

Waldemar KARWOWSKI*

A CONGRUENCE BETWEEN THE KNOWLEDGE OF HUMAN FACTORS / ERGONOMICS AND MANAGEMENT: AN ONTOLOGICAL APPROACH

This paper discusses the natural congruence between the knowledge of human factors/ergonomics (HFE) and contemporary management. Such congruence is described in the context of the main elements of the knowledge base of the two disciplines, and modeled by mapping the main categories of management knowledge to specific categories of HFE knowledge. The meaningful relationships are demonstrated through relevant ontologies at both high-level general HFE and management knowledge, as well as detailed low-level HFE and business management processes.

Key words: human factors, macroergonomics, management,

1. INTRODUCTION

It is the basic premise of this paper that the knowledge bases of business process management and human factors and ergonomics (HFE) are intimately interrelated. The contemporary field of HFE has evolved over the last 60 years as a unique and independent discipline that focuses on the nature of human-artifact interactions, viewed from the unified perspective of the science, engineering, design, technology, and management of human-compatible systems, including a variety of natural and artificial products, processes, and living environments [9]. HFE discipline promotes a holistic, human-centered approach to work systems design that considers physical, cognitive, social, organizational, environmental and other relevant factors [12, 17].

* University of Central Florida, Department of Industrial Engineering and Management Systems, Institute for Advanced Systems Engineering.

On the other hand, contemporary management includes knowledge of: (1) planning and decision making, (2) organizing, (3) leading, and (4) controlling, directed at an organization's resources (human, financial, physical, and information) with the aim of achieving organizational goals in an efficient and effective manner [5, 15]. HFE knowledge plays an important role in achieving organizational goals in an effective and efficient way [8, 10]. Examples of the main elements of management processes which are central to the mission of the HFE discipline include: (1) organizing, (2) human resource planning, and (3) effective and efficient achievement of organizational goals. In the context of safety and health management, such factors are: (1) work stress in context of the individual worker's behavior, and (2) human resource management. Work stress may be related to four categories of organizational and individual factors: (1) decisions related to task demands; (2) work environment demands including physical, perceptual and cognitive task demands, as well as quality of the work environment, that is adjustment of the tools and machines to human characteristics and capabilities; (3) role demands related to the relations with supervisor and coworkers; and (4) interpersonal demands, which can cause conflict between workers, e.g. management style, group pressure, etc.

Common to management and HFE knowledge are the issues of job design and job analysis. Job design is widely considered to be the first building block of an organizational structure. Job analysis, as a systematic analysis of jobs within an organization, allows to determine an individual's work-related responsibilities. *Human resource planning* is an integral part of human resource management. The starting point for this business function is a *job analysis* that is a systematic analysis of the workplaces in the organization. *Job analysis* consists of two parts: (1) *job description*, and (2) *job specification*. *Job description* should include a description of the tasks' demands and work environment conditions, such as: work tools, materials and machines needed to perform specific tasks. *Job specification* determines abilities, skills and other worker characteristics necessary for *effective and efficient* task performance in a particular job.

The elements of management knowledge described above, such as *job design*, *human resource planning* (job analysis and job specification), *work stress management*, *safety and health management*, are also essential knowledge components of the HFE sub-discipline called industrial ergonomics. Industrial ergonomics, which investigates the human-system relationships at the individual workplace (workstation) level or at the work system level, embraces knowledge that is also of central interest to management. From this point of view, industrial ergonomics focuses on the organization and management at the workplace level (work system level), through the design and assessment (testing and evaluation) of job tasks, tools, machines, and work environments, in order to adapt these to the capabilities and needs of workers [1].

2. MACROERGONOMICS AND BUSINESS MANAGEMENT PROCESS

The basic knowledge of business process management, related to planning and decision making, organizing, leading, and controlling, constitutes an essential part of the HFE knowledge. Organizing is deciding which way of organizational elements grouping is the best. Job design is the basic building block of organizational structure. Job design focuses on identification and determination of the tasks and activities that the particular worker is responsible for.

Another important part of HFE knowledge with respect to the central focus of business management design is macroergonomics [4, 11]. According to Hendrick and Kleiner [6], macroergonomics is concerned with the analysis, design, and evaluation of work systems. Work denotes any form of human effort or activity. System refers to *sociotechnical* systems, which range from a single individual to a complex multinational organization. A *work system* consists of people interacting with some form of: (1) job design (work modules, tasks, knowledge and skill requirements), (2) hardware (machines or tools) and/or software, (3) internal environment (physical parameters and psychosocial factors), (4) external environment (political, cultural, and economic factors), and (5) organizational design (i.e., the work system's structure and processes used to accomplish desired functions).

3. THE CONGRUENCE BETWEEN THE DISCIPLINES OF HFE AND MANAGEMENT

The natural congruence between contemporary management and HFE can be described in the context of the main elements of the knowledge base of these two disciplines. Such relationships are then modeled by mapping the main categories of management knowledge to specific categories of HFE knowledge (see Fig. 1), and extensions of such mapping at three levels of complexity. The meaningful relationships are demonstrated through relevant ontologies at both high-level general HFE and management knowledge, as well as detailed low-level HFE and business management processes.

4. KNOWLEDGE ONTOLOGIES

An ontology relates a set of concepts, properties of those concepts, and the nature of relationships between those concepts. Ontologies describe specific knowledge domains, and can serve as vehicles for relating concepts between domains. Ontologies do consist of taxonomies, but they are not limited to strictly being hierarchies. Ontologies may span many layers of abstraction, and introduce terminology and logic that surpasses simple hierarchical relationships.

In the late 1990s “ontology” became an industry buzzword as it became relevant to many business strategic plans. It was embraced along with the other terms of the day, including enterprise modeling, e-commerce, knowledge management and meta-standards [16]. Ontologies were especially lauded for their role in knowledge sharing activities, a concept made possible by the proliferation and integration of wide area networks (WAN) into business. The modern meaning of “ontology” in a business setting is that of a “conceptual model.” This conceptual model can be further developed and modified at varying levels of abstraction to promote understanding of the domain under investigation.

5. HUMAN FACTORS AND BUSINESS PROCESS KNOWLEDGE

HFE and management knowledge ontologies are depicted below. These can be linked to each other, revealing powerful and subtle similarities and important relationships between the two bodies of knowledge. The main categories of HFE and management knowledge are outlined in Tables 1 and 2.

Table 1. Main Categories of Human Factors and Ergonomics Knowledge (adopted after Ergonomics Abstracts, 2014)

• General Ergonomics
• Human Characteristics
• Performance Related Factors
• Information Presentation and Communication
• Display and Control Design
• Workplace and Equipment Design
• Environment
• System Characteristics
• Health and Safety
• Social and Economic Impact of the System
• Methods and Techniques

Table 2. Main Categories of Management Knowledge (adapted after [5])

• Management
• Environment
• Planning
• Organizing
• Leading
• Controlling

6. MAPPING LEVELS OF HFE AND MANAGEMENT KNOWLEDGE

6.1. First level knowledge mapping

The first level of knowledge mapping illustrates a high-level dependency between HFE knowledge and knowledge of management processes. Knowledge about human characteristics can help managers lead employees more effectively when informed about human performance characteristics. These general linkages organize underlying methods and procedures that can aid and improve management processes. Each of the concepts shown on the left of Figure 1 are further decomposed and linked to specific elements of HFE knowledge.

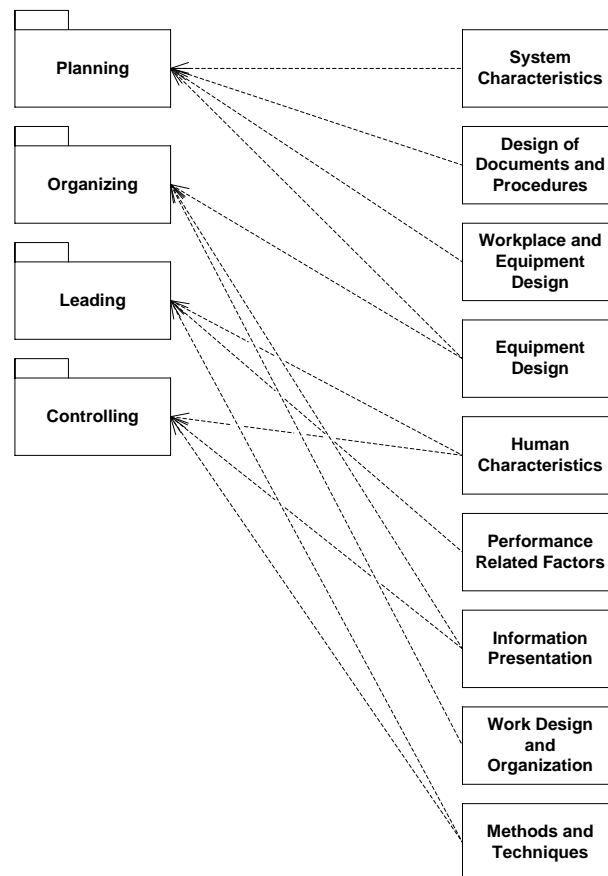


Fig. 1. Relationships between High Level Human Factors Knowledge and Business Processes

6.2. Second level knowledge mapping

Management involves many planning operations. Planning work schedules and job design are well-suited for business planning processes and techniques. Knowing human limitations, comfort levels and abilities has a direct influence on designing work systems and tasks and the processes that govern it. It should be noted that the explored relationships are in no means exhaustive.

Figures 2–7 shown below illustrate the second tier of the knowledge mapping classification scheme. The second level mapping of HFE and management knowledge relationships describes more low-level operations. The main HFE knowledge elements contain concepts such as age, gender and other defining characteristics that aid in human resource management. For example, knowing about individual differences can aid further in business operation actions, as well as in work/task assignment and job training.

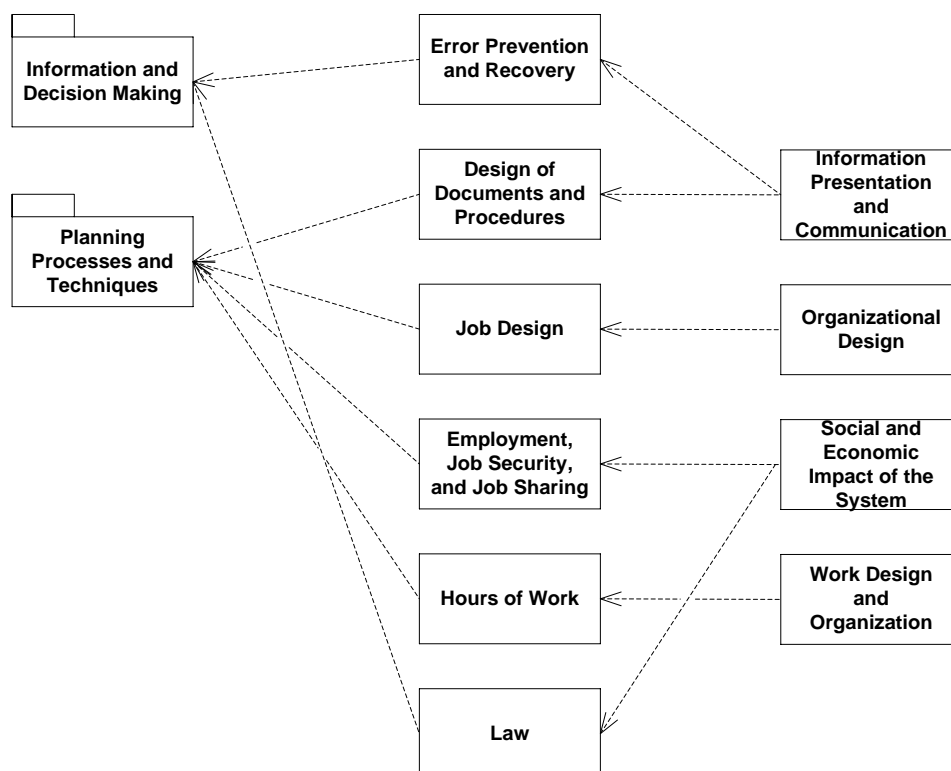


Fig. 2. Information Planning Processes related to Workplace Design and Information

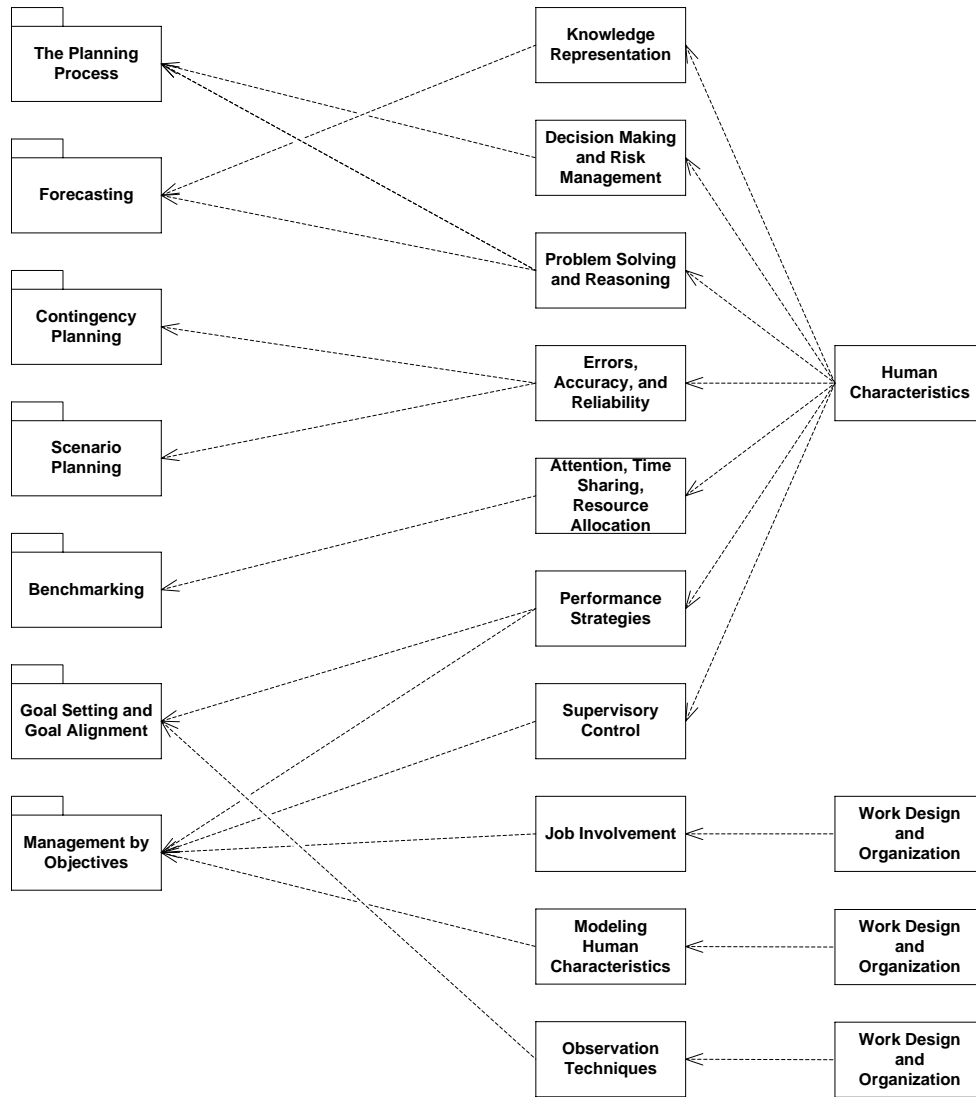


Fig. 3. Planning Processes related to Human Characteristics and Organizational Design

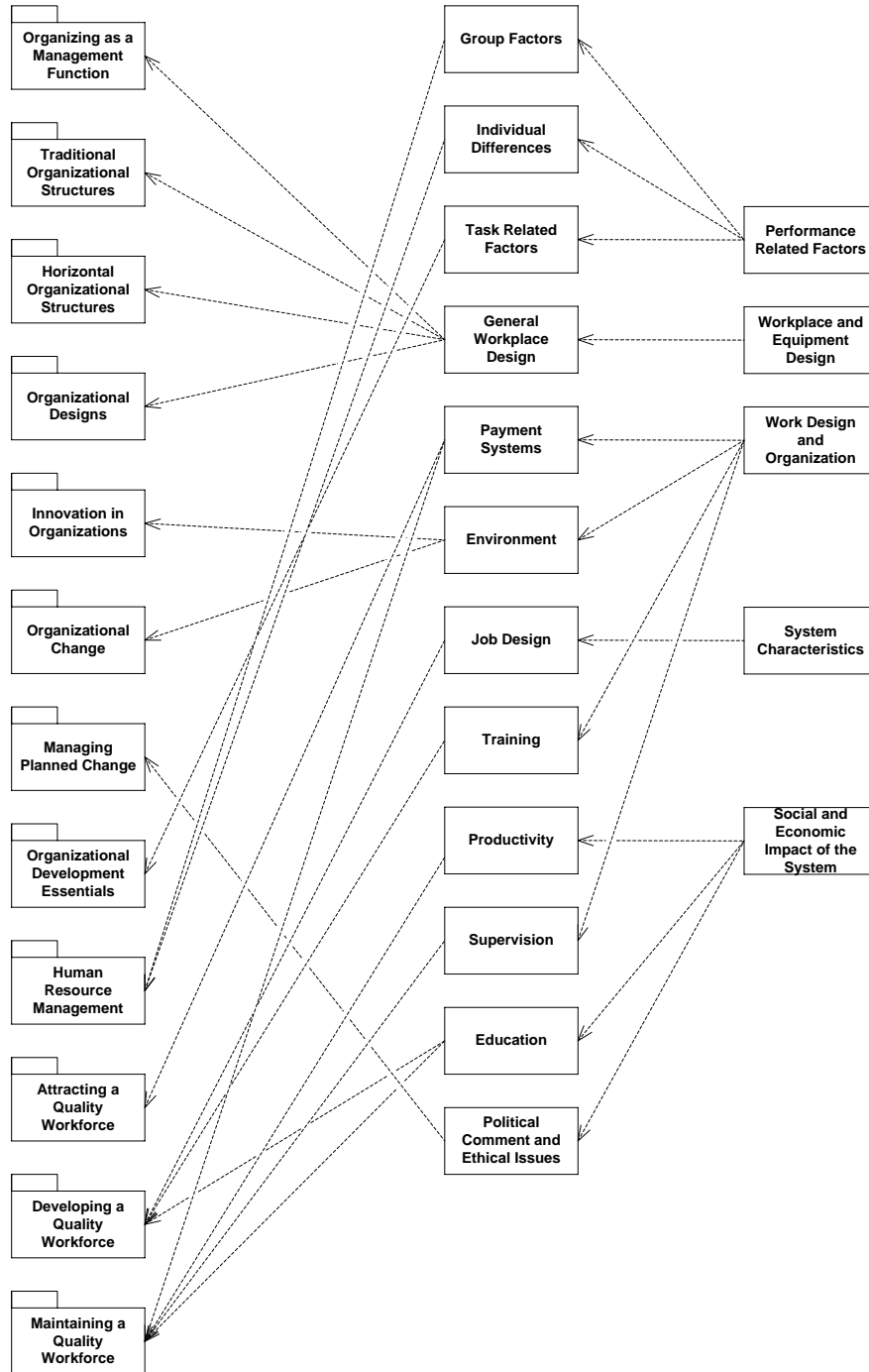


Fig. 4. Organizing Concepts Related to Work Design and System and Organizational Design Characteristics

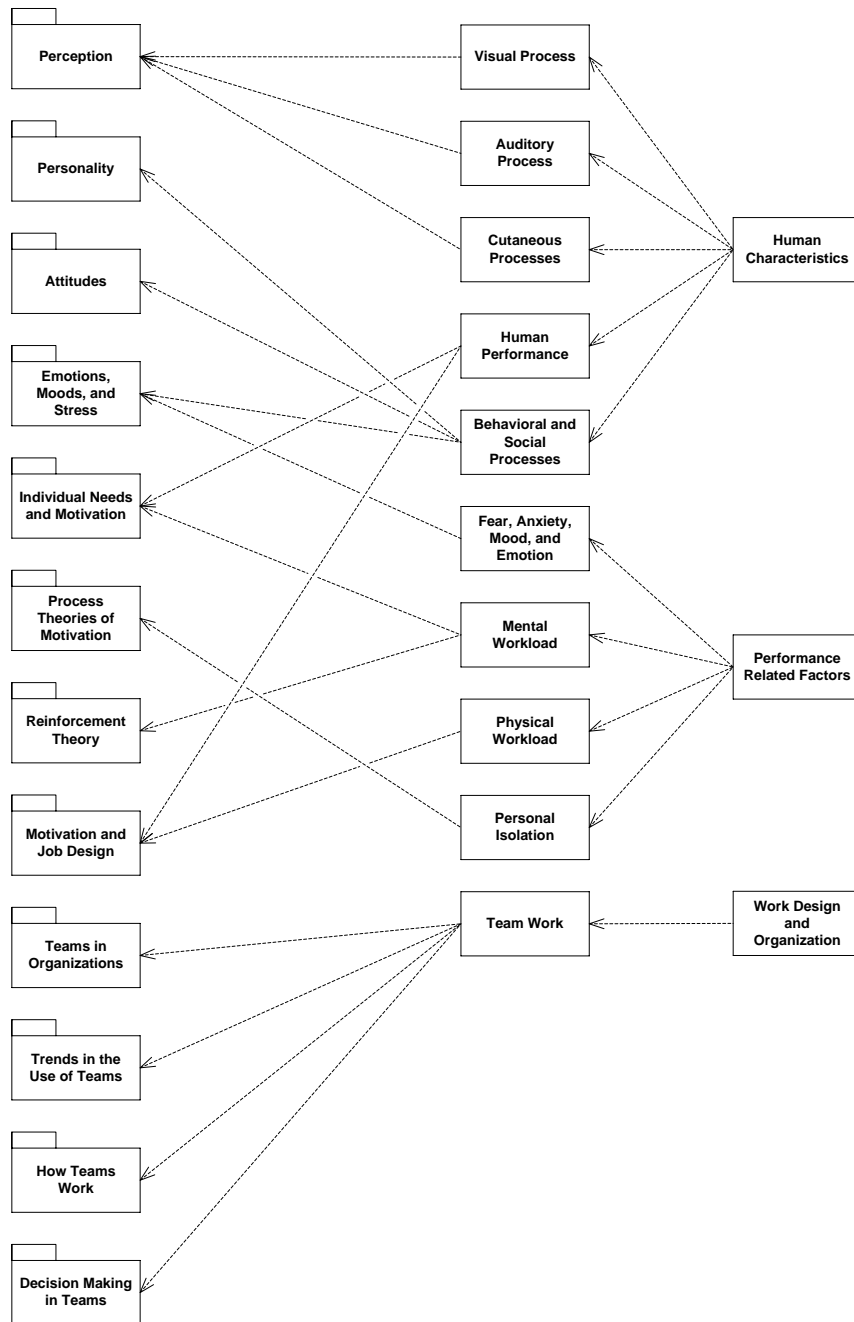


Fig. 5. Managerial Leading Concepts related to Human Performance and General Human Characteristics

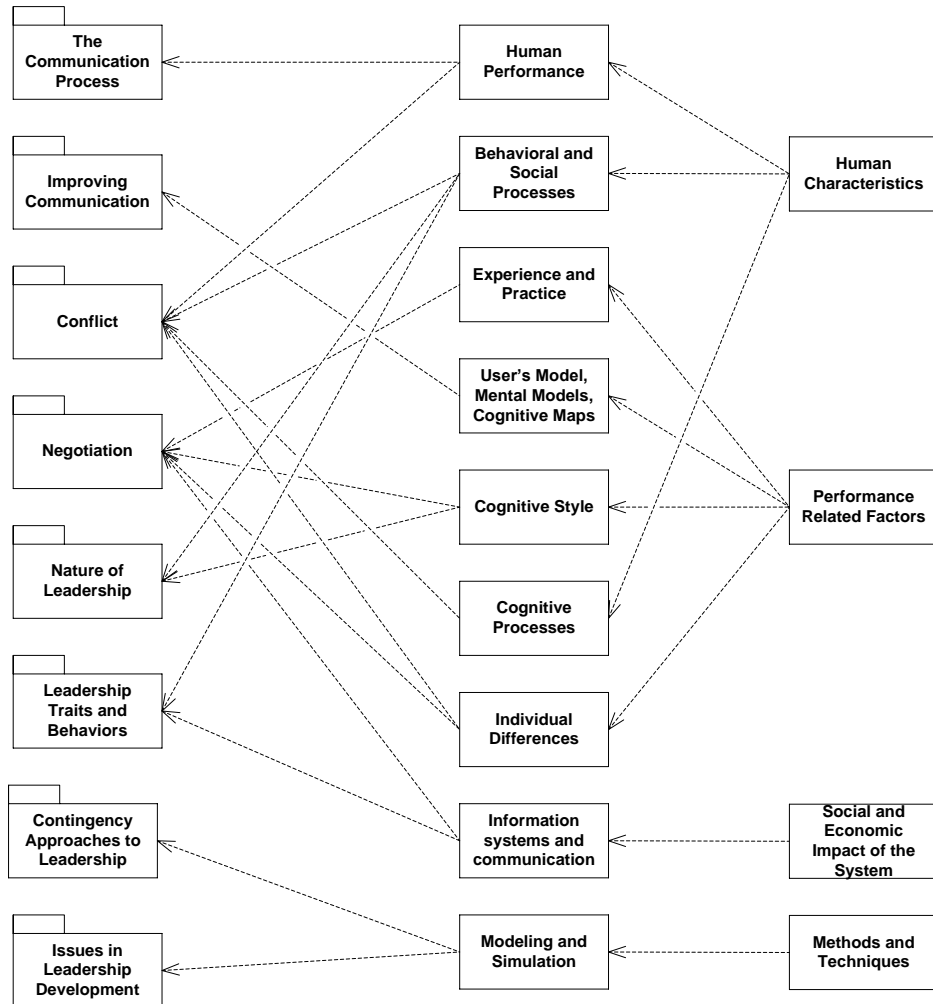


Fig. 6. Managerial Leadership Concepts related to Human Characteristics, Performance, and Systems Impacts and Methods

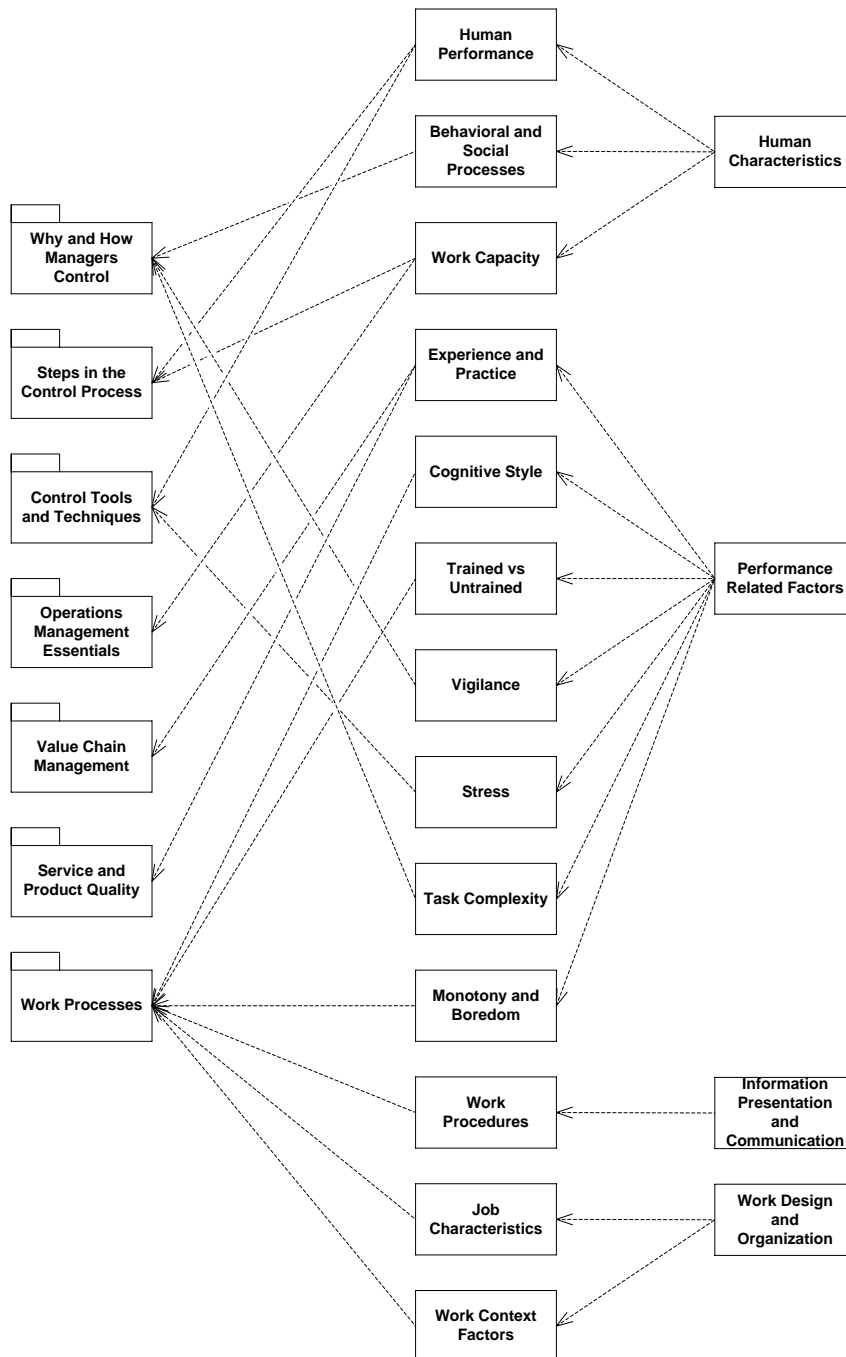


Fig. 7. Managerial Controlling Elements related to Human Performance Factors and Organizational Design

The knowledge of human performance and behavioral and social processes can be used to explain employee emotions, moods and stress. Behavioral and social processes can aid managers in predicting and managing various attitudes at work. For example, data on workloads, both mental and physical, can give managers more complete ideas of what is going on in regards to employee behavior under various working conditions. The field of HFE is also well-suited for providing useful models with regard to business process control. General data on human performance, human capacities and limitations, and related models can aid in the controlling process.

6.3. Third level knowledge mapping

Figures 8–16 below illustrate the third level of the knowledge mapping classification scheme. This mapping describes management processes and relevant parts of HFE knowledge that afford successful business process planning and execution. Knowledge representation, an area receiving increasing attention from educators and scientists, can aid in decision making, benchmarking, and employee development and training activities. Decision making and problem solving knowledge constructs aid most planning activities. Other relevant parts of HFE knowledge include modeling of human characteristics, performance strategies and resource allocation. These knowledge concepts contribute towards planning, goal setting and employee involvement in business activities. Finally, knowledge on reliability and errors can aid in forecasting and contingency planning.

HFE knowledge domains range from theories of behavior to individual traits to job satisfaction. These linkages demonstrate that relationships exist between specific human factors knowledge elements and business processes. HFE knowledge also includes data on job planning, such as enlargement, enrichment and rotation. HFE knowledge continues to provide meaningful science to aid managers. For example, data on task analysis, job analysis and mental abilities can provide guidelines as well as specific behaviors for successful leadership.

Another important aspect of business activities is teamwork. HFE contains knowledge on autonomous work groups, which can aid managers in creating high performance, unsupervised teams. HFE knowledge can provide data on how teams work, as well as on psychological constructs such as fear, anxiety and motivation. Business management could greatly benefit from understanding human performance tendencies and capabilities in advance of team creation and employee selection.

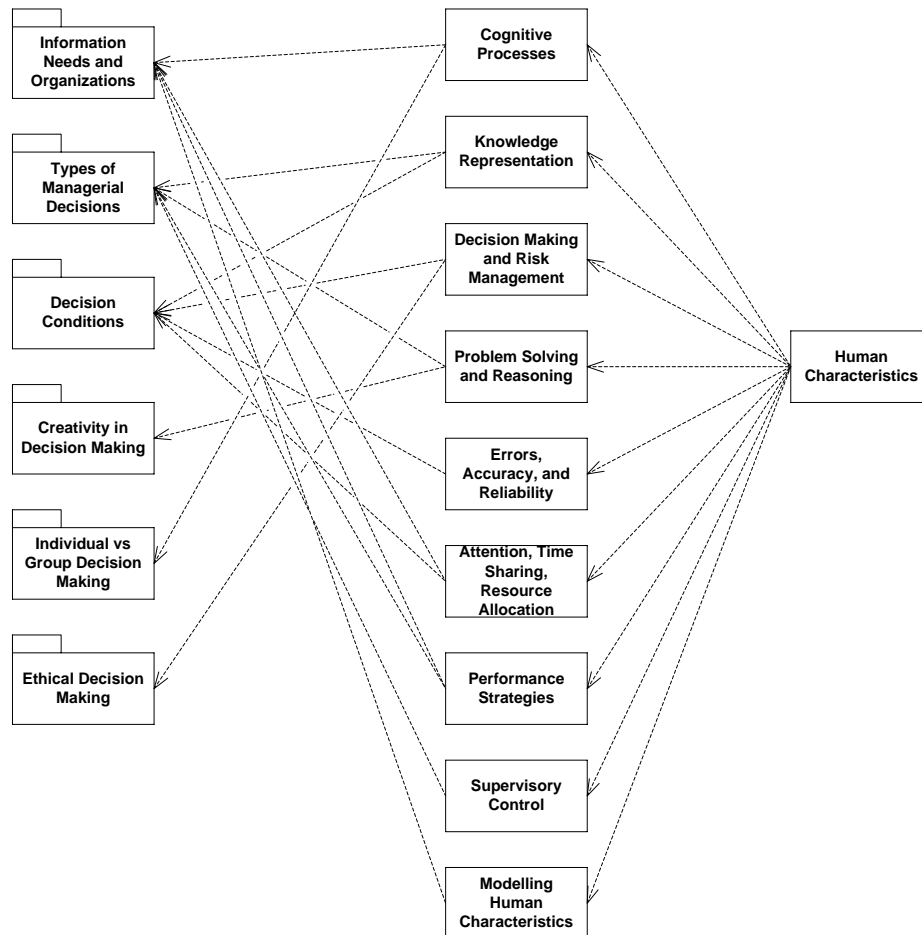


Fig. 8. Managerial Decision Making related to and aided by Human Characteristics

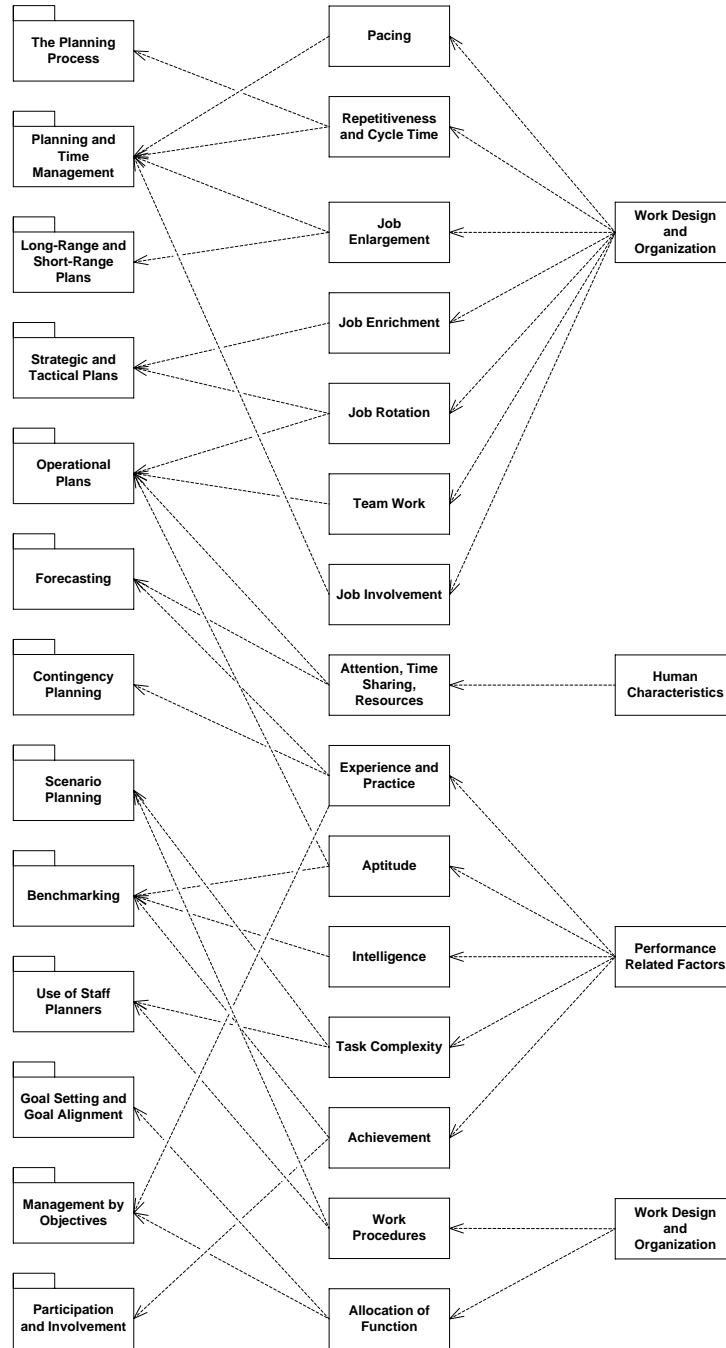


Fig. 9. Managerial Planning Functions related to Human Characteristics, Performance, and Organizational and Work Design

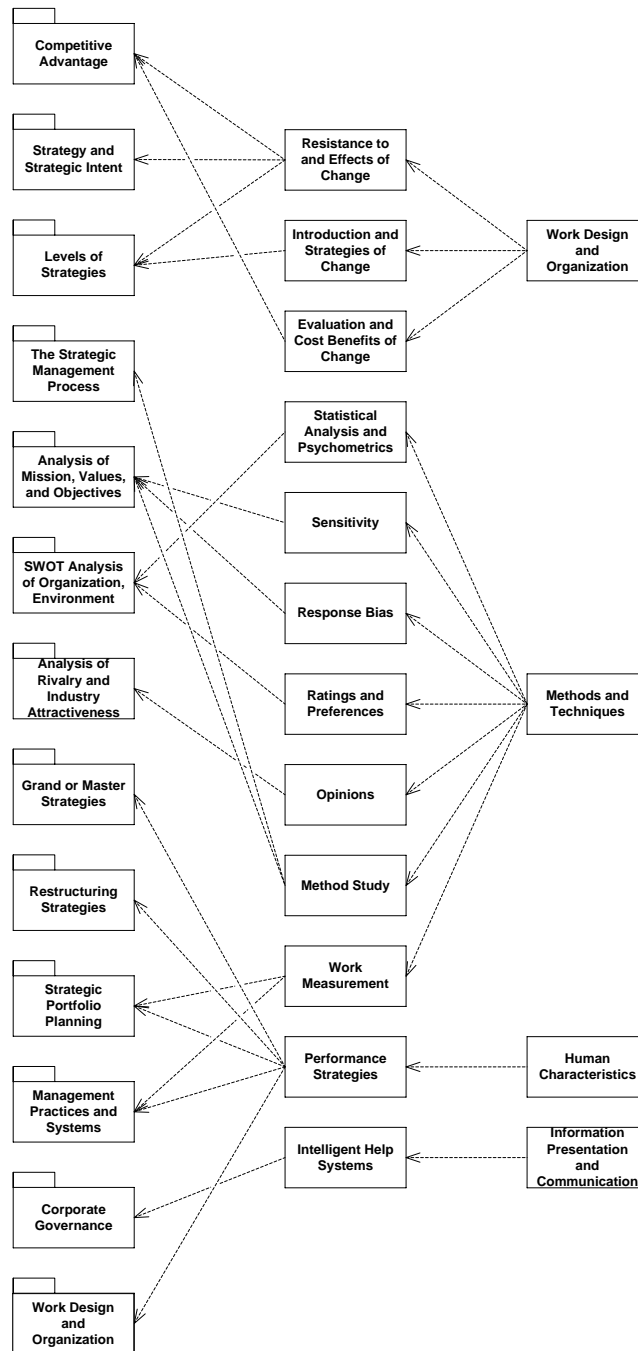


Fig. 10. Managerial Planning related to Methods, Human Characteristics, and Information Sharing

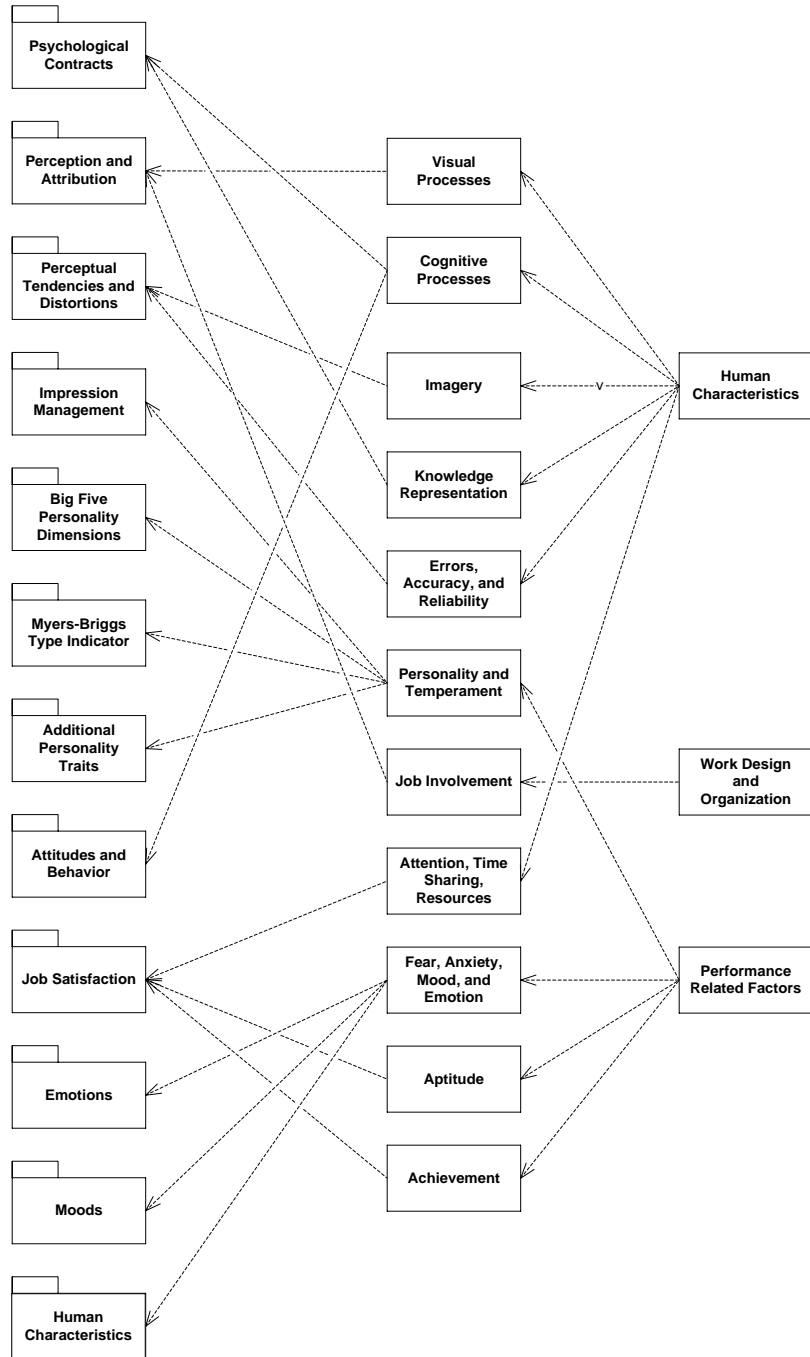


Fig. 11. Managerial Leading Elements Related to Human Performance, Characteristics, and Work Design

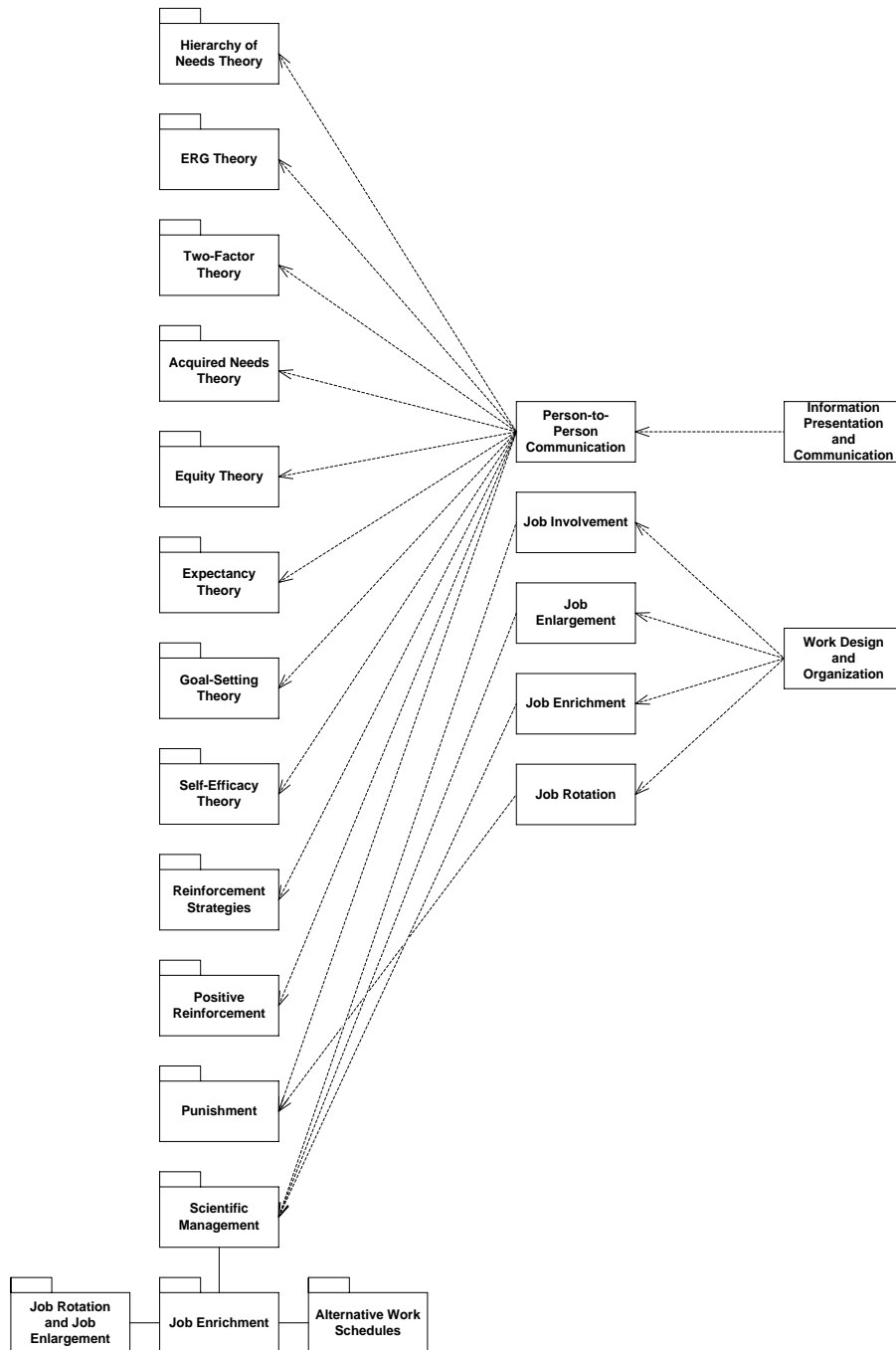


Fig. 12. Managerial Leading Activities related to Organizational Design Concepts

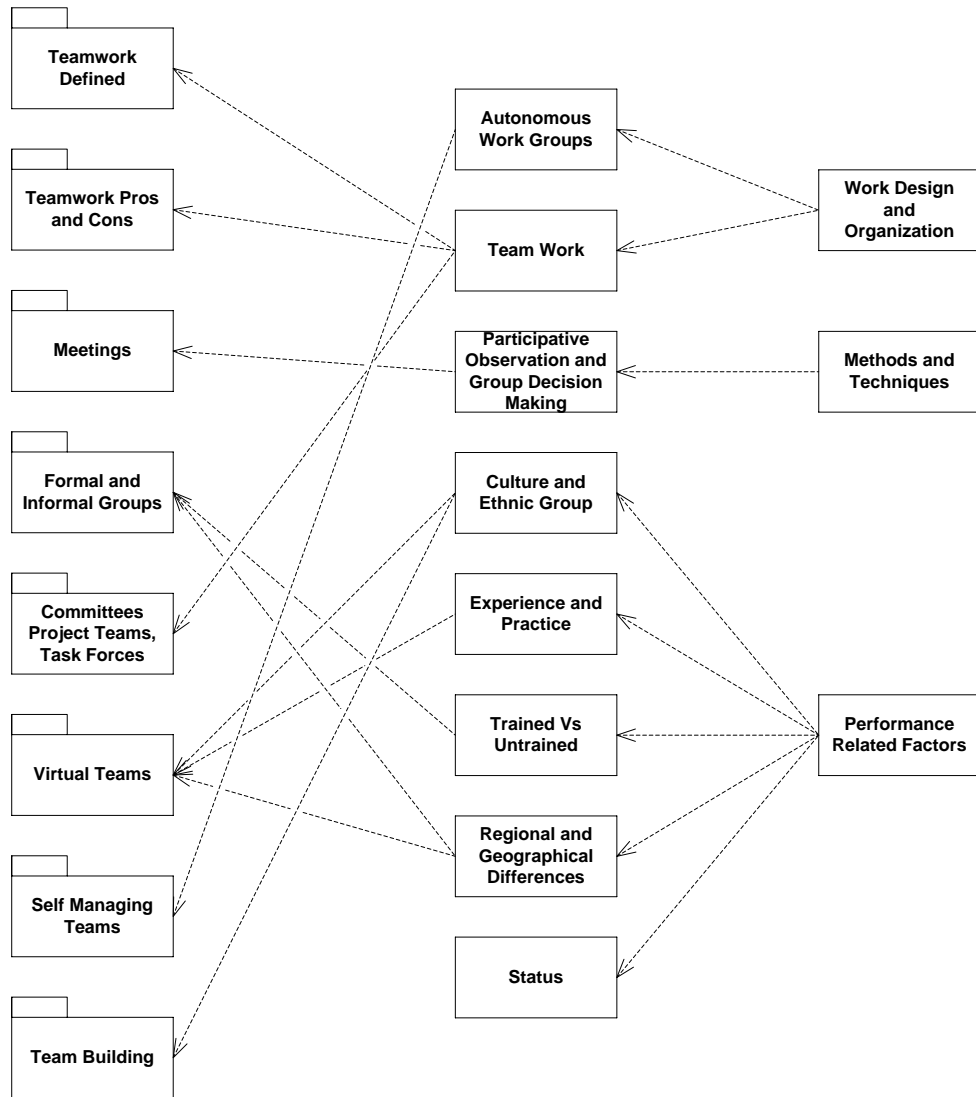


Fig. 13. Managerial Team Building Activities related to and aided by Human Performance, Methods, and Organizational Design Concepts

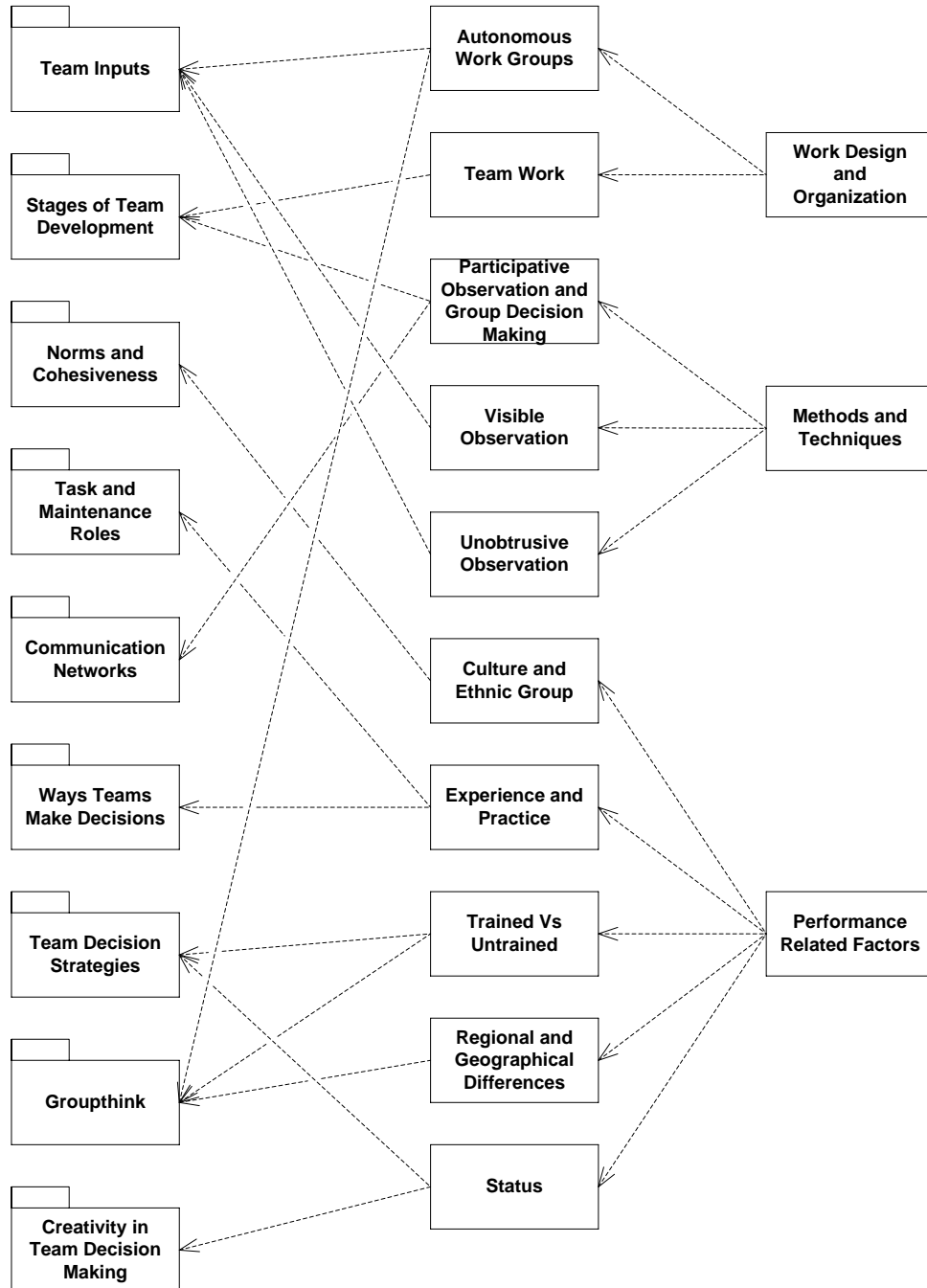


Fig. 14. Managerial Leading Activities aided by Performance, Work Design, and Methods

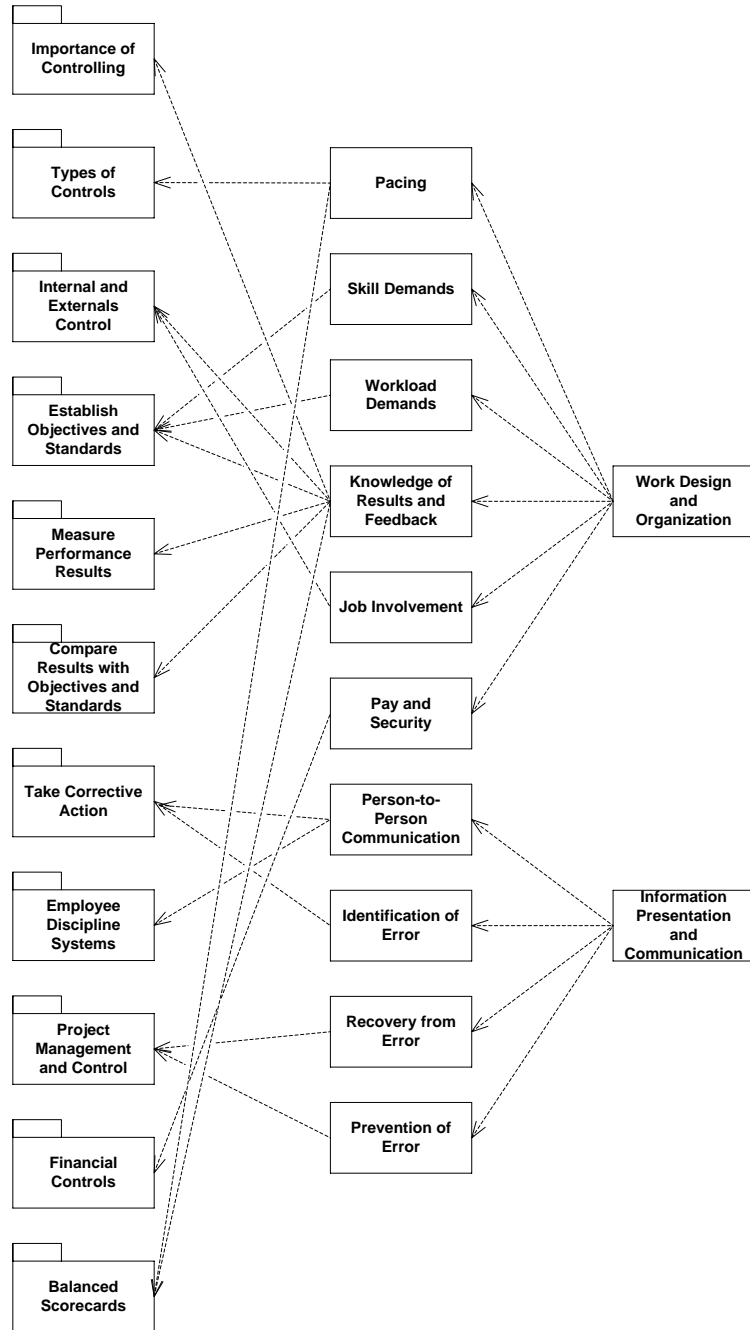


Fig. 15. Managerial Controlling Activities described through Work Design and Informational Concepts

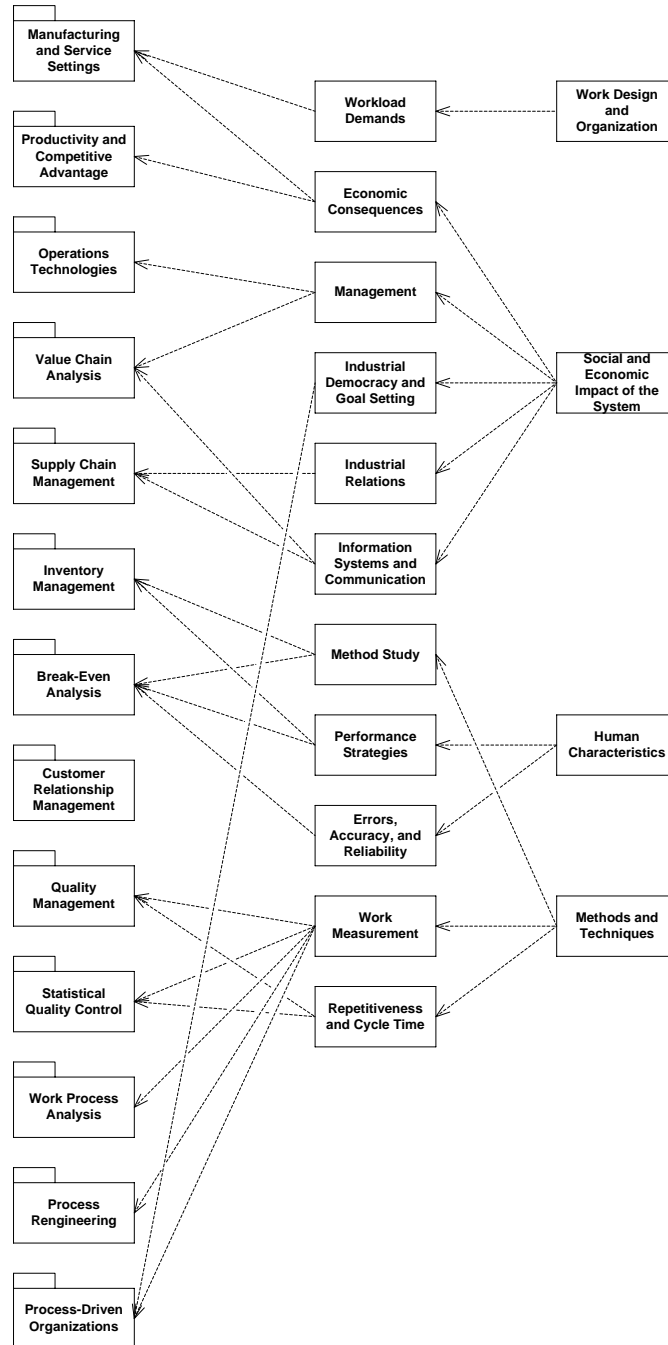


Fig. 16. Managerial Controlling Processes related to Societal Concerns, Human Characteristics, and Specific Methods

7. CONCLUSIONS

The knowledge mapping processes outlined above demonstrate how varying domains of HFE can contribute to and benefit from the knowledge of business process management. The HFE knowledge that describes human performance is at its very essence applicable to all facets of human productive work activities. Finally, it should be noted that the mapping concepts presented above demonstrate how business management can elicit useful knowledge from the HFE domain. Such elicitation is increasingly important in today's highly complex organizations and business processes.

LITERATURE

- [1] Bedny G., Karwowski W., *A Systemic-Structural Theory of Activity: Applications to Human Performance and Work Design*, CRC Press, Taylor & Francis, London 2007.
- [2] Fuentes-Fernandez R., Gomez-Sanz J.J., Pavon J., Requirements elicitation and analysis of multiagent systems using activity theory, *IEEE Transactions on Systems, Man, and Cybernetics*, March 2009, Vol. 39, No 2.
- [3] Greenberg J., Baron R.A., *Behavior in Organizations: Understanding and Managing the Human Side of Work*, 8th ed., Prentice Hall, New Jersey 2002.
- [4] Gołaś H., Mazur A., Macroergonomics aspects of a quality management, w: *Macroergonomics Paradigms of Management: In Honor of 40 Years of Scientific Activity of Professor Leszek Pacholski*, red. A. Jasiak, Poznan University of Technology, Poznan 2008.
- [5] Griffin R.W., *Management*, 6th ed., Houghton Mifflin Company, Boston 2010.
- [6] Hendrick H.W., Kleiner B.M. (red.), *Macroergonomics: Theory, Methods, and Applications* Mahwah, NJ: Lawrence Erlbaum Associates, 2000.
- [7] Karwowski W., Salvendy G. (red.), *Organization and Management of Advanced Manufacturing*, Wiley, New York 1994.
- [8] Karwowski W., *Human Factors and Ergonomics*, w: *The Technology Management Handbook*, red. C. Dorf, CRC Press, Boca Raton, FL, 1998.
- [9] Karwowski W., *Ergonomics and human factors: the paradigms for science, engineering, design, technology, and management of human-compatible systems*, *Ergonomics*, 2005, 48 (5), 436-463.
- [10] Karwowski W., Salvendy G. (red.), *Organization and Management of Advanced Manufacturing*, Wiley, New York 1994.
- [11] Pacholski L., Jasiak A., *Makroergonomia*, Wyd. Politechniki Poznańskiej, Poznań 2011, ISBN 83-7775-0457.
- [12] Pacholski L., Quo vadis polska ergonomio?, w: *Materiały X Międzynarodowego Seminarium Wykładowców Ergonomii*, red. L.M. Pacholski, J.S. Marcinkowski, Politechnika Poznańska, Instytut Inżynierii Zarządzania, Poznań 1993.

- [13] Pacholski L., Macroergonomic paradox of entrepreneurship and economic renewal, w: Ergonomics for the New Millennium, Vol. 2, Human Factors and Ergonomics Society Annual Meeting, Santa Monica, California, USA, 2000.
- [14] Salvendy G., Karwowski W. (red.), Design of Work and Development of Personnel in Advanced Manufacturing, Wiley, New York 1994.
- [15] Schermerhorn J.R., Management, 10th ed., Wiley, Inc. Hoboken, NJ, 2009.
- [16] Welty C., Guarino N., Supporting ontological analysis of taxonomic relationships, Data & Knowledge Engineering, 2001, 39 (1), 51-74.
- [17] Wilson J.R., Corlett E.N. (red.), Evaluation of Human Work: A Practical Ergonomics Methodology, 2nd ed., Taylor & Francis, London 1995.

SPÓJNOŚĆ POMIĘDZY ZNAJOMOŚCIĄ CZYNNIKA LUDZKIEGO / ERGONOMICZNEGO I ZARZĄDZANIEM: PODEJŚCIE ONTOLOGICZNE

Streszczenie

W artykule omówiono naturalną spójność między znajomością kryterium czynnika ludzkiego / ergonomicznego (HFE) i współczesnym zarządzaniem. Przedstawiono ją w kontekście głównych elementów wiedzy z zakresu obu dyscyplin i modelowano przez mapowanie w głównych kategoriach zarządzania wiedzą w odniesieniu do HFE. Znaczące relacje zostały wykazane poprzez odpowiednie ontologie, zarówno wysokiego poziomu wiedzy ogólnej HFE i zarządzania, jak i niskiego poziomu wiedzy szczegółowej HFE i procesów zarządzania przedsiębiorstwem.

