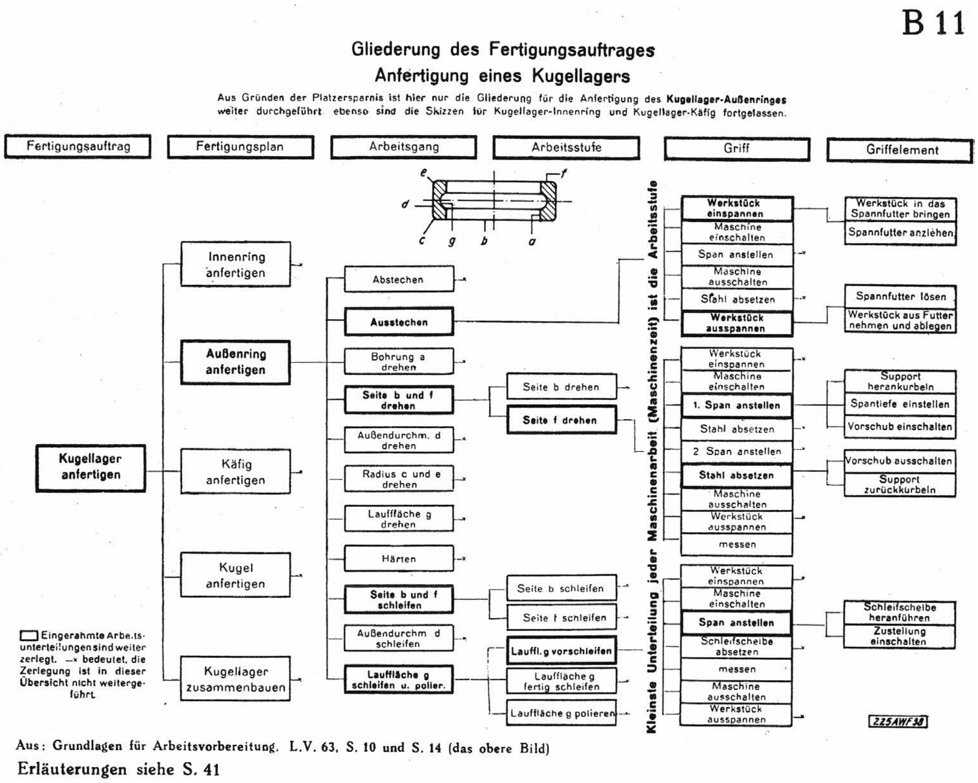



*Figure 11: Example B 11 belonging to the category B 1: Work structure and work distribution (Nordsieck 1932, p. 98)*

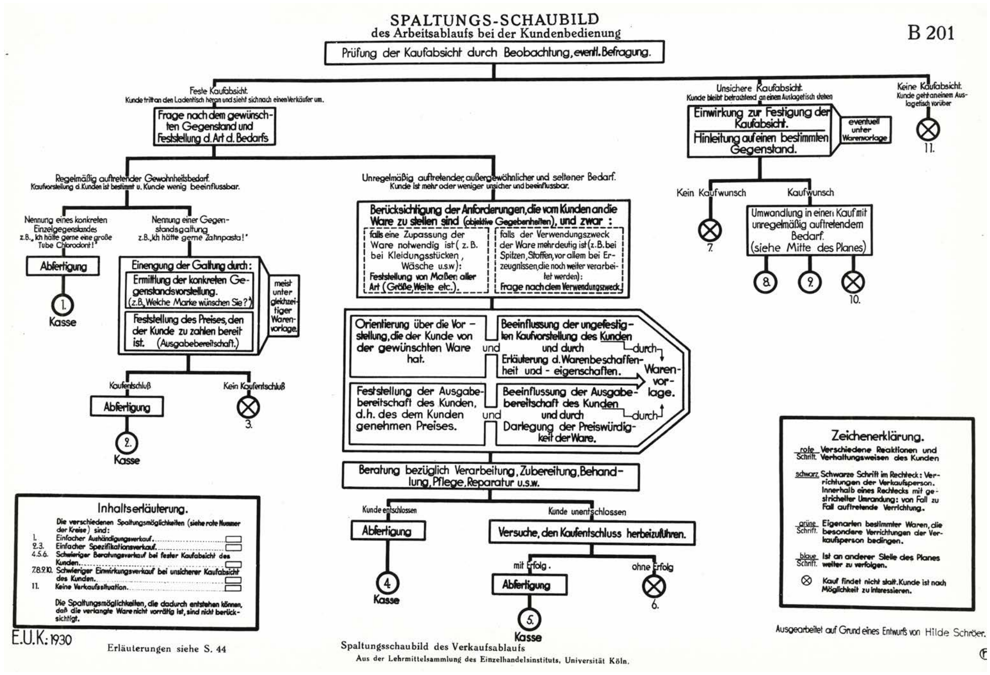



*Figure 12: Example B 201 belonging to the category B 2: Workflow and work cycle (Nordsieck 1932, p. 103)*

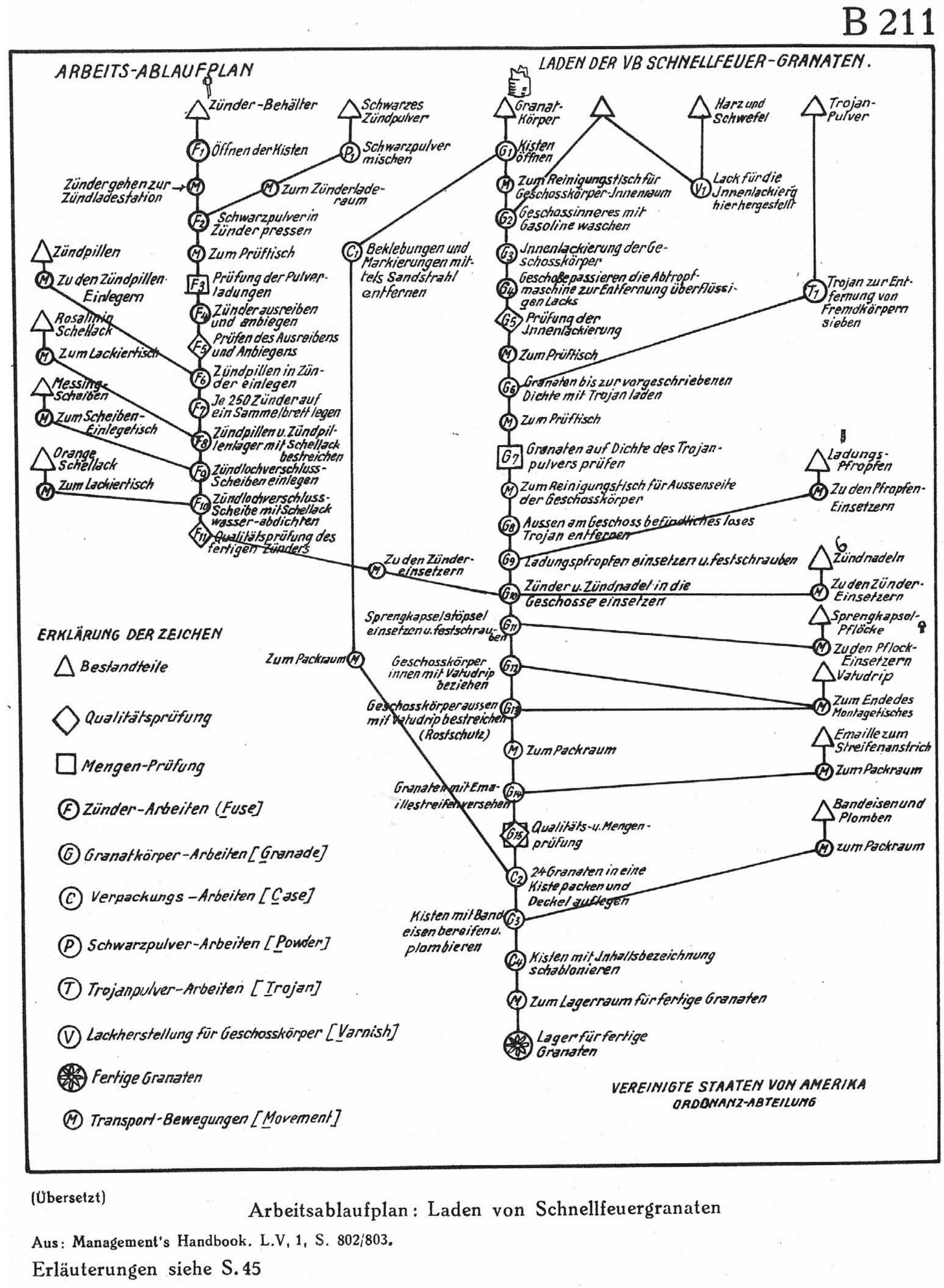



*Figure 13: Example B 211 belonging to the category B 2: Workflow and work cycle (Nordsieck 1932, p. 105)*

Vol. 16, No. 6 (2021). DOI:10.18417/emisa.16.6

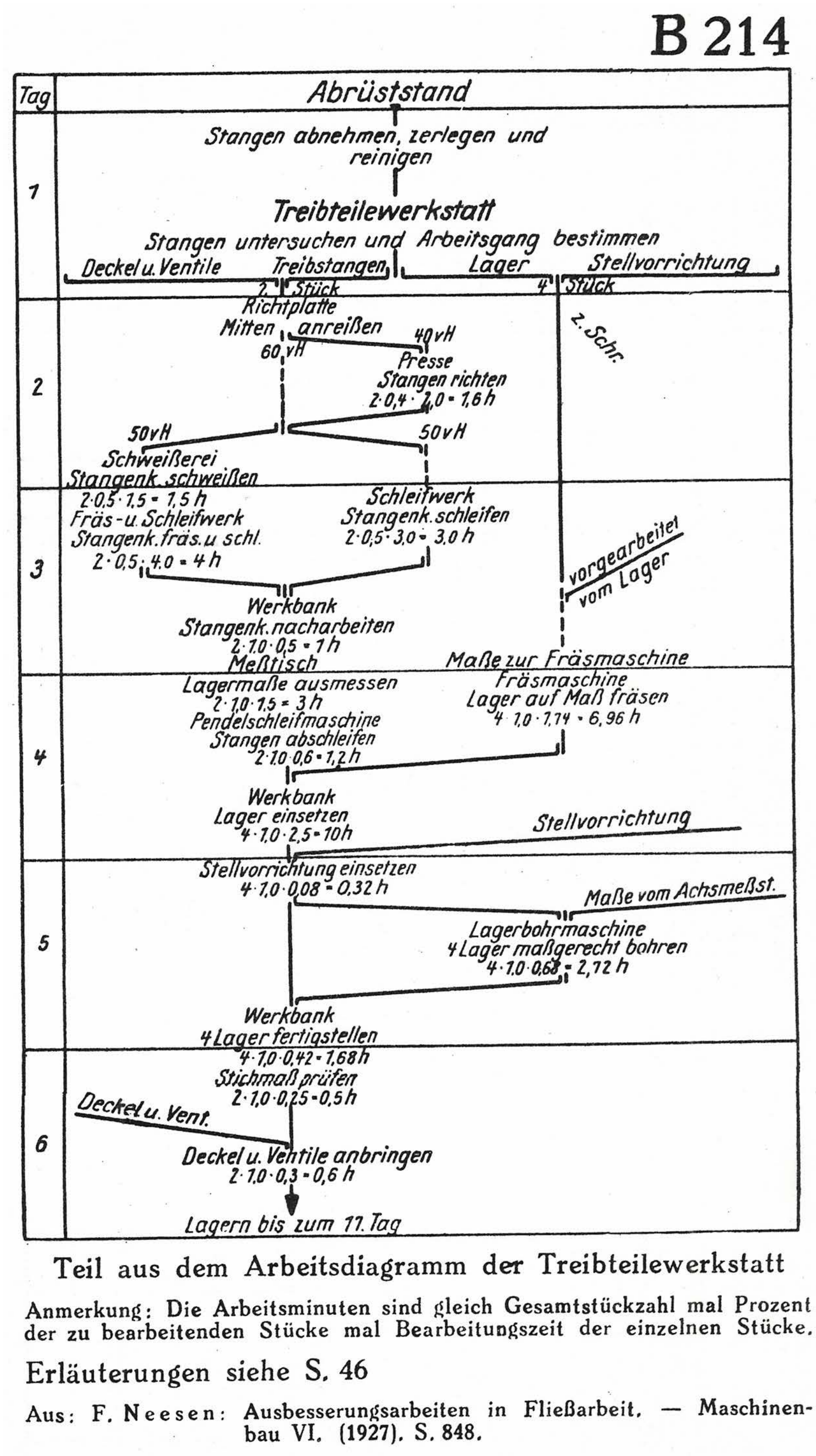
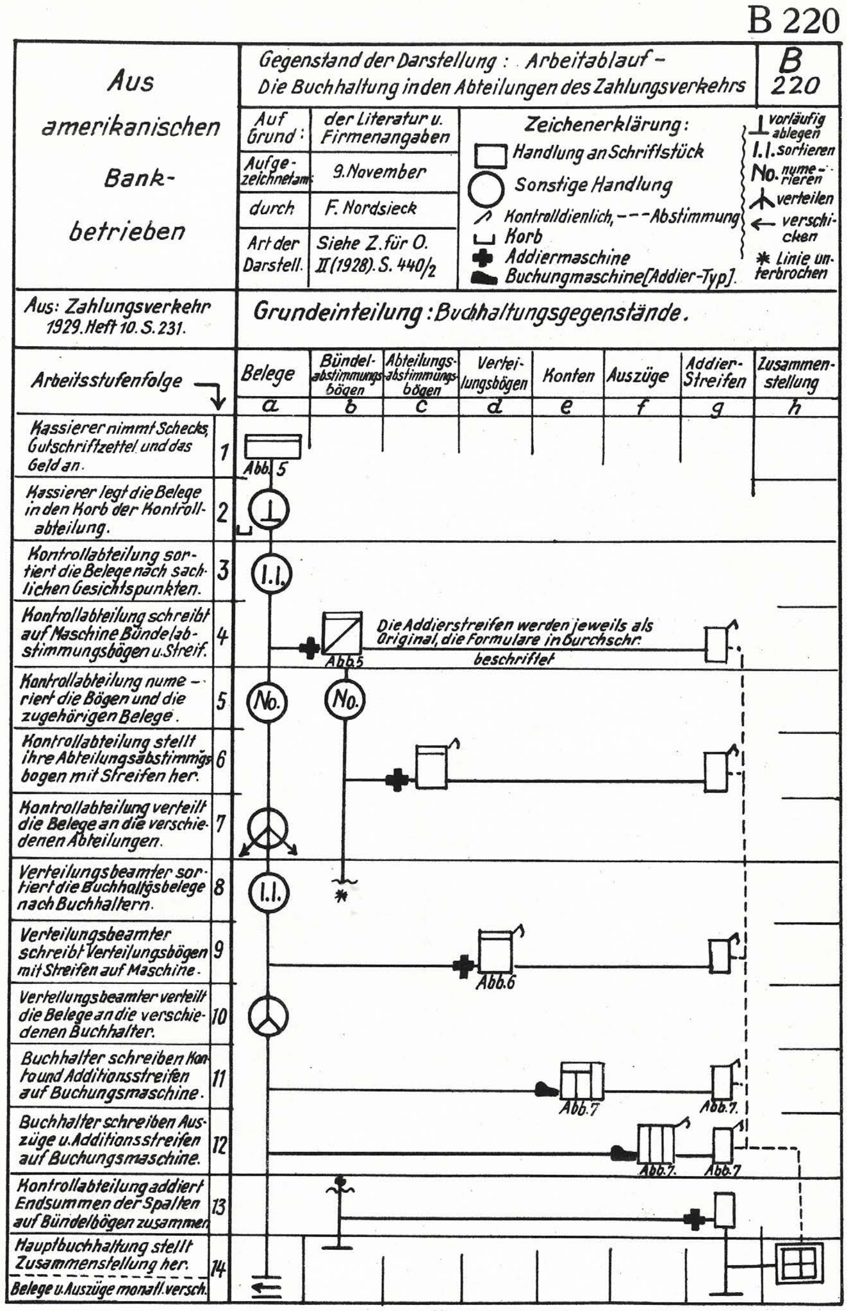




*Figure 14: Example B 2141 belonging to the category B 2: Workflow and work cycle (Nordsieck 1932, p. 117)*




Die Darstellung soll den gegenständlichen Aufbau der Buchhaltung zeigen.
Die Linienführung bedeutet:
a) Horizontale Verbindungslinien zwischen den Symbolen = Gegenständlicher Aufbau (lose Reihung);
b) Vertikale Verbindungslinien = Bearbeitungsfolge an den einzelnen Gegenständen;
c) Durchgezogene horizontale Netzstriche = Trennung der Arbeitszyklen.
Ablauftyp: Stufenweise Trennung (mit loser Reihung).
(Die mit dem Zusatz „Abb. 5, 6, 7“ versehenen Schriftstücke sind in dem betreffenden Aufsatz im Original wiedergegeben.)
Erläuterungen siehe S. 46
Aus: F. Nordsieck: Die Gestaltung der innerbetriebl. Organisation der amerikan. Banken usw. L.V. 69, S. 231.

*Figure 15: Example B 220 belonging to the category B 2: Workflow and work cycle (Nordsieck 1932, p. 107)*

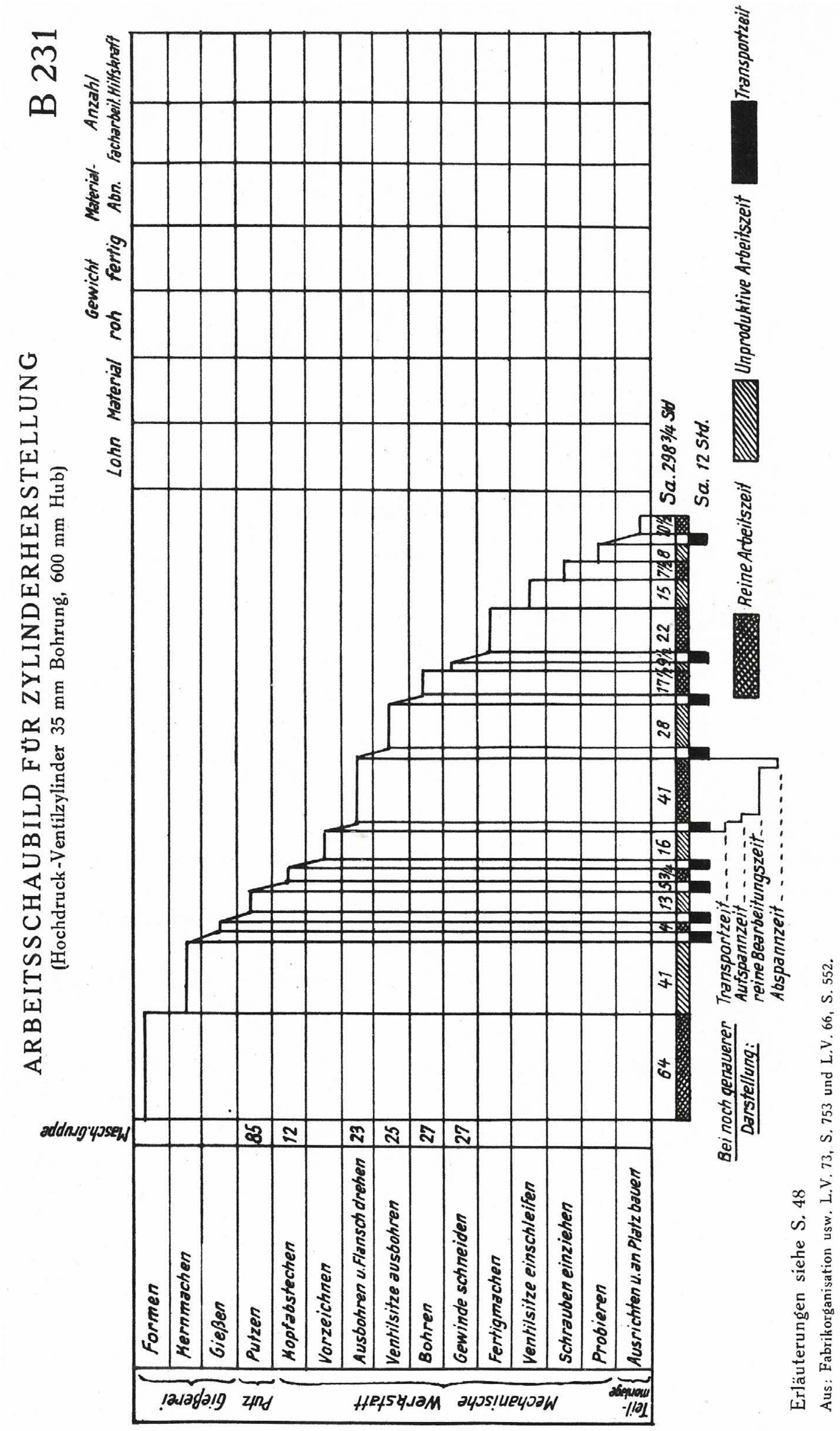



*Figure 16: Example B 231 belonging to the category B 2: Workflow and work cycle (Nordsieck 1932, p. 111)*

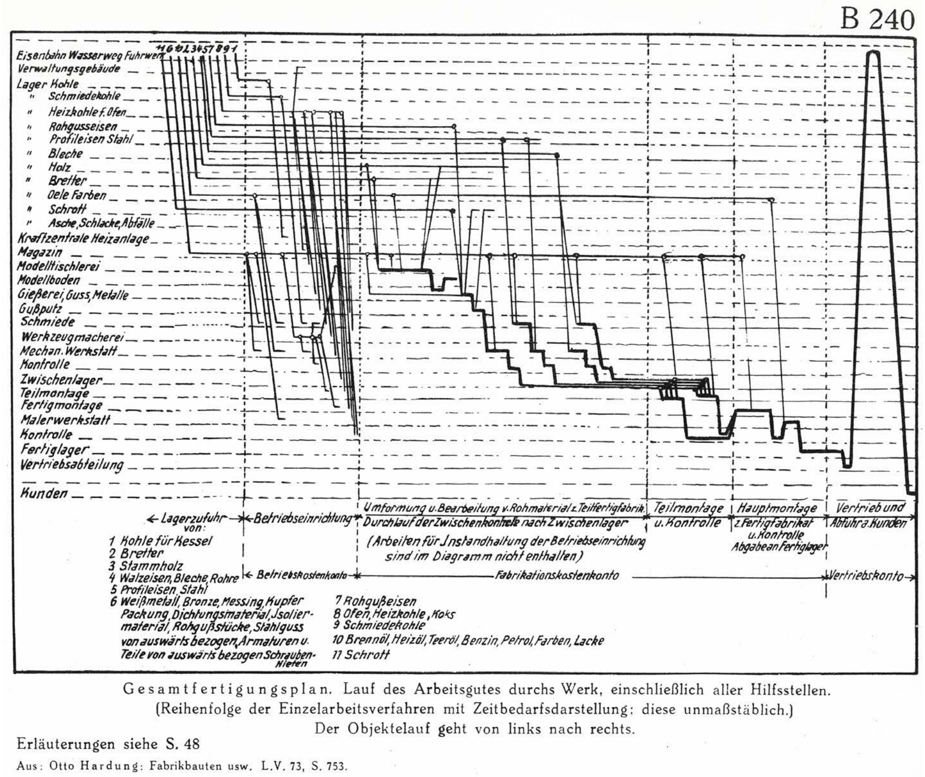



*Figure 17: Example B 240 belonging to the category B 2: Workflow and work cycle (Nordsieck 1932, p. 112)*

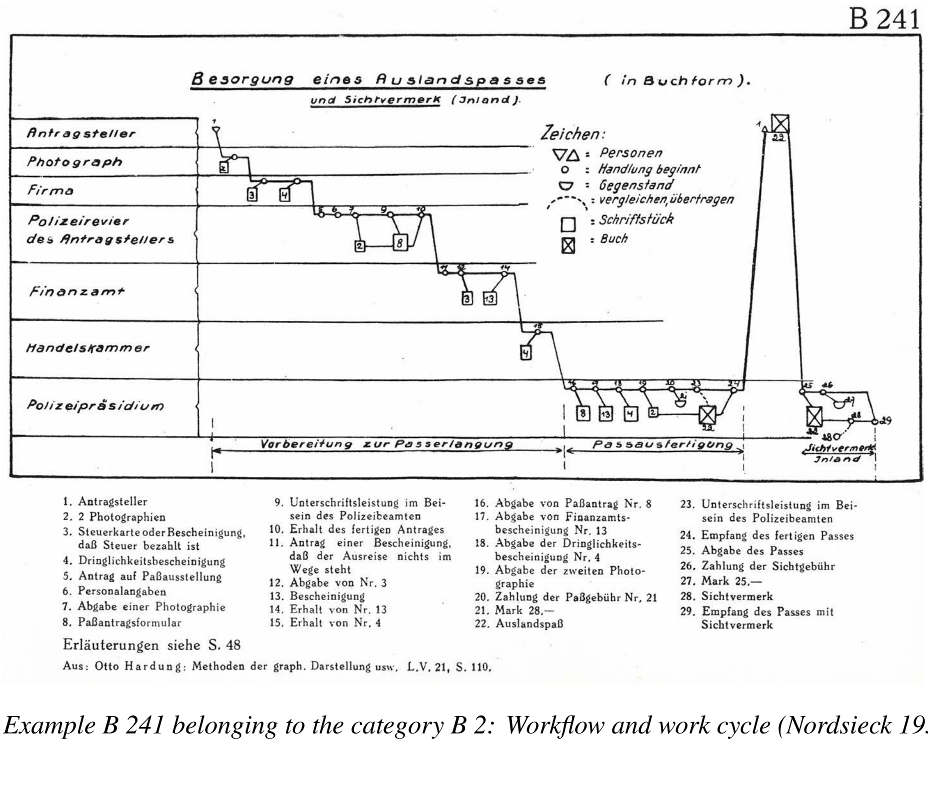



*Figure 18: Example B 241 belonging to the category B 2: Workflow and work cycle (Nordsieck 1932, p. 112)*

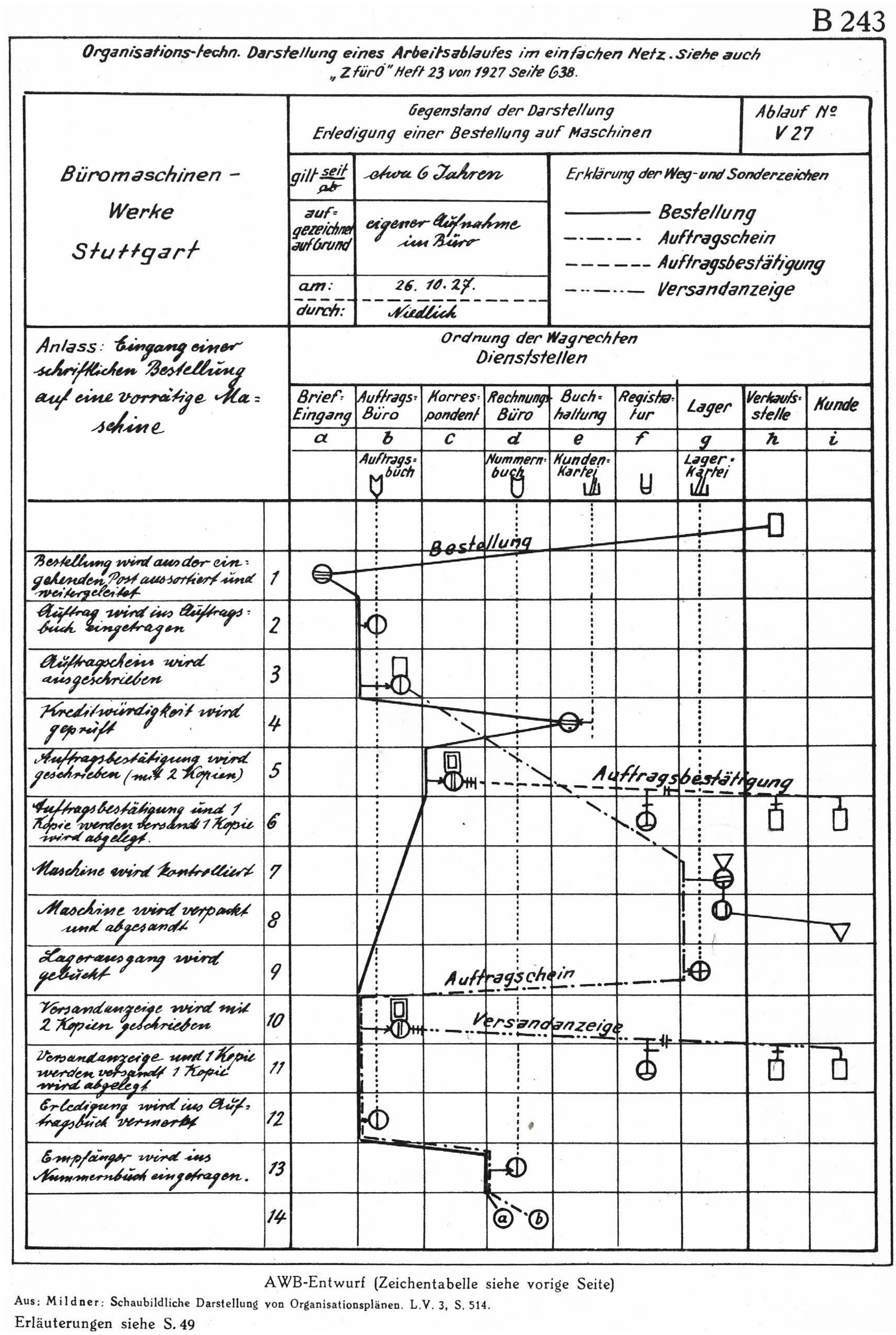



*Figure 19: Example B 243 belonging to the category B 2: Workflow and work cycle (Nordsieck 1932, p. 115)*

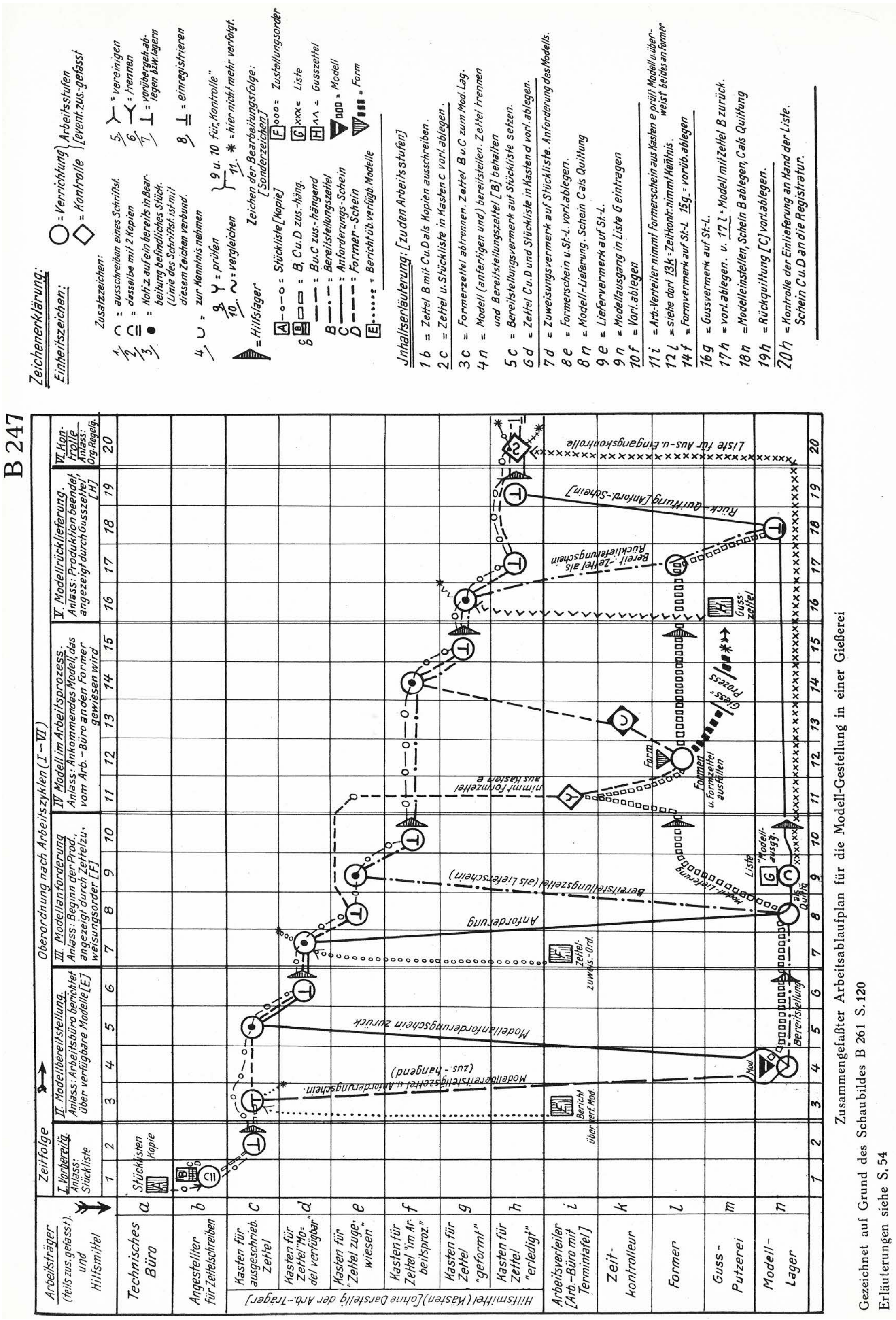



*Figure 20: Example B 247 belonging to the category B 2: Workflow and work cycle (Nordsieck 1932, p. 121)*

International Journal of Conceptual Modeling
Vol. 16, No. 6 (2021). DOI:10.18417/emisa.16.6

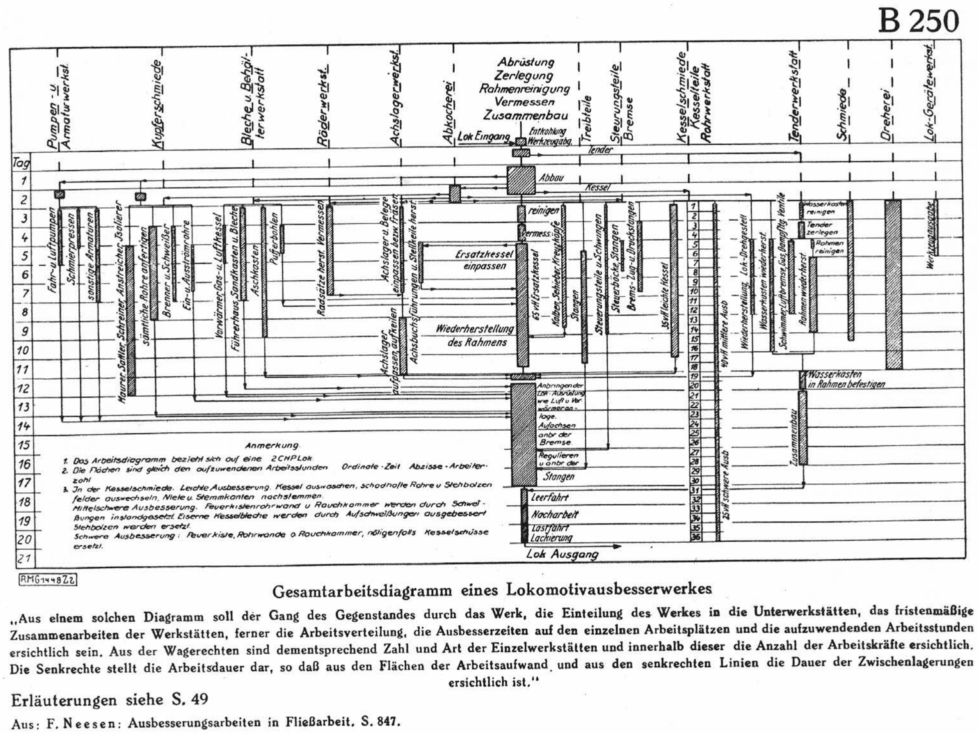




*Figure 21: Example B 250 belonging to the category B 2: Workflow and work cycle (Nordsieck 1932, p. 117)*

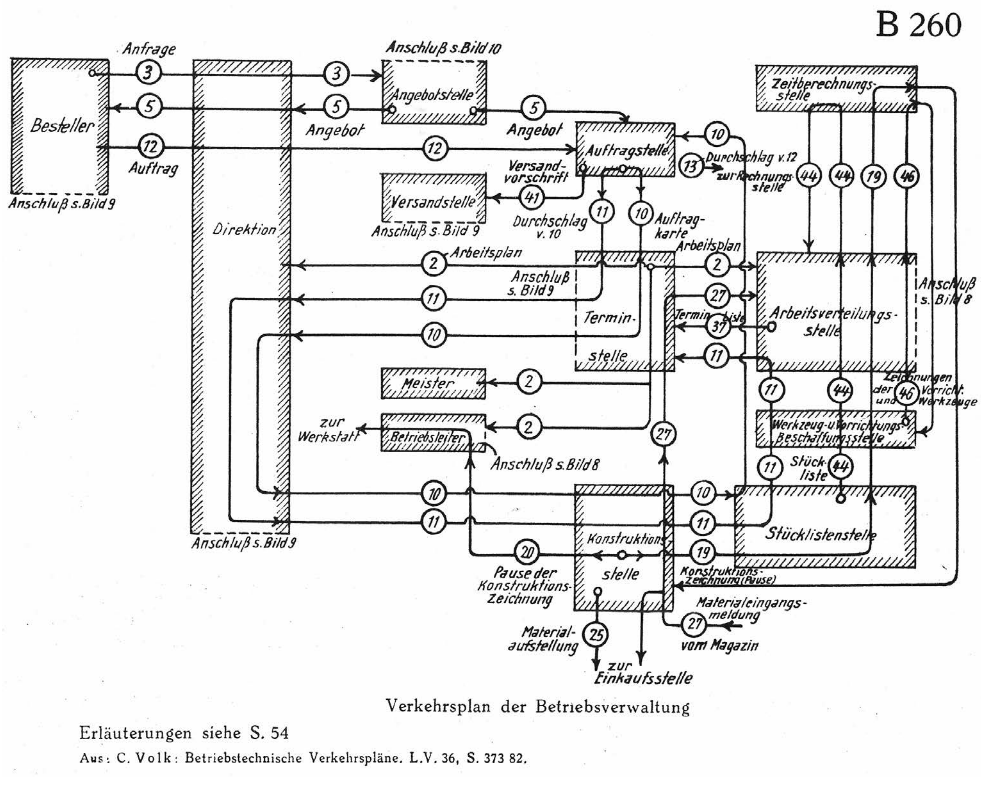



*Figure 22: Example B 260 belonging to the category B 2: Workflow and work cycle (Nordsieck 1932, p. 119)*

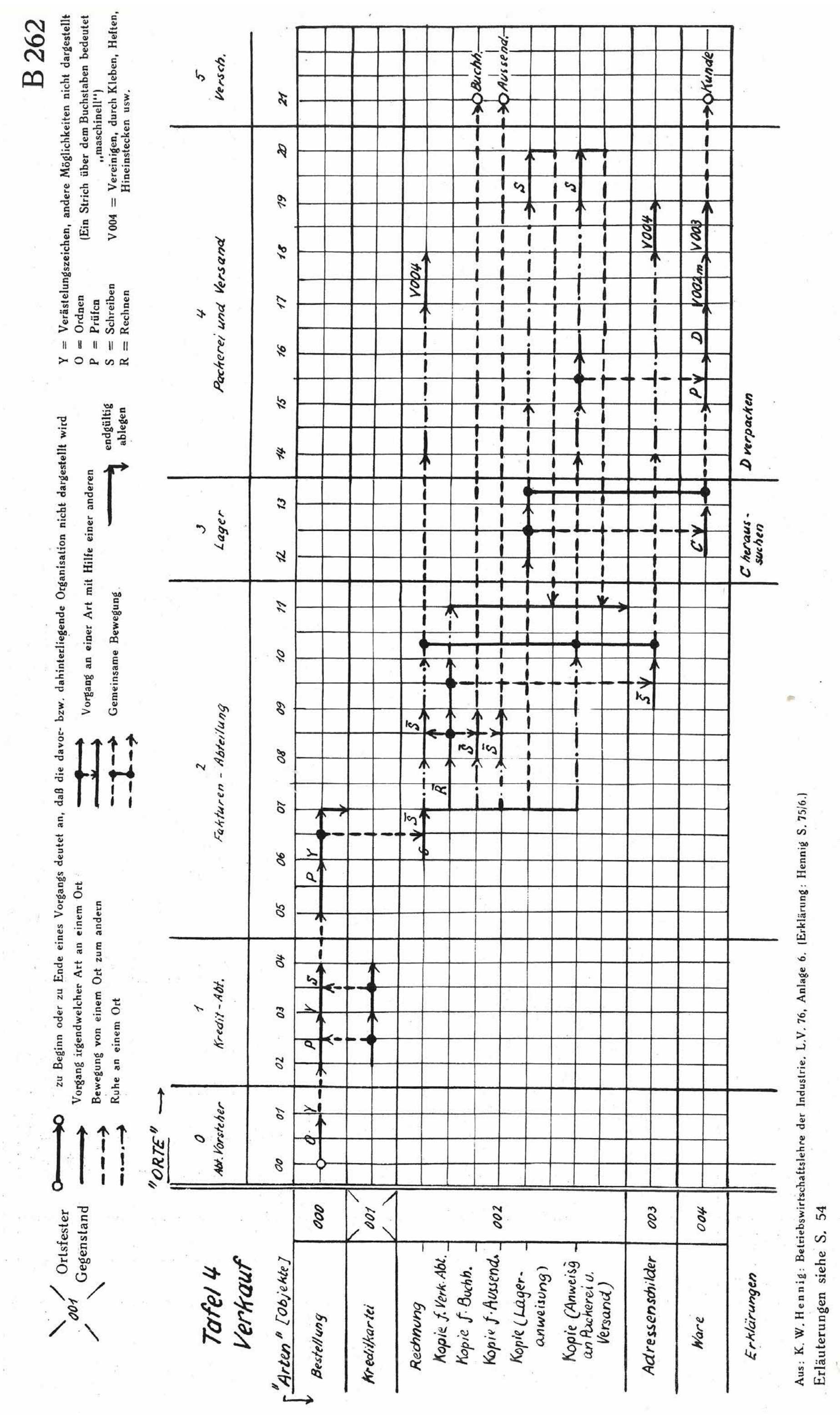



*Figure 23: Example B 262 belonging to the category B 2: Workflow and work cycle (Nordsieck 1932, p. 122)*

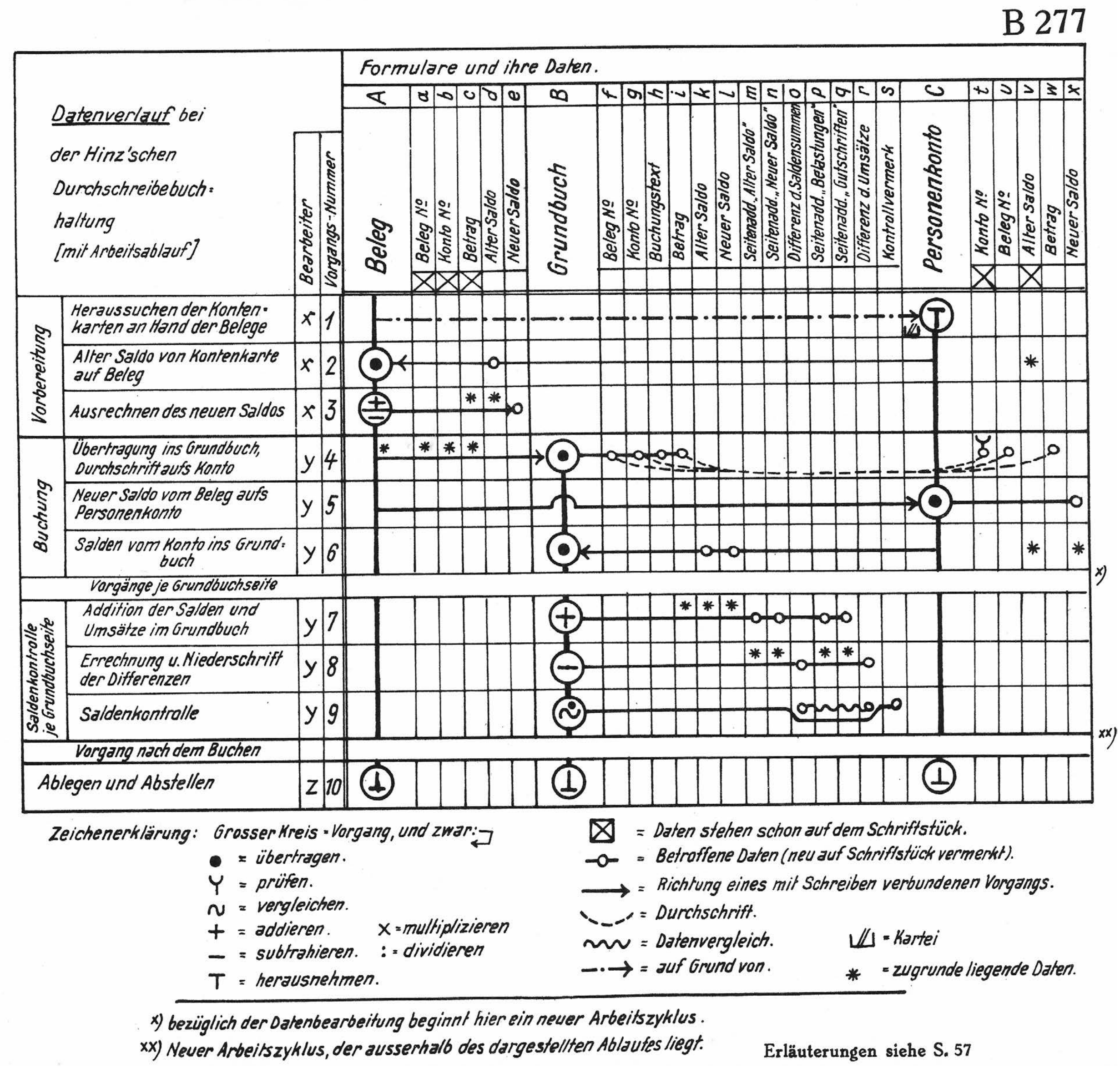



*Figure 24: Example B 277 belonging to the category B 2: Workflow and work cycle (Nordsieck 1932, p. 127)*

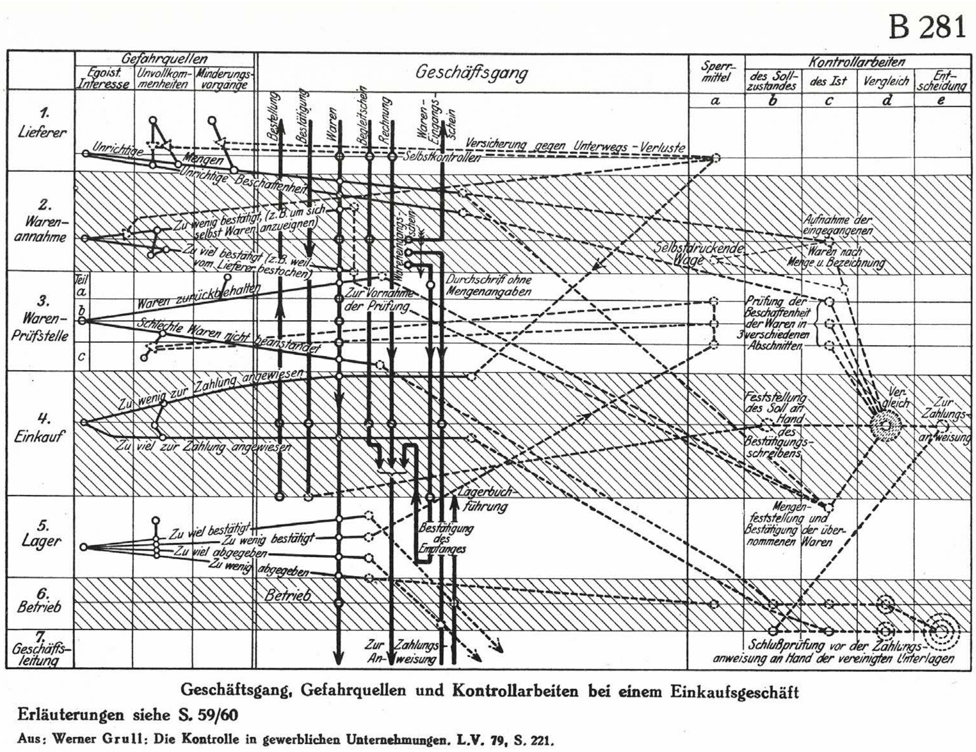



*Figure 25: Example B 281 belonging to the category B 2: Workflow and work cycle (Nordsieck 1932, p. 129)*

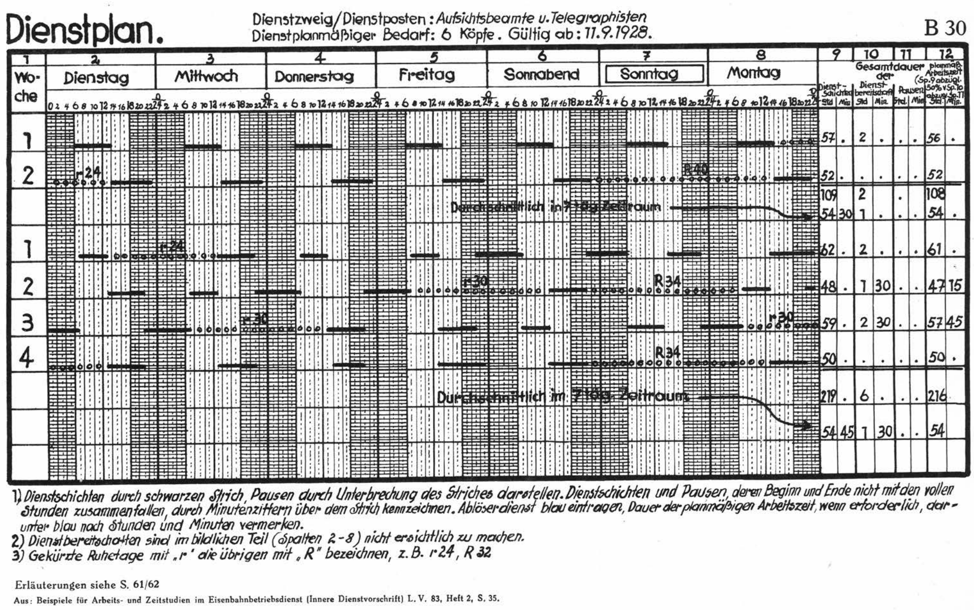



*Figure 26: Example B 30 belonging to the category B 3: Staffing schedule (Nordsieck 1932, p. 131)*

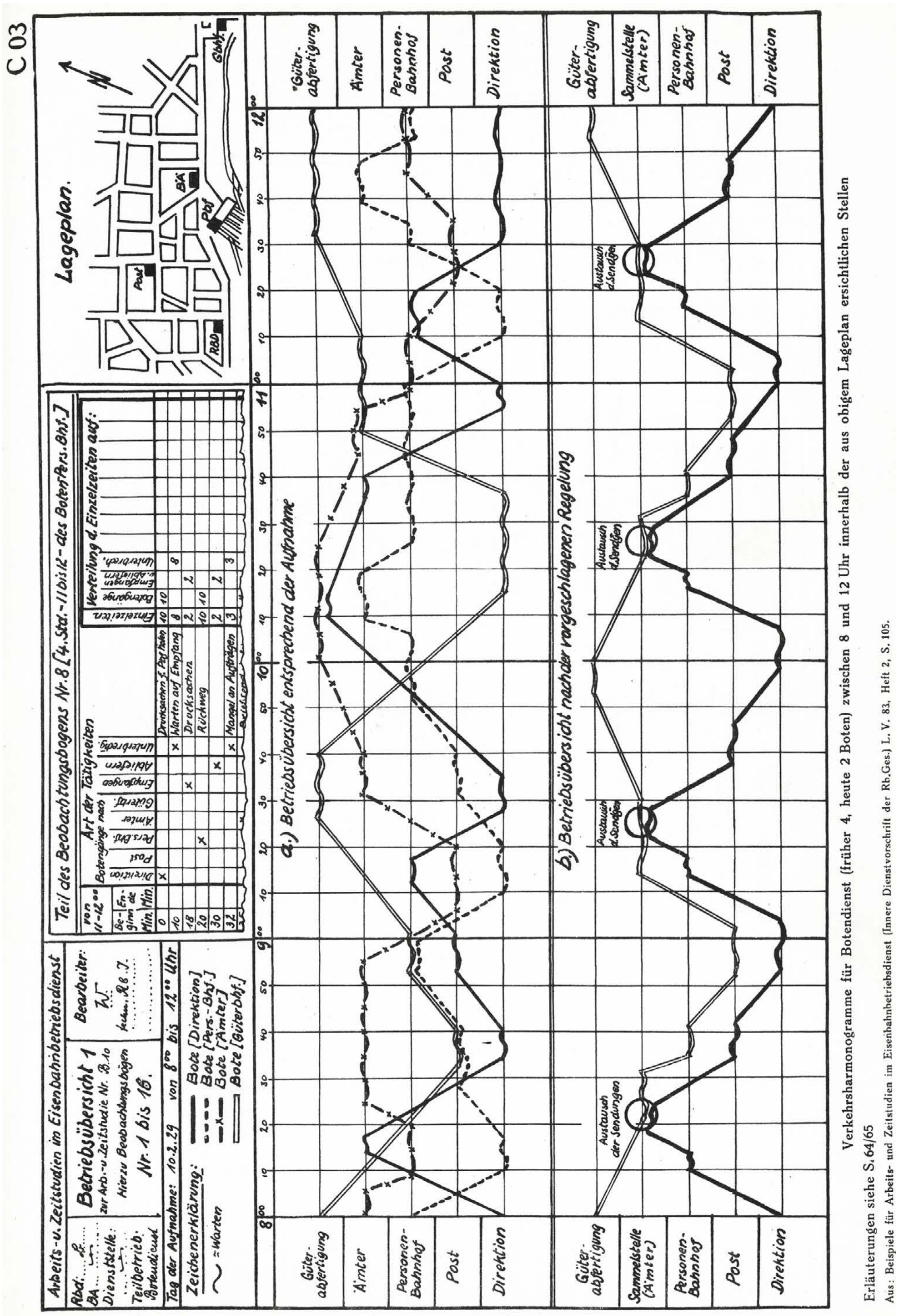



*Figure 27: Example C 03 belonging to the category C 0: Traffic timelines (Nordsieck 1932, p. 135)*

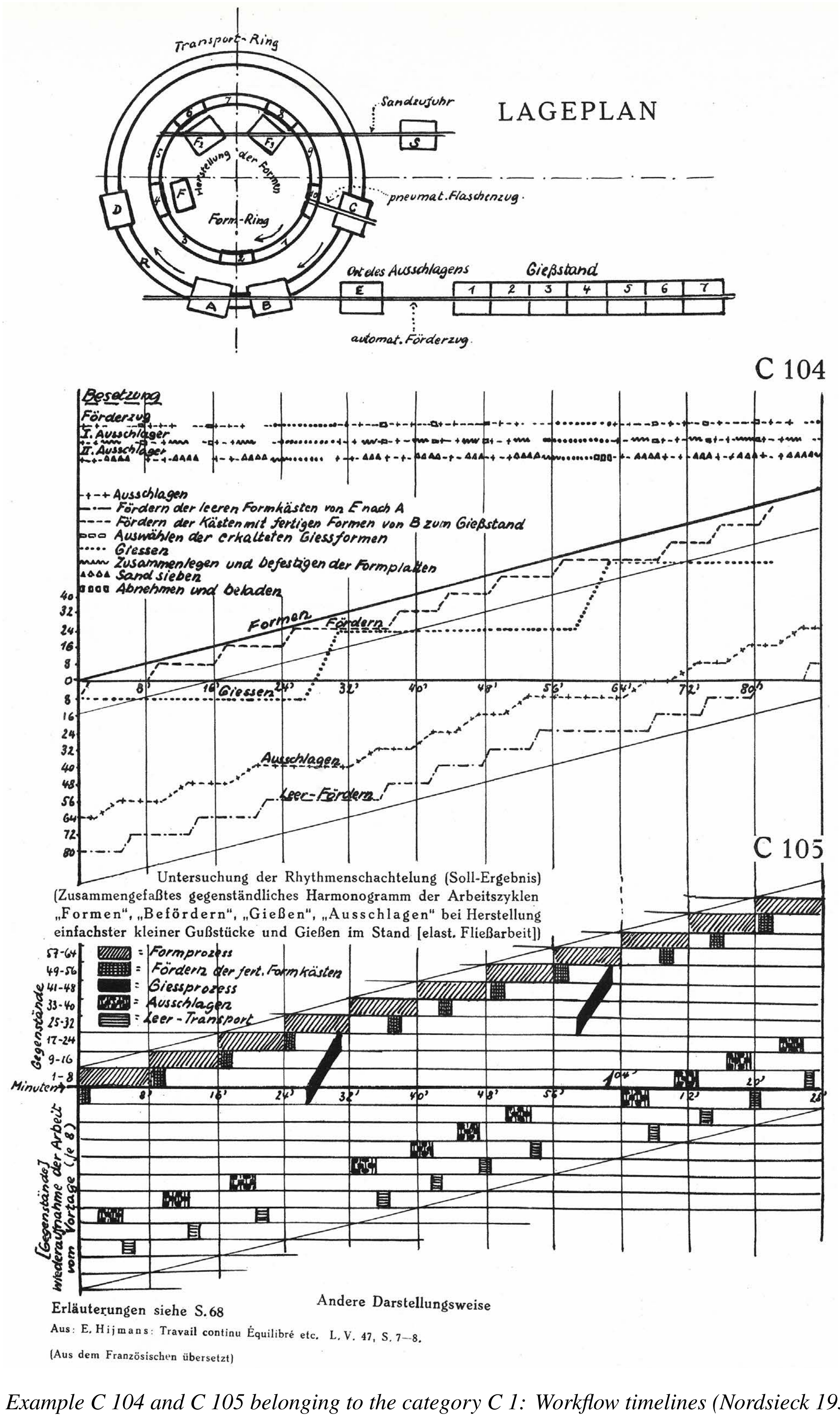



*Figure 28: Example C 104 and C 105 belonging to the category C 1: Workflow timelines (Nordsieck 1932, p. 140)*

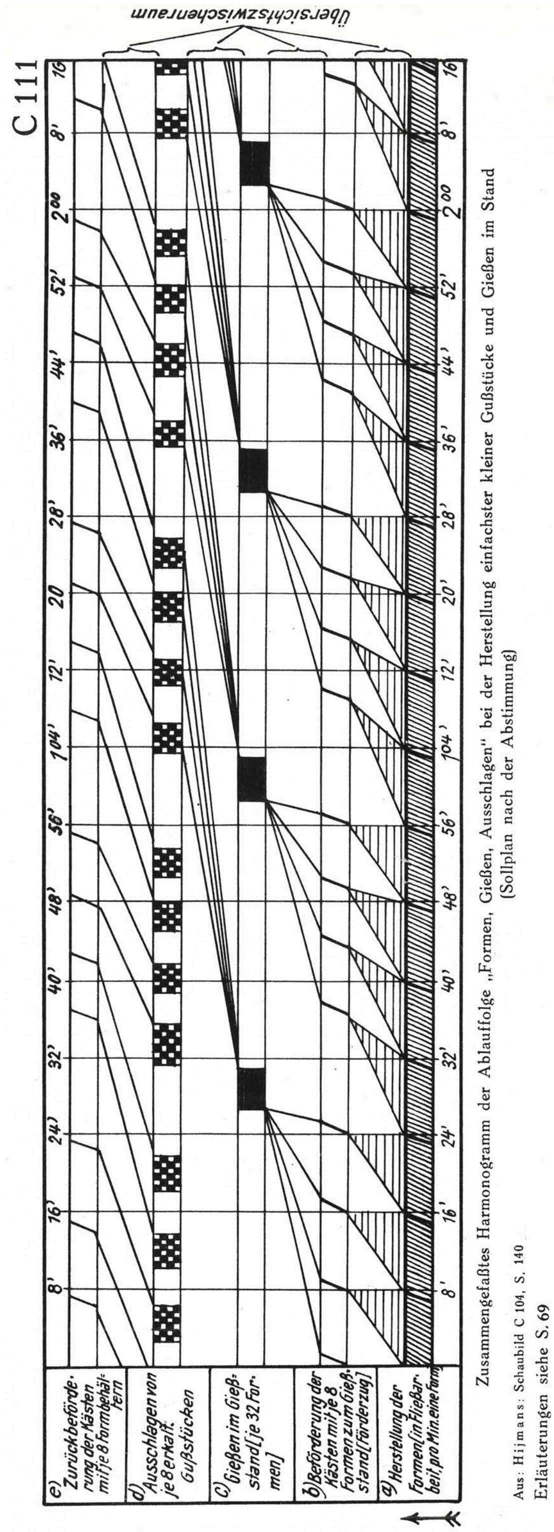



*Figure 29: Example C 111 belonging to the category C 1: Workflow timelines (Nordsieck 1932, p. 142)*

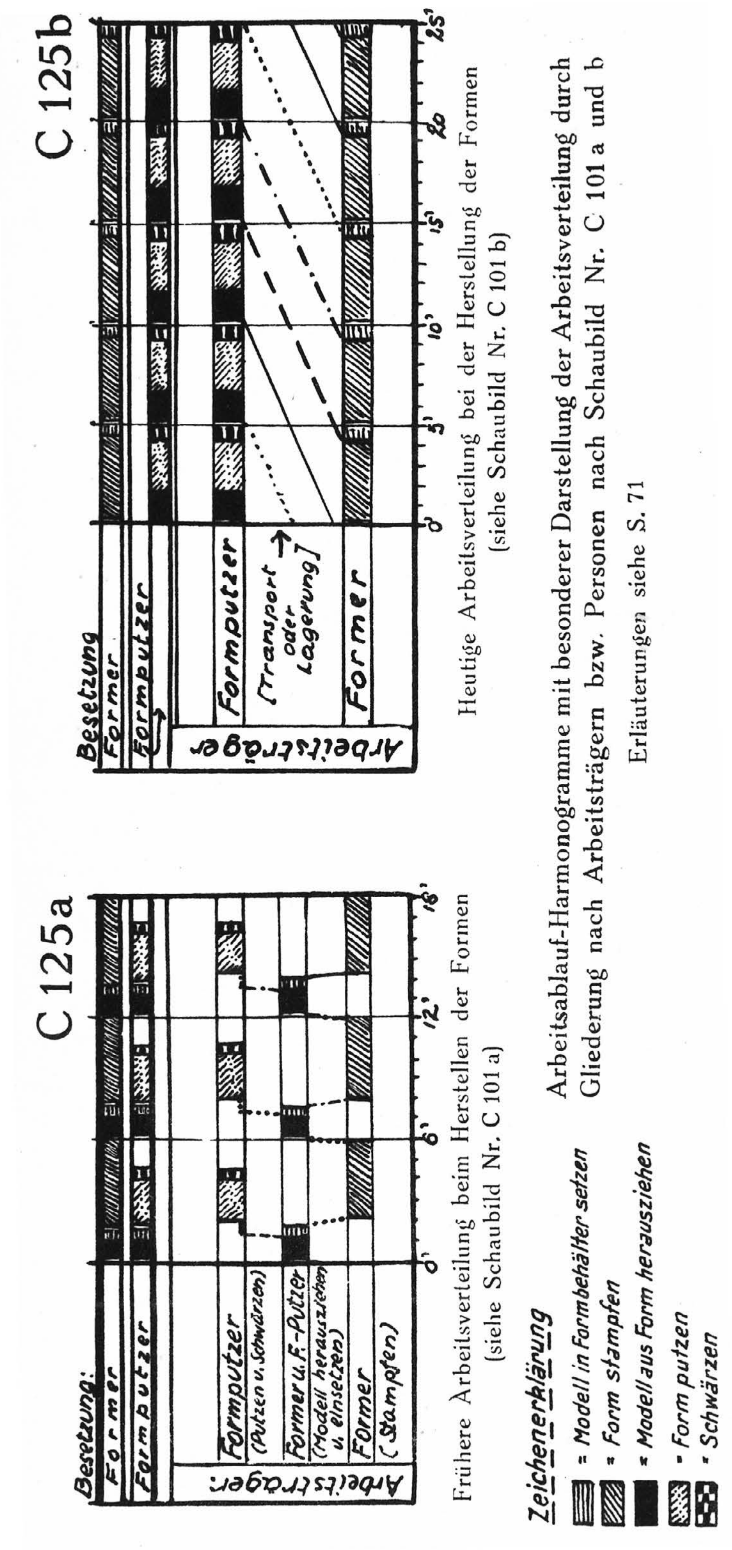



*Figure 30: Example C 125 belonging to the category C 1: Workflow timelines (Nordsieck 1932, p. 144)*

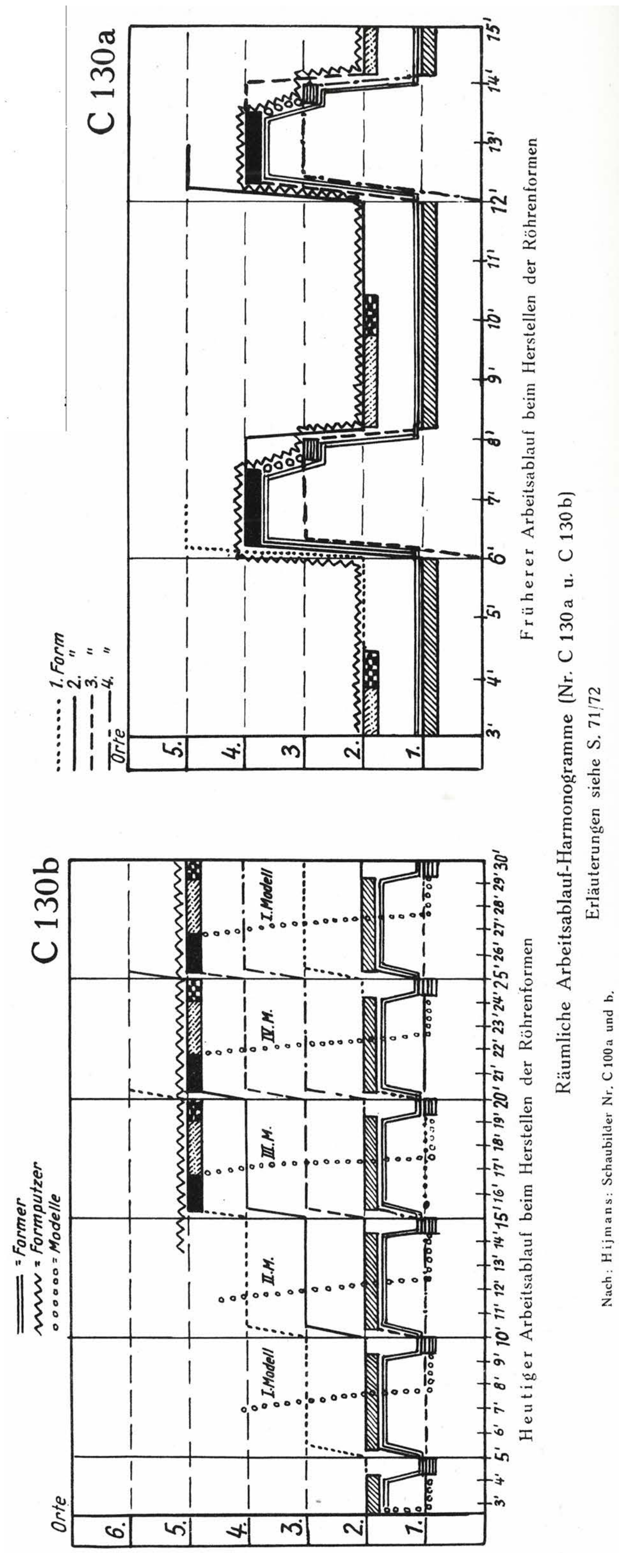



*Figure 31: Example C 130 belonging to the category C 1: Workflow timelines (Nordsieck 1932, p. 144)*

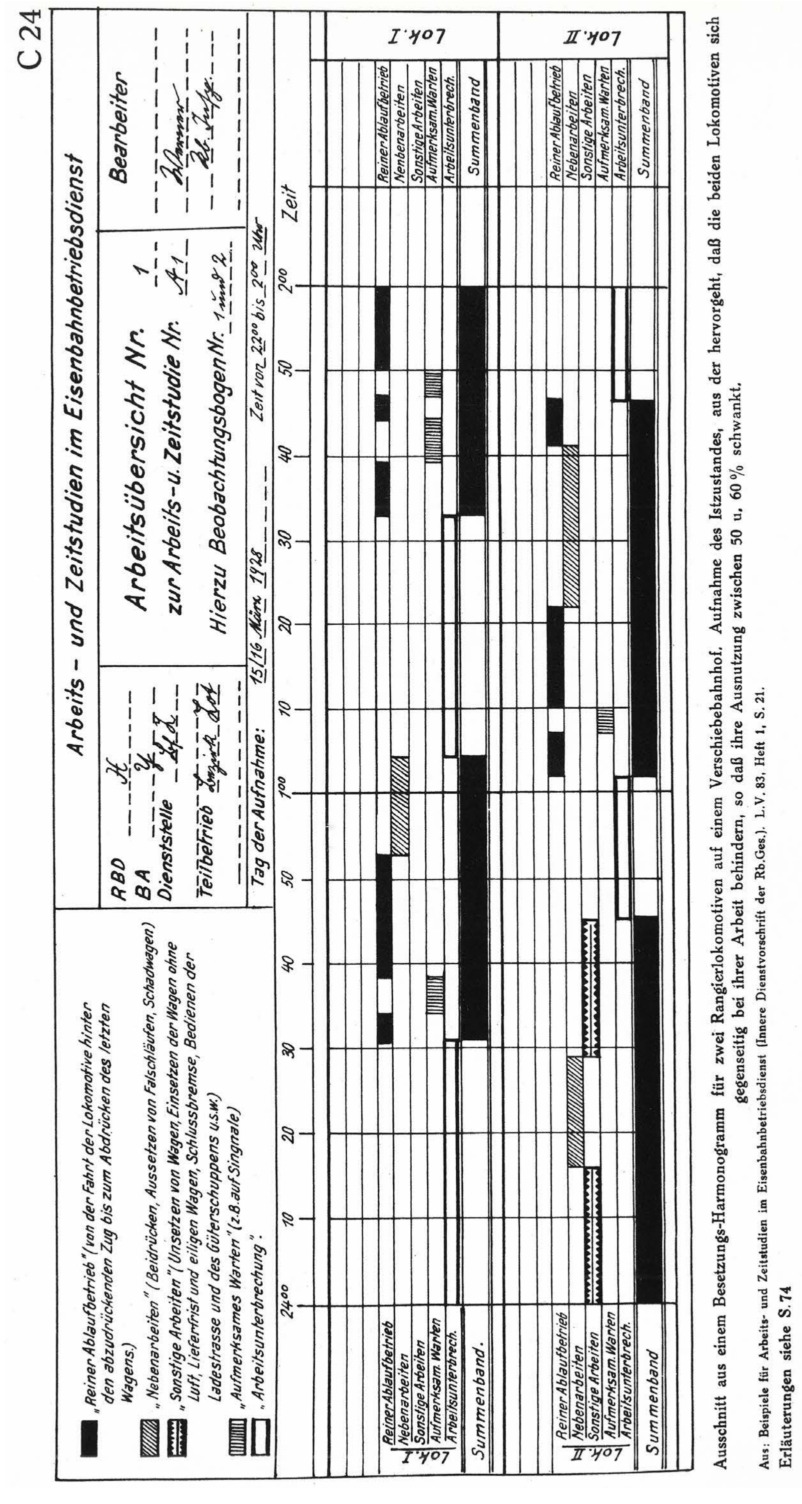



*Figure 32: Example C 24 belonging to the category C 2: Staffing timelines (Nordsieck 1932, p. 149)*