Impact of various work-breakdown structures on project conceptualization

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For a project to be properly managed, there is a need to generate its work-breakdown structure (WBS), and to define work packages so that they can be correctly assigned to organizational units. The WBS may be considered the taxonomy of a project. Several possible patterns of WBS can be generated, despite the fact that all of them describe the same project. However, different WBS patterns call for different organizational structures and management styles during project implementation. Thus, the WBS designer already has a significant impact on the way that a project is to be managed at the very early stage of proposal submission, sometimes without being aware of it. A mismatch between the project WBS, the organizational structure, and the management style of the project manager has a negative impact on the likelihood of the project being completed successfully. Chaos results if the various parties to the project each produce a different WBS. The paper discusses the above issues, and presents an analysis of the different options for a WBS for an example project, and the possible impact of the options on the preferred organizational structure and management style.

For a large project to be properly planned and executed, it must be 'decomposed' into small segments in a structural manner. The planning and execution of these segments is then assigned to specific organizational units. This 'slicing' approach, called the work-breakdown structure (WBS), is not new. The US Government formalized this concept for project management as early as 1962, when it started to demand that the WBS be used by all organizations working on federal projects.

The PERT Coordinating Group[1] defines a WBS as a family-tree subdivision of a programme that begins with the end objectives, and subdivides these objectives into successive smaller end-item subdivisions. The WBS establishes the framework for

- defining the work to be accomplished;
- constructing a network plan;
- summarizing the cost and schedule status of a programme for progressively higher levels of management.

The smallest element in the WBS is called a 'work package', and it is defined by the PERT Coordinating Group[1] as the work required to complete a specific job or process, such as a report, design, documentation requirement or portion thereof, piece of hardware, or service. A work package may consist of one or more cost-significant activities. Its content may be limited to the work which can be performed by a single operating unit in an organization, or it may require the contributing services of several operating units. The overall responsibility for the work content of a work package should be assigned to a single organization or responsible individual. In other words, the proper planning and execution of a project requires the assignment of each work package to a specific organizational unit.

Other definitions of WBS government documents can be found in later publications, such as References 2 and 3. However, although the wordings differ, the meanings are similar, and, for the purposes of this paper, it is not essential to emphasize the differences.

From the very early stage of submitting a project proposal, it is important to formulate the content of the project via a WBS. Such an early WBS formulation enables project needs to be better defined, and the resource and time estimations required to complete the project to be improved. Nevertheless, it is important to note that the WBS of a project changes over time, according to altering
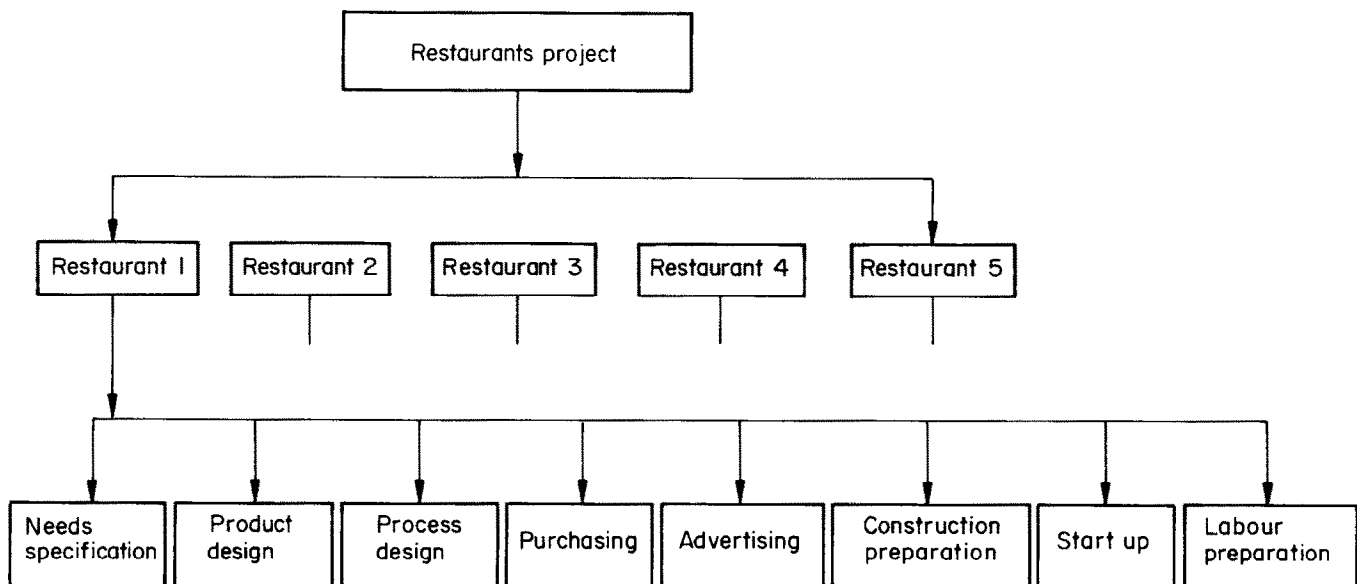
Figure 1 WBS of project with geographical location as second level

needs and constraints. Therefore, to avoid chaos in introducing the changes, configuration-management techniques should always be used. In other words, although the WBS should be introduced at the very early stage of the project, it will be permanently exposed to changes, which should be properly presented in the WBS. The establishment of the WBS has an impact not only on the project configuration, but also on organizational issues. Design and configuration issues relate to the technical functions which the project should achieve, while organizational issues relate to the managerial process through which the project is executed.

There is extensive research evidence that projects fail because the technical content of the programme is not efficiently planned and controlled[4]. The correct use of a WBS contributes significantly to the probability of successful project completion. The proper formulation of a WBS enables all participants, customers and suppliers alike, to implement effective information, involvement, regulation, and monitoring channels throughout the whole lifetime of the project. For example, Hall[5] reports on the successful completion of a large-scale project costing in the range of $225M, and claims that a major contribution to this success was the appropriate use of a WBS. Therefore, a major issue to be tackled is the identification of the proper components of a WBS. Youker[6] claims, and rightly so, that the WBS must often be an artistic blend of a breakdown by subsystems, lifecycle phases and resources units. Lavold[7] also considers the WBS to be an effective basis for project control, policies and procedures. However, in spite of the artistic part of the WBS's construction, there are general guidelines which can be used in its formation.

WBS considerations

The example described below is used to demonstrate various features and considerations that have to be taken into account when designing a WBS. This example was selected from the service sector rather than from high technology for the following two reasons: (a) the terminology used in high-technology projects is not always clear to all project managers, and (b) the concepts used in an industrial

environment can also be used in a service environment.

A company won a contract to open five new restaurants on five campuses attached to the same university. It assigned a single individual to manage the project. Additional information about the features of the project is supplied below.

The following paragraphs discuss issues, items and concerns relating to the construction of a WBS. Each item in the list is followed by an example taken from the example project.

WBS levels

The first level of the WBS refers to the project. The second level of the WBS may refer to the geographical location, functions, or components. The third level includes attributes not included in the second level. For example, if the second level includes the geographical location, the third level may refer to functions.

Figures 1 and *2* show two possible WBS configurations of the example project that relate to the content of the second and third levels.

Examining *Figures 1* and *2*, it is obvious that each may fit a different managerial style, although both include the same items. A manager favouring a product-oriented approach prefers the WBS shown in *Figure 1*, as, if this is used, he/she is able to assign restaurant managers from a very early stage. A manager favouring a functional approach with centralized responsibilities prefers *Figure 2*.

Organizational structure and culture

The WBS should fit the organizational culture and structure so that the vocabulary regularly used in the organization can also be used for the project. If the organization is structured in a particular functional manner, the WBS should be similarly formulated.

To demonstrate this issue, let us examine *Figure 1*, in which 'need specification', 'product design' and 'process design' are at the same third level. If an organization has a design department in which all three items are being treated, then it may be an advantage to have the third level as 'design', and to have under it the three items at the
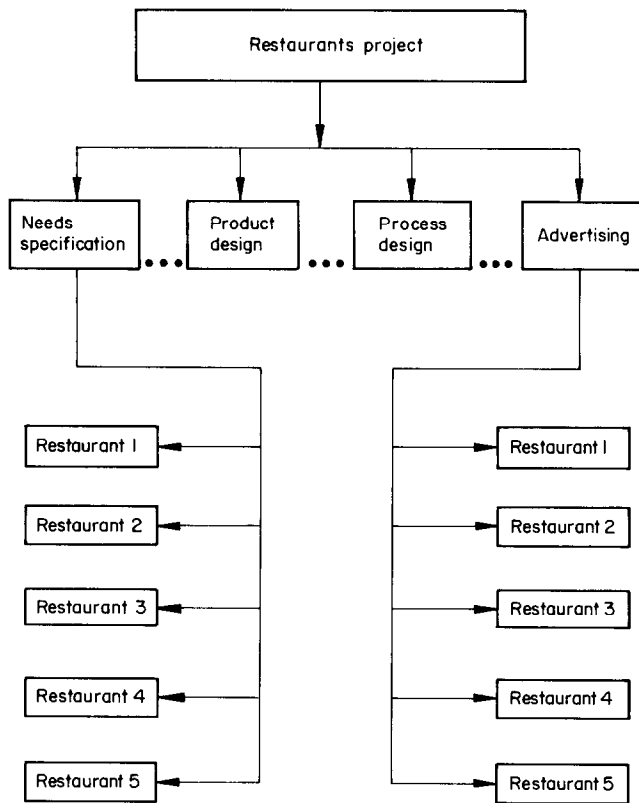
Figure 2 WBS of project with functions as second level

Figure 3 WBS of project with subsystem orientation

fourth level. There are also other ways to present the same project, as shown in *Figures 3–5*. Each is oriented towards a different second level, as denoted by their titles, and each is equally valid.

The WBS format selected may be a function of the existing organizational structure while the project is under way. For example, an organization having departments specializing in subsystems, such as kitchens and dining rooms, will be in favour of using the WBS described in *Figure 3*. If another organization is based on a logistics
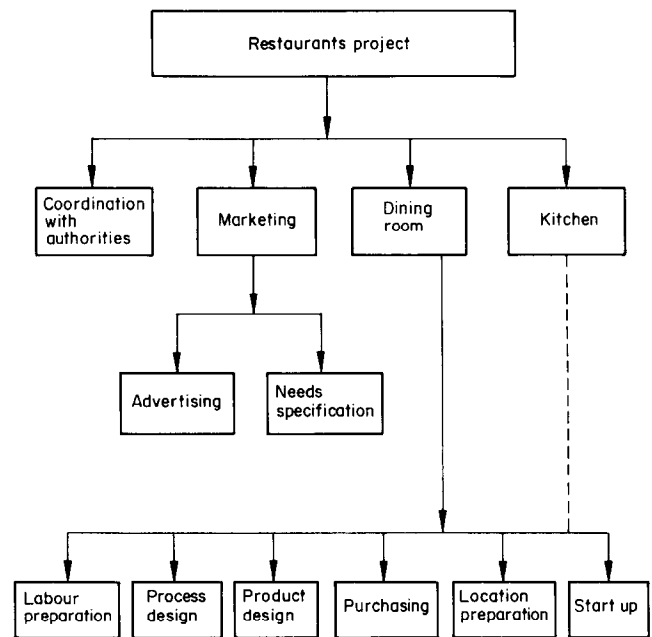
orientation, then it will probably vote for the WBS presented in *Figure 4*. *Figure 5* presents another version of the WBS which may eventually have the same work packages, but may not fit a relevant organizational structure.

Organizational needs

Organizational needs relating to the WBS may be changed in time. An organization will, in the design stage, vote for the use of a WBS with a system or function orientation. However, at the implementation stage, it may prefer to use a 'geographic' WBS orientation.

Although proper coding of the WBS enables the work content to be grouped according to any desired feature, the orientation of the original chart is of great importance to its users. The conflict relating to the WBS and the work-package definition may continue until operation, and even
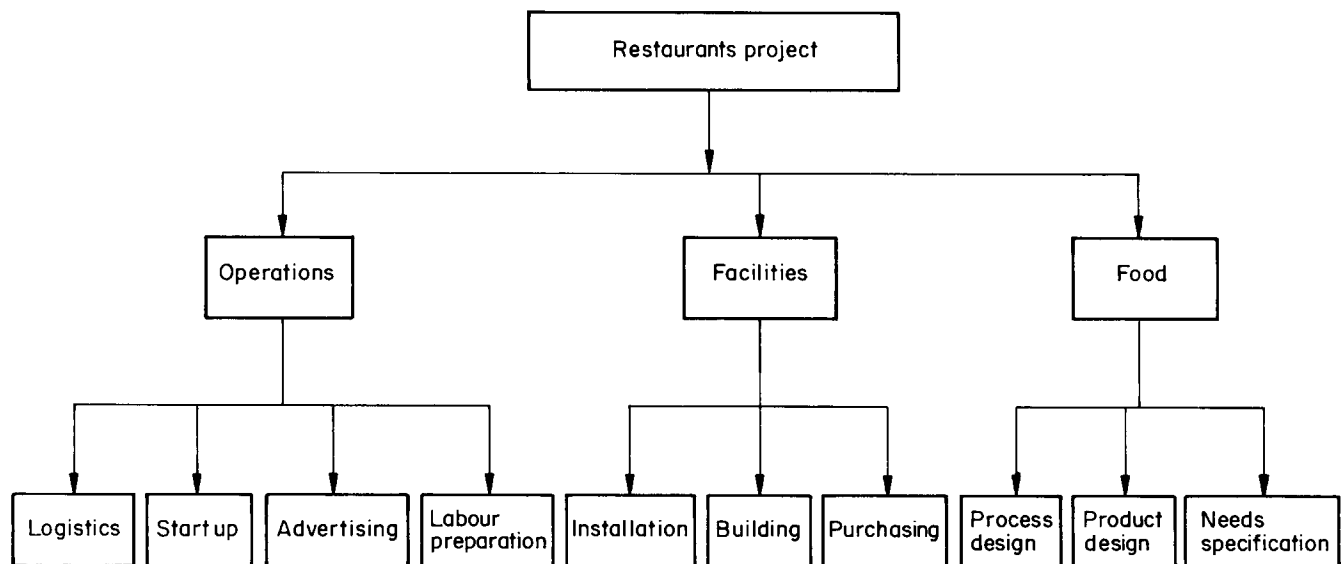

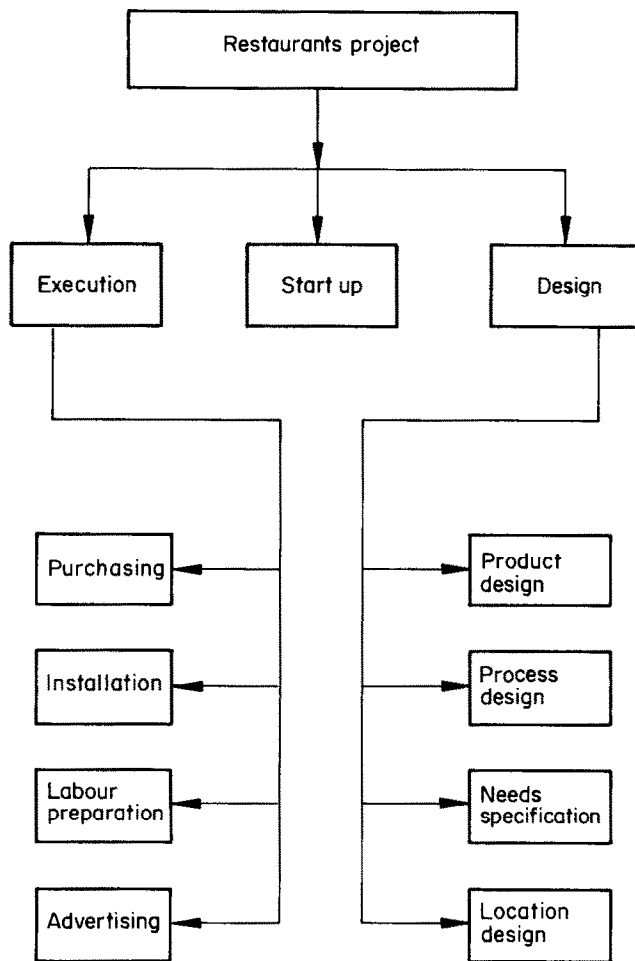**Figure 4** WBS of project with logistics orientation

Figure 5 WBS of project with timing orientation

Figure 6 WBS broken down into lower-level work packages

maintenance, if there is interest in using a lifecycle-cost orientation and accumulating expenses throughout the project's lifetime. Consider, for example, the case of constructing a power plant. During the design stage, it is more convenient to use a system-oriented WBS, the systems perhaps consisting of different kinds of cooling, pressure and electrical array. Subsequently, in the construction stage, it is common to implement a location-oriented WBS, since the team has to build all the portions of the systems that pass through its geographic area.

Work-package sizes

The size of a work package can be measured in units, such as labour hours, budget, weight etc. There is an optimum size for a work package. Hughes[8] claims that the amount of required management effort as a function of detail has an inverse U shape. This optimum differs from one organization to another. For example, a typical work package in the aircraft industry may include hundreds of hours. Small work packages load management with too much detail and administrative work, but enable management to define better the content and resources required to accomplish the package.

To demonstrate this issue, *Figure 6* describes a further breakdown of *Figure 1* into smaller work packages.

Figure 6 presents a seven-level WBS which was developed for one of the WBS branches. As can be seen from its structure, one of the two smallest work packages is
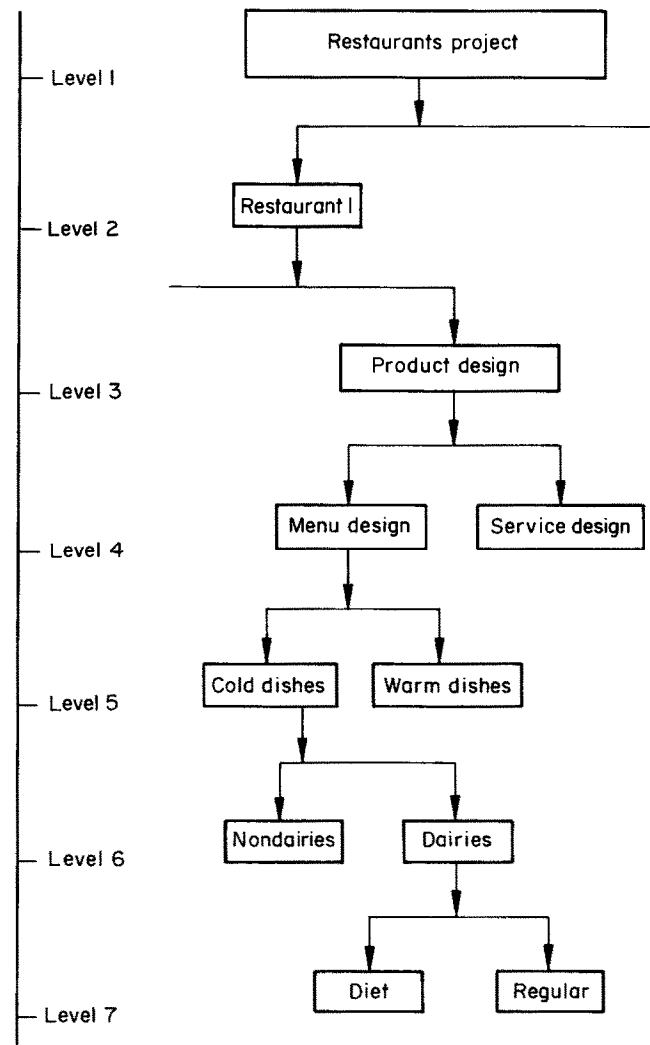
the 'design of cold dairy, diet, dishes'. This work package includes a few dishes which should be planned. In the same manner, it was possible to consider each single cold dish as a separate work package, or to consider all dairy, diet and regular dishes as a work package. If a project manager wishes to be involved in specific details, he/she may request 'design of a dairy diet dish' to be defined as a work package, whereas a manager who believes in little involvement in detail may vote for the 'design of cold dairy dishes' as the lowest-level work package. Too many levels in the WBS loads the organization with too much information, and complicates the management process of that project. Too few levels generates communication difficulties and poor coordination among organizational units. According to Lavold[7], and also in the author's experience, four to six levels seems to be an adequate number of levels for large-scale projects. From *Figure 6*, it appears that reaching an eighth level complicates the management of the process without there being much improvement. This level calls for lower-level work packages, such as a 'cold diet dairy dish', and so on. It is important to note that an increase of the WBS by a further level may multiply the number of packages, assuming that each previous package is, on average, divided into two subpackages.

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Work packages as entities

A work package should be presented and defined as a separate entity. This approach facilitates the design, execution and control process.

To demonstrate, let us consider the following possible work packages, which can be generated around the WBS shown in *Figure 6*:

- a cold dairy diet dish;
- cold dairy diet dishes;
- cold dairy dishes (diet and regular).

The first one should not be treated as a separate entity by the designer, since a diet-conscious customer observes the whole diet menu when selecting a meal. He/she expects the menu to be well balanced in terms of both dairy and nondairy items. Since it is difficult, if not impossible, to generate a balanced dairy diet section if each dish is defined as a separate work package, it is logical to define the 'cold dairy diet dishes' as the smallest work package. If 'dairy dishes' are selected as the work package, this may damage the required separate balance of the diet and regular sections. There are also other possible work-package options. For example, a manager may vote for a work package that includes all diet dishes, dairy and nondairy. The application of this approach calls for a different WBS structure: level 6 will include diet and regular work packages, and level 7 will be eliminated. If this option is selected, there are no specific work packages for dairy dishes and nondairy dishes. However, the technical specification of each work package will include the description of such dishes within each package.

Activity relationship

It is desirable to define a work package in such a way that only one organizational unit is responsible for its implementation. It is important to note that a work package includes several activities, which are interconnected by a network between these and the activities of other work packages. Therefore, even if all the activities in a certain work package are performed by one organizational unit, this unit may still not have complete control over the execution of the package, since some activities belonging to that work package are preceded by other activities which are not within the responsibility of that organizational unit.

To demonstrate the issues involved with the activity relationship and its impact on work-package completion, let us analyse a possible set of activities belonging to the example project and their precedence relationships, as shown in *Figure 7*.
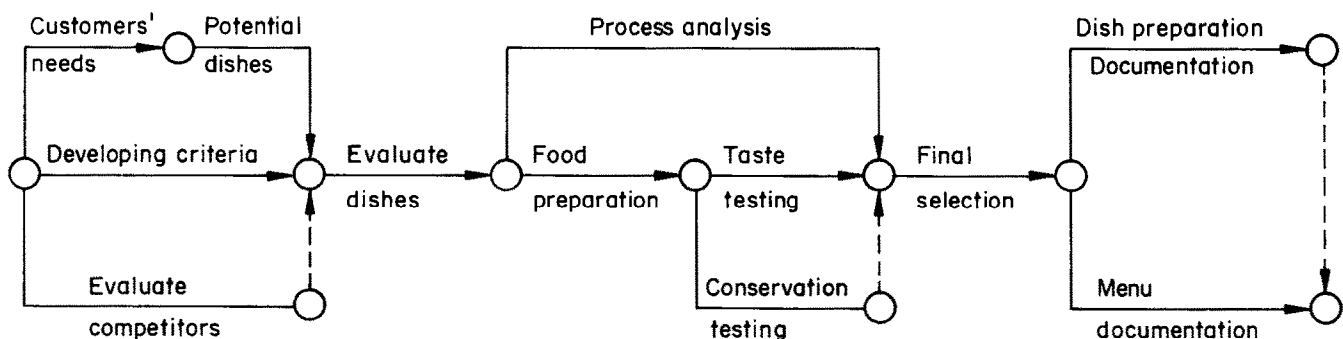
Figure 7 shows that there are 11 activities which should be carried out for the successful completion of the work package 'designing diet dairy dishes', where one of them is the 'process analysis' of preparing the dishes. If it is desired to separate the process from product design, it is necessary to remove 'process analysis' from this work package. The transfer of this activity to another more appropriate work package transfers the responsibility of the execution of that activity to another organizational unit. However, there is still a need to consider this activity, since it precedes the activity 'final selection'. This example demonstrates the fact that, although it is simple to require that all the activities needed to complete a certain work package be within the responsibility of a certain organizational unit, it is a difficult principle to implement.

One may claim that, for the correct design of the menu, the 'product design' and 'process design' of each dish should be treated together, since the final selection of the menu depends on both. This integration can be achieved by various means, such as concurrent engineering, or other contents of the work package.

Concurrent engineering is defined as a systematic approach to an integrated designed orientation with a lifecycle cost. Rather than there being sequential decision making by different functions in the organization, all relevant functions are involved simultaneously. Keys *et al.*[9] claim that concurrent engineering is now behind the development of all major new products. Referring back to our example, the process-design team is involved in the dish design during the design stage itself, rather than a dish being transferred after its design to the process-design team so that it can work on the details of preparation.

Other contents of the work package may include both product and process design. The execution of the new expanded work package may be performed through two different types of organizational change. The first one calls for the integration of the two organizational units, the product-design and the process-design units. This integration enables the whole package to be assigned to the new organizational unit. The second way to manage the change in work-package content is through the use of a matrix-management concept. A work-package manager is made responsible for execution, and 'borrows' professionals from relevant organizational units. From a work-package point of view, the first approach is project-oriented, and the second is matrix-oriented.

The above discussion indicates the difficulties faced when attempting to assign all the activities required to complete a particular work package to just one organizational unit.

Figure 7 Network of activities included in 'diet dairy dishes' work package

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These difficulties may explain Matthews'[10] statement that many, if not most, projects do not have a WBS, but only an activity network. However, the simultaneous use of both a WBS and a network, which is a blow up of the WBS, coupled with the required operational sequence, helps to identify potential problems, such as complicated precedence relationships, or leftover activity connections. Early detection of these problems assists in eliminating them.

There are very few studies of the integration of activity and work-package constraints. An exception is the study of Deckro *et al.*[11], in which a mathematical model for scheduling project activities in a work-package environment was formulated.

Economic benefits

It may be an advantage to separate work packages according to economic benefits.

To demonstrate this point, let us consider a different example. When a municipality designs a new bathing beach, it is an advantage to separate work packages according to their potential profit rather than the geographic location, as with beach strips. Using this approach, a hut is considered to be a nonprofitable work package, whereas a kiosk is a profitable one, since it draws income. Therefore, the municipality may first concentrate on all the profitable work packages through which it intends to generate income, which may then be used to support the execution of the unprofitable work packages.

Impact of project manager

A project manager has a significant impact on a project's WBS, as well as on the organizational-breakdown structure (OBS) which is used to execute the project under his/her responsibility. However, he/she may not have an impact on the structure of the organization in which the project is performed (a functional, matrix or project structure), since it is beyond his/her authority.

The impact of the project manager on both the WBS and OBS of a project can be demonstrated through work-package analysis. As shown in the previous sections, a project manager may design the work packages in various ways. However, different work package constructions call for different OBS designs if clear defined responsibilities for the execution of the work packages are desired. The potential impact may be even more extreme, since different WBSs that include identical sets of work packages may demand different organizational and management styles.

The last point is illustrated through an analysis of the following simple example, taken from *Reference 12*. A university intends to develop a Master of Business Administration (MBA) programme. The WBS of this project can be described via various WBS formats, such as the two shown in *Figure 8*.

Here, a basic work package is defined as a course preparation for a certain subject, say 'introduction to finance'. Each such work package includes activities, such as reviewing relevant material, preparing the course syllabus, and preparing exercises and transparencies. From *Figure 8*, it is obvious that the two WBSs have the same work packages at their lowest level. For efficient project management, an OBS should be formulated such that each work package is assigned to an organizational unit, and a group of work packages is further assigned to an upper-
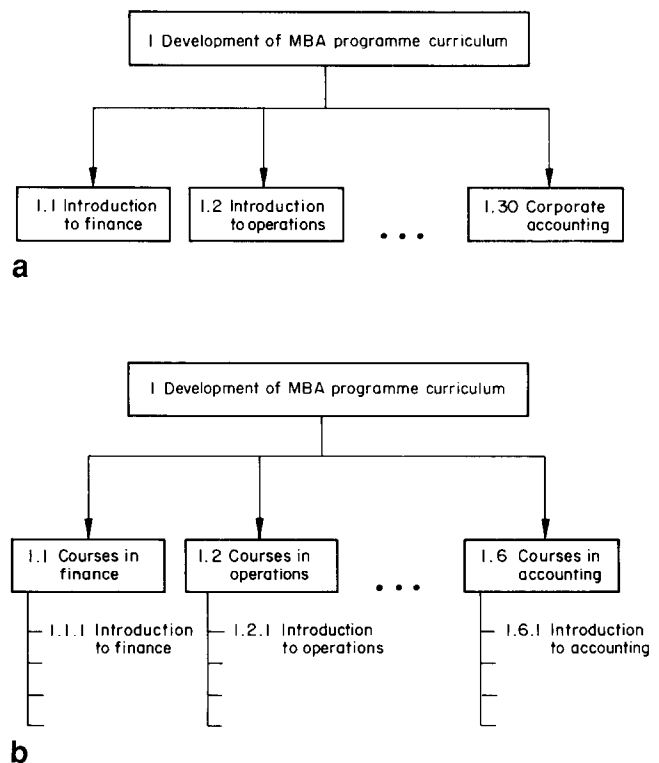

Figure 8 MBA-programme WBS; (a) three-level WBS, (b) WBS formats for MBA curriculum

level organizational unit. It is interesting to note that each WBS described in *Figure 8* calls for a different organizational hierarchy and management style. The WBS in *Figure 8a* demands a centralized managerial approach, where the project manager directly supervises all the organizational units responsible for the single work packages, as well as their integration. He/she should, therefore, have a general knowledge of the material in all 30 subjects, since he/she may otherwise face difficulties in the integration and 'configuration management' of this project. Very few managers are sufficiently qualified to run a project with such a flat WBS.

The three-level WBS shown in *Figure 8b* includes the same set of work packages, but is grouped in a functional manner as well; courses from the same discipline are grouped together. This structure requires a different OBS. The project manager is now directly responsible for only six group managers, rather than 30 work-package managers, as in the first WBS. This approach is less centralized than the previous one; if a work-package manager wants to introduce a change which is of internal interest, he/she need only coordinate with the group manager, and not with the project manager. The group manager then has to decide whether the change is only of internal interest, or whether it has an impact on other groups as well. If the former is the case, the change can be resolved within the group without the project manager's involvement.

If there is no proper coordination between the WBS and the OBS formats, the successful completion of the project is in jeopardy. Let us demonstrate the issue by referring to the example shown in *Figure 8*. We assume that the WBS format selected by the project manager is the flat one (see *Figure 8a*), with two levels only. If the project manager lacks overall knowledge of all the subjects within an MBA

curriculum, and is unable to handle many subordinates simultaneously, the project is bound to fail. The opposite situation may also occur, that is, the selected WBS format is the one shown in *Figure 8b*, where the project manager favours tight control, is able to handle it, and intends to do so. In such circumstances, he/she may circumvent the group managers, destroy regular communication and decision channels, and harm the project as well.

Work-package coding

If all the work packages are coded correctly, a software package can generate alternative WBSs on the basis of different categories.

To demonstrate this point, let us consider the coding system used in *Figure 8*. The manager responsible for this project was requested to construct the WBS so that all the introductory courses would be under the same entity, called basic courses. Using the coding system shown in *Figure 8b*, the generation of the new format is fairly simple to obtain: (a) establish a new 2nd-level entity called 1.7 'basic courses', and (b) subordinate to entity 1.7 all the work packages $1.i.1$ for $i = 1-6$. Obviously, this procedure can be performed via a computer.

Conclusions

The work-breakdown structure is the backbone of the proper planning, execution and control of a project, although it is not as well known as CPM or PERT. The three typical items required to drive the project to successful completion, namely scope, schedule and cost, are greatly enhanced by the ability of the project manager and his/her team to define accurately a WBS and all the related aspects.

There is not one unique construct of a WBS for a project. Therefore, its final design should be the result of a group effort of professionals from different functions and responsibilities. If a WBS format for a particular project is not accepted as valid by all the parties involved, parties may develop their own WBSs. If the various WBS structures used are not strictly derived from one basic structure, it will obviously bring chaos to the project.

Surprisingly, the literature does not attach sufficient importance to the WBS. Several professional publications refer to the activity-network analysis of a project without mentioning that it is almost impossible to generate a proper activity network and estimate the cost, resources and budget of each activity without establishing the WBS of the

project. This paper has shed some light on the impact of the WBS. There is, however, a need for additional studies of the impact of various WBSs on project performance in different environments and industries.

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