DOCUMENT RESUME

ED 123 783 EA 008 340

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TITLE Operations Technology and Organizational Structure.
SPONS AGENCY National Science Foundation, Washington, D.C. RANN Program.
PUB DATE [Apr 76]
CONTRACT RANN-AEN-74-24079
NOTE 28p.; Paper presented at the Annual Meeting of the Midwest sociological Society (St. Louis, Missouri, April 21-24, 1976)

EDRS PRICE MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS Conceptual Schemes; Definitions; *Group Structure; *Literature Reviews; *Models; Operations Research; *Organizational Theories; Organizations (Groups)
IDENTIFIERS *Operations Technology; Primary Task Operations

ABSTRACT

This paper reviews and synthesizes the literature relating operations technology to organizational structure and offers a refined definition of operations technology that is intended to facilitate the comparison of different organizational types. The authors present a theoretical model that imposes consistency on the existing literature and illustrates the impact of operations technology on three dimensions of organizational structure. Specifically, the model demonstrates the relationship between primary task operations and the structural dimensions of formalization, horizontal differentiation, and vertical differentiation. The authors conclude that operations technology is a pervasive and important concept in the study of organizational structure. (Author/JG)

Operations Technology and Organizational Structure*

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*This research was partially supported by National Science Foundation-RANN contract AEN 74-24079 which is gratefully acknowledged.

Operations Technology and Organizational Structure

The relationship between operations technology and organizational structure is analyzed from the perspective of a "technological imperative." A literature review is conducted, a refined definition of operations technology is developed, and its impact on organizational structure is illustrated by way of a formal theoretical model, thereby integrating and imposing consistency on existing literature. It is suggested that primary task operations is a key determinant of horizontal and vertical differentiation as well as formalization in organizations. Operations technology is therefore posed as a pervasive and important concept in explaining organizational structure.

Operations Technology and Organizational Structure

The relationship between operations technology and organizational structure has received substantial attention (12, 14, 15, 18, 36, 42) focusing on the broad issue of a "technological imperative." Findings, however, are inconsistent. This is not surprising in that operations technology has been defined differently by, for example, Woodward, Hage and Aiken, Hickson, et al., and Khandwalla; conceptualized in different ways by, for example, Harvey and Aldrich (1); and measured differently by, for example, Woodward, Hickson, et al., Harvey and Khandwalla. It is appropriate, therefore, to address this literature, develop a refined definition of operations technology, and, most importantly, point out its impact on organizational structure in a formal model, thereby rendering theoretical implications of existing findings consistent while posing specific propositions to be subjected to further empirical test.

Our review is based on a four-point perspective of organizational technology which will permit the eventual comparison of different organizational types. First, technology, or the process by which work gets done, is conceptualized as a defining characteristic of an organization. Second, the unit of analysis is the whole organization--in order to systematize the diversity of organizations in a manner permitting explanations of differences in structure, different types of organizations must be considered. Third, organizational technology is regarded as an important a variable for organization comparison as any other variable [Hickson,

et al., (15) concluded that organizational size is a more important predictor of structure than is technology]. Fourth, technology is a causal variable capable of shaping and directing organizational structure.

Operations Technology Defined

Operations technology now stands with varied meanings. Thompson and Bates defined technology as "those sets of man-machine activities which together produce a desired good or service" (37, p. 325). Woodward analyzed technology by a "scale of technical complexity," or "the extent to which the production process is controllable and its results predictable" (42, p 12). Perrow defined technology as "the actions that are performed on an object in order to make some change in that object" (28, p. 194). Thompson defines it "as the manner in which relevant variables are manipulated given a desired outcome and the state of man's knowledge" (38, p. 14). Hickson, et al., define technology as "the techniques that it (the organization) uses in its workflow activities" (30, p. 310) with "workflow meaning the process of producing and distributing output" (15, p. 380). Hage and Aiken (12) prefer to define only the aspect of technology called the routineness of work. It is "the degree to which organizational members have non-uniform work activities" (11, p. 927).

Primary task operations technology is the core of technology (38) upon which the organization depends for its productivity. The primary task operations variable is conceptualized to include the extent of routineness of processes or mechanisms of transformation, the extent of intricacy of operations and the length of time it

takes to assemble a good, process a typical client, or produce a standard service. It is, therefore, best defined as those sets of processes, procedures or mechanisms of transformation taken on input materials or resources in order to produce a good, process a client or provide a service.

Technology and Organizational Structure

Efforts to empirically test the viability of technology as a variable across organizations have focused primarily on production or manufacturing organizations (8, 14, 15, 18, 42), although Hage and Aiken (12), Mohr (25), and Perrow (29), have provided exceptions by studying hospitals and health and welfare organizations. Attempts to measure technology, when the unit of analysis is the organization, have used the case study method (4, 39, 40) and more recently the comparative method (8, 14, 15, 18, 20, 25, 29, 34, 42).

Thompson and Bates made one of the earliest attempts to specify structural ties to technology. They saw the "elongation" of technology, the fractioning of single work units into multiple and specialized units, leading to increased complexity. Also, the "type of technology available...sets limits on the types of structures appropriate for organization" (37, pp. 325-326). And, in a later work, Thompson suggested that technology was a "source of major orientation for the social structure of the organization" (38, p. 52). His typology of technologies, non-linked, mediating, and intensive is the result of an effort to provide an instrument with which to deal with the range of technologies found in many

organizations (38). He concluded that the consequences of any organizational activity impacts on not one "single technology but upon a technological matrix" because most organizations have many technologies one or more of which constitute the core technology (38, p. 22). Central to all organization is a core of technical functions constituting the core technology. Other supportive technologies concern the acquisition of input resources and the distribution of finished products that support but are not included in the core technology. And, the primary task operations technology plays a most influential role in determining the dimensions of organization structure.

Most studies emphasized the mode of production (14, 36, 42), the workflow process (8, 15), and operations activity (12, 18). The first empirical effort illuminating the effects of technology on structure was made by Woodward. The relationship was analyzed along a "scale of technical complexity", or "the extent to which the production process is controllable and its results predictable" (42, p. 12). Woodward maintained that technology is measured by the complexity the whole system of production.

Woodward classified manufacturing organizations according to their mode of production as a direct expression of technology. Production mode was measured as variation in product range over time; standardization of product parts, interchangeability of parts; number of production stages, and definition of product (44). Her original classification described an eleven-point scale of technical complexity or production quantity extending from unit production or custom technology (e.g., custom engineering) through mass production or mass-output technology (e.g., auto manufacturing) to process production

or continuous flow technology (e.g., pharmaceuticals). She conceived the most technologically complex system to be the process production and the least complex to be the unit production system. The scale measured the degree of production smoothness (35) or the continuity of production workflow (15, p. 390; 18, p. 74), from which Woodward sensed "an increasing ability to predict results and to control the physical limitations of production" (43, p. 51).

Her analysis suggested that organizations at the extremes of the scale tended to have more structural similarities than those in the mid-range; and that organizations "with similar production systems appear to have similar organizational structures" (43, p. 209). Woodward found a direct linear relationship between technical complexity and the length of the line of command (vertical differentiation), the span of control of the chief executive (horizontal differentiation), and the ratio of managers to total personnel. A curvilinear relationship was found between technical complexity and the span of control in work groups--small spans of control in unit and process production; the number of skilled workers--skilled workers comprised the largest group in both unit and process production systems; the amount of paper work--reaching a peak in assembly line production; and the specificiation of duties and responsibilities--with much more delegation of authority and responsibility for decision making in unit and process production firms (43). These findings led Woodward to conclude that "variations in organizational requirements between firms are nearly always linked with differences in their technologies of production"

(42, p. 37). However, "because of the complex nature of the relationship which connects the technology of a firm with its structure, it is likely that some, but not all, characteristics of technology will be reflected in organizational structure" (44, p. 15).

Several criticisms of Woodward's methodology have been raised. Hopkins (16) cited her failure to theoretically define key concepts as a fundamental constraint to the replication of her work. Khandwalla (18) noted that Woodward failed to delineate precisely what it was that she was attempting to do with the complexity scale; and, to demonstrate on an empirical basis the unidimensionality of her technology measure. Both Hopkins and Khandwalla criticize Woodward's research for not making known the kind of observations needed in order to classify an organization with more than one technology. Finally, in some of her analyses, Woodward uses samples of less than 80 organizations without explaining why varying sample sizes occur.

Harvey (14) redefined Woodward's scale of technical complexity to reflect the extent of variance within technology. In his study of 43 industrial organizations, Harvey's scale of technical diffuseness extended from the most specific production system (e.g., little variation in clients, product, or service) corresponding to Woodward's continuous process production to the most technically diffuse production system (e.g., an organization with a number of technical processes that yield a wide range of products) corresponding to Woodward's unit production system. Harvey's findings suggest a positive linear relationship between technical specificity and a number of dimensions of organization structure, such as

number of levels of authority, number of specialized work units, and the ratio of supervisors and managers to total personnel. The more changeful the technology, "the less likely that a considerable amount of internal differentiation and program specification" will occur. In technically specific production systems the "infrequency of product change appeared to be conducive to the establishment of stable divisions" (14, p. 256). Change in the more routinized primary task operations took a form of "further refinement rather than simplification." Four criticisms have been lodged against Harvey's work.

First, he fails to deal adequately with the distinction between technologies that were customized and those which were changeable by innovation. Second, the measure of technical specificity based on the number of product changes is very sensitive to the process by which product change is generally defined. Third, Mohr rejects Harvey's method of operationalizing the technology concept, insisting that "changes in product and product design or utility have more to do with output" than with an organization's process or mechanism for turning out its work (25, p. 447). Finally, Harvey's use of retooling as a measure of major changes in product was criticized by Mohr as having "less to do with characterizing a particular technology" than it does with documenting its shift in character (25, p. 447).

In their study using a randomly selected sample of 31 manufacturing and 15 service organizations to test the proposition of the "technical imperative," Hickson, Pugh, and Pheysey (15) define operations technology as the "equipping and sequencing of

activities in the workflow" (15, p. 380) and conceptualize it in terms of workflow integration and production continuity. Production continuity was adapted from Woodward's classification of the predominant technology of an organization and was used to distinguish ten modes of production ascending from unit or custom production to continuous process production. Workflow integration is the "degree of automated,continuous, fixed sequence operations in the technology" as measured by summing each organization's score on five scales of aspects of workflow: workflow rigidity/adaptability, interdependence of workflow segments, automaticity mode, automaticity range, and the specificity of operation evaluations. Each of these aspects of workflow was expected to be applicable to both manufacturing and service organizations (15, p. 381). However, this conceptualization is suitable and valuable primarily for systems of industrial production and is not appropriate in explaining the technology of non-industrial or service organizations. As the Aston Group found, measuring technology in terms of workflow activities and characteristics proved to be incapable of distinguishing among service organizations on the basis of technology.

By using multivariate analysis, they concluded that "the broad technological imperative hypothesis that operations technology is of primary importance to structure is not supported" (15, p. 387).

They found that by itself workflow integration was not significantly correlated with any of the main structured variables of structuring of activities, concentration of authority and line control of workflow. Structuring of activity (including functional

specialization, overall standardization of procedures, overall formalization or documentation) refers to the extent of formal regulation of the activities of employed personnel; concentration of authority (including overall centralization of decisions, organization autonomy) is the degree to which authority for decisions is centralized at the upper hierarchical levels or in external controlling units (15). However, some moderate correlations existed between workflow integration and these structural dimensions, but these correlations were overshadowed by those of size with the structural dimensions (32). And in multiple regression workflow integration and size with structuring of activities did not raise the correlation significantly, disclosing that concentration of authority was not related to workflow integration. These findings suggest that earlier reported relationships between technology and structure may have been spurious in that the "effects which were attributable primarily to technology were likely to be due to the simultaneous growth in size of the organization" (15, p. 338).

Production continuity was not significant when correlated with the main structural variables. However, a few dimensions of organizational shape were correlated with workflow and some production level dimensions of structure were significantly correlated to production continuity even when size was controlled. In short, operations technology accounted for only a small portion of the total variance in the three dimensions of structure (15). This suggested a more local effect of technology on structure (18), at "the level of the operative and his immediate supervisor (15, p. 394) and is in sharp contrast to the findings of Woodward (42) and Harvey (14) that suggest a more broad impact.

However, if the technological imperative hypothesis is construed to account for organization size the contrast can easily be reconciled as suggested by the following reformulated hypothesis:

> Structural variables will be associated with operations technology only where they are centered on the workflow. The smaller the organization the more its structure will be pervaded by such technological effects; the larger the organization the more these effects will be confined to variables such as job counts of employees on activities linked with the workflow itself, and will not be detectable in variables of the more remote administration and hierarchical structure (15, pp. 394-395).

In their replication of Hickson, et al.'s (15) research, Child and Mansfield (8) used a sample of 82 industrial organizations and the same measures of the technology and structure variables. Contrary to the findings of the Aston Group's study, they found that for the "sample of organizations as a whole, workflow integration is related to the structural variables of functional specialization" and standardization (8, p. 377). Aspects of the composite measure of workflow integration, were found to be differentially related to the variables of organization structure and became obscured by the composite score for workflow integration. This finding is contrary to the finding by Lynch in that in her study when the sample was compared on the three component scales of her library technology scale no pattern of similarity among cases appeared (20). Child and Mansfield's findings together with some of those of the Aston study indicate that technology variables are associated with structure in specific definable respects: the main structural variables, particularly functional and role specialization are related to technology independent of

size, and "in smaller organizations there appears to be a stronger relationship between technology and structural" dimensions (8, p. 388).

One significant criticism of the works of Woodward, Harvey, Hickson et al., Inkson et al., and Child and Mansfield is that each study was not "guided by propositions derived from an explicit model" of how technology and structure in an organization might be related (18, p. 77). Woodward arrived at her classification of industrial production in terms of its technology and according to the technical complexity of the production process after a fruitless attempt to understand the conduct of business organizations on the basis of the classical principles of management (43). Harvey's (14) error of assumption rests upon Woodward's simplified three-point continuum of technological complexity in that he fails to deal appropriately with the distinction between customized technologies and those changeable by innovation. The Aston Group's studies were ambiguous in their specification of intent to develop a causal model to explain relationships between organizational variables. They made statements that can "only be interpreted causally" and "statements denying any intent to develop a causal model" (1, p. 56). Hence the search for significant empirical relationships between variables of organizational technology and structure maybe described as serendipitious with spurious relationships becoming a frequent finding.

In his examination of the findings of the Aston Group, Aldrich used path analysis and challenged their finding that technology is

not as important a predictor of organization organization structure as is organization size. He noted a lack of an explicitly causal model to guide their research as one essential factor in their losing a large amount of information that was available for analysis (1). After creating a more plausible theory that treats operations technology as an independent variable, Aldrich reconstructs from the Aston data a causal model of organizational structure. Included within his concept of technology is Pugh, et al.'s (32) factor of operating variability, however workflow integration and operating variability are operationalized and analyzed separately. Aldrich concluded that operating varability has a positive impact on workflow integration and a modest and indirect effect on structuring of activities through workflow integration. Workflow integration has a causal impact on concentration of authority and a direct causal impact on structuring of activities (1). Size is regarded as a function of workflow integration, operating variability, and structuring of activities (1).

Khandwalla (18) analyzed the relationship between operations technology and organizational structure in 79 American manufacturing organizations. He asked organizational officials to rate the extent to which each of five major technologies were used most often in the production process of their organization. Controlling for size did not significantly alter relationships between technology and dimensions of organization structure (18, p. 88). He also found that technology does not directly affect decentralization in top-level decision-making and the use of sophisticated controls to regulate work processes and the behavior of organization members.

Khandwalla also found that the impact of mass-output orientation of operations technology on structural variables is modest and selective; but when organizations were grouped by profitability this impact became sizable and pervasive (18). Also a positive relationship was noted between mass-output production orientation of an organization's technology and each of vertical integration, decentralization, and use of sophisticated controls. And, it was found that the impact of size on structure appeared to be independent of and at least comparable to the impact of technology (18).

Hage and Aiken (12) used Perrow's framework but conceptualized "routineness of work" as a component of technology in their investigation of the relationship between organization technology, structure and goals. They defined routineness of work as "the degree to which organizational members have non-uniform work activities (11, p. 927) and conceptualized it as the degree of variety in work (12). A factor analysis was performed to differentiate routineness of work and other closely similar variables such as job specification or codification.

Analysis of data produced support for Hage and Aiken's predictions that since the 16 organizations provide rehabilitation, psychiatric, and psychological services their scores would tend more toward nonroutineness of work. Also, they found evidence that the higher the occupational level within the organization the more likely the respondent is to report that his tasks are more nonroutine. Concerning technology and structure, they found that organizations with more routine work are more centralized in decision making about basic organizational issues and more formalized

by the presence of rule manuals and specificity of job descriptions. It was found that one variable of complexity, amount of professional training, was negatively related to routineness of work. No relationship was found between routineness of work and stratification; and only a small and insignificant relationship was noted between routineness of work and the size of the organization (12).

Dimensions of Structure

Two specific dimensions of structure have been identified: formalization (1, 8, 12, 15, 25) and complexity or differentiation (14, 18, 34, 43). Perrow defines structure as "the arrangements among people for getting the work done" (27, p. 195). Formalization is referenced variously as styles of supervision by Mohr (25) and as structuring of activities (e.g., overall standardization of procedures, overall formalization or documentation) by Hickson, et al. (15), Child and Mansfield (8) and Aldrich (1). Formalization is a process of increasing control by promoting social integration via formal devices of coordination and communication. Specific work and behavioral practices and duties are given legitimate recognition and sanction by being formalized into explicit rules and limitations. Rules and procedures are developed to codify the intersections between work units. Pugh, et al., (30) suggest that "formalization or standardization....includes statements of procedures, rules, roles, and operations of procedures which deal with (a) decision-seeking, (b) conveying of decisions and instructions (plans, minutes, requisitions, etc.), and (c) conveying of information, including feedback" (30, pp. 303-304). The degree of formalization in an organization which follow the broader

meaning of formalization given by Pugh, et al. (30) are: (a) rules and procedures - the extent to which work rules, procedures and policies are in written form; (b) roles - the degree to which all the positions in the organization have written job descriptions and specifications; (c) communication - the degree of emphasis on written memoranda accompanying official communications; and (d) decision-making - the extent to which the process by which decisions are made is clearly understood. We assume no priority among these dimensions of formalization.

Structural complexity comprises both horizontal and vertical differentiation. Hall, Haas, and Johnson suggests that as a structural condition of organizations, complexity or structural differentiation is "the degree of internal segmentation--the number of separate 'parts' of the organization as reflected by the division of labor, number of hierarchical levels and the spatial dispersion of the organization" (13, p. 906). Blau defines differentiation specifically as "the number of structural components that are formally distinguished in terms of one criterion" (the division of labor) (23, p. 11). As the division of labor increases, organizations increase in horizontal differentiation; and, as horizontal differentiation occurs new vertical differentiation occurs to provide regulation and control processes (10). Horizontal differentiation refers to the number of divisions or departments in an organization; vertical differentiation refers to the number of occupational positions or jobs both in total for the organization and for the largest division or department of the organization:

Spatial or geographical differentiation refers to the number of distinct, "spatially separated" (33, p. 770) places where work is performed (9). We assume no priority among the three dimensions of differentiation.

A Formal Model

We suggest that primary task operations will be related to formalization, horizontal differentiation, and vertical differentiation in the specific manner illustrated in Figure 1. This suggestion eminates from a synthesizing and ordering of particular

(Insert Figure 1 about here)

findings in several of the preceding empirical studies.

The findings of Woodward, Child and Mansfield, Aldrich, Hage and Aiken, and Mohr suggest that there is a relationship between technology and formalization: Woodward (43) found a curvilinear relationship between technical complexity and the amount of paper work produced in association with manufacturing. It reached its peak in assembly line or mass production. She also found a curvilinear relationship between technical complexity and the specification of duties and responsibilities, delegation of authority and responsibility for decision-making. These were greater in unit and process production firms. Hage and Aiken found that organizations with more routine work are more centralized in decision making and more formalized by the presence of rules manuals and specificity of job descriptions (12).

Contrary to the findings of the study by Hickson, et al., (15) and Child and Mansfield (8) Aldrich (1) found association between

technology and formalizations. Hickson, et al. and Child and Mansfield found that positive relationships between operations technology and structural variables became insignificant when the size of the organization was partialled out except where they were centered on the workflow. Aldrich found that technology as workflow integration had a direct causal impact on structuring of activities.

Consequently, we hypothesize that primary task operations will be related to several variables of formalization in specific and definable ways. Those organizations with more routine primary task operations will evidence higher levels of formalization than those organizations with more non-routine primary task operations. Organizations with higher levels of formalization will exhibit a higher precentage of written rules, procedures and policies, a greater degree of written job descriptions and specifications, more clarity of the process by which decisions are made, and a greater emphasis upon the use of written memoranda in accompaniment of official communications. Organizations with a greater number of non-routine, intricate primary task operations will tend to be the least formalized with regard to rules and procedures and roles. Organizations with the lowest levels of formalization will exhibit formalization only with regard to clarity in the process by which decisions are made.

Organizations with more routine primary task operations, those with the fewest or the most different routine operations will exhibit similar and higher levels of formalization than organizations with a middle range number of routine operations. The higher

levels of formalization will be evidenced by a greater number of and dependence on rules, procedures, and written communications.

With regard to structural differentiation, empirical findings (1, 14, 18, 42, 43) suggest a positive relationship between operations technology and differentiation. Woodward (43) found a linear relationship between technical complexity and the length of the line of command (differentiation vertical) and the span of control (differentiation horizontal) of the chief executive. She also found a curvilinear relationship between technical complexity and the number of skilled workers, with skilled workers comprising the largest group of all workers engaged in unit and process production systems. Harvey's data support the findings of Woodward's study in that they indicate a positive linear relationship between technical specificity and the number of levels of authority (vertical differentiation) and the number of specialized work units (horizontal differentiation). He noted that change in the more routine task units took the form of "further refinement rather than simplification" (14, p. 256).

Aldrich's (1) use of an explicit causal model and path analysis of the original Aston Group (15) data resulted in the finding of a causal impact of operations technology upon concentration of authority or vertical differentiation. Khandwalla (18) found that when organizations were grouped by profitability that the impact of operations technology on vertical integration and the use of sophisticated controls became sizable and pervasive.

In light of these findings, we predict that organizations with higher levels of routine primary task operations will evidence

less horizontal differentiation than will organizations with lower levels of routine operations. Organizations characterized by higher levels of non-routine operations will have more horizontally differentiated structures than organizations with lower levels of non-routine operations. When comparing organizations with routine primary task operations with organizations characterized by non-routine operations, the organizations with routine operations have less horizontal differentiation than the organizations characterized with non-routine operations. Also, organizations characterized with higher levels of non-routine operations will have the most horizontally differentiated structures. There will tend to be a positive linear relationship between non-routine primary task operations and horizontal differentiation and a negatively linear relationship between routine operations and horizontal differentiation. The positive linear relationship will be higher than the negative linear relationship.

As organizations increase in horizontal differentiation new vertical differentiation occurs to provide necessary regulation and control of organization processes (10). We expect that organizations characterized by higher levels of routine primary task operations will have less vertically differentiated structures when compared with organizations having lower levels of routine operations and with organizations having higher levels of non-routine primary task operations. Organizations with higher levels of non-routine operations will exhibit greater vertical differentiation than organization with comparatively high levels of routine primary operations and organizations with low levels of routine operations.

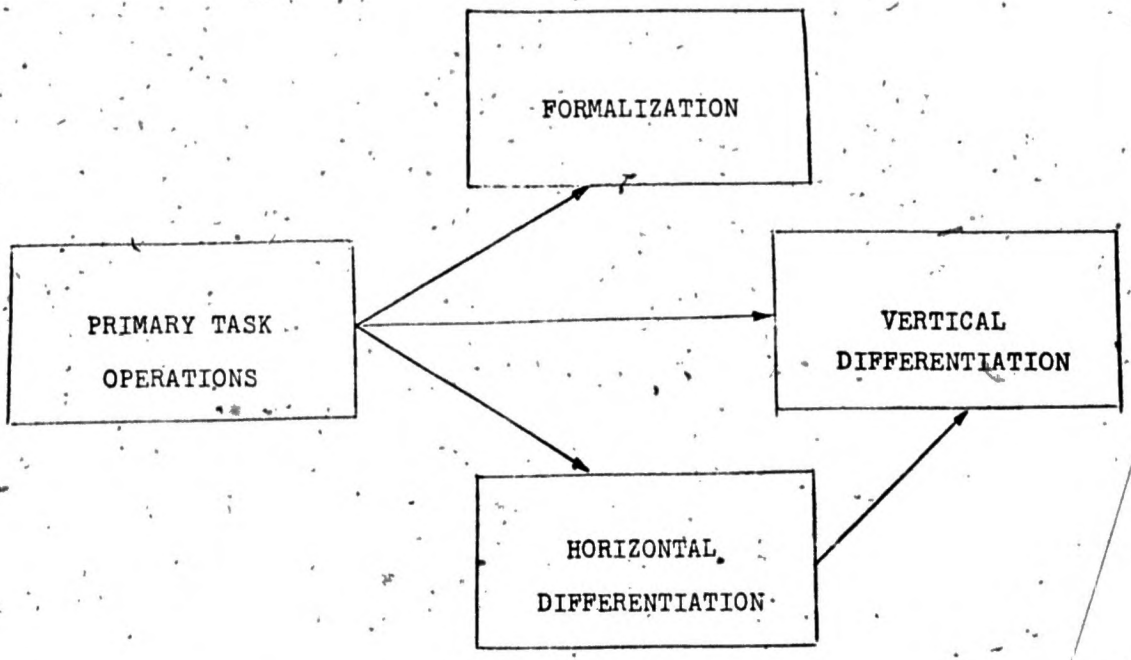
Comparisons of organizations with routine operations and those with non-routine operations will disclose that organizations with non-routine operations will have greater vertical differentiation. The most vertically differentiated organizations will be those with the highest levels of non-routine operations. There will tend to be a positive linear relationship between non-routine operations and vertical differentiation as contrasted with a negatively linear relationship between routine operations and vertical differentiation. Organizations characterized by routine primary task operations will exhibit a negatively linear relationship between operations and structural differentiation; while organizations with non-routine operations will exhibit a positive linear relationship between operations and structural differentiation.

Conclusion

This paper presents a formal synthesis of the literature relating operations technology to organizational structure. The authors develop and present a refined definition of operations technology that will permit the eventual comparison of different organizational types. In a formal model rendering consistent the theoretical implications of existing findings, the impact of operations technology on three dimensions of organizational structure is conceptually illustrated. It is suggested that primary tasks operations will be related to formalization, horizontal differentiation and vertical differentiation. Operations technology is, therefore, posed as a pervasive and important concept in relation to organizational structure. The model stands as a series of empirically refutable propositions which must now be subjected to empirical test.

Figure 1

Theoretical Relationship Between Operations Technology and Dimensions of Organization Structure



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